Selected Papers on Hands-on Science

Science

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Selected Papers on
Hands-on Science

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This book is composed by a selection of papers published in the proceedings books of the first four editions of the annual International Conferences on Hands-on Science. The most relevant papers therein were selected and reviewed by the conferences' program committees. They are exclusive responsibility of the authors and are essentially published herein as submitted, in interest of timely dissemination.

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Foreword

The International Association “Hands-on Science Network” was established in the sequence of the Comenius 3 project “Hands-on Science” partially financed by the European Commission in the frames of the Socrates Program, from October 2003, coordinated by the University of Minho and involving over 200 institutional members from all over the EU. Now the Hands-on Science Network is a non-profit organization legally registered in Portugal. With a broad open understanding of the meaning and importance of Science to the development of our societies, each individual and of the humankind, the main goal of the Network is the development and improvement of science education and scientific literacy by an extended use of investigative hands-on experiments based learning of Science and its applications.

Among the many activities we organised, our annual conferences (and workshops) were especially successful. Apart from allowing and promoting an open broad and friendly exchange of experiences on good practices and all aspects and perspectives on Science Education, among the one thousand participants, over 500 very interesting and meaningful works were published. It represents a set of work material of the highest interest to the Science and Science Education community. Among those a good number of papers are of especially high quality and relevance.

The papers herein were selected and reviewed by the conferences’ program committees and the board of the Hands-on Science Network. The papers are organised chronologically *per* conference allowing also, in some way, to access the evolution in these matters on last 5 years. My first paper will give the readers an idea of the goals, planning methods and strategies of the Hands-on Science project.

We think this book will be an invaluable tool to all readers and are looking forwards to welcome the active involvement of all in our Hands-on Science Network

…towards a better Science Education…

Manuel Filipe Pereira da Cunha Martins Costa
(Chair)

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The Hands-on Science Network (*www.hsci.info*) exists to promote the development of science education and scientific literacy. It encourages a generalized use of innovative active hands-on experimental investigative approaches to science and technology education. In raising the profile and attractiveness of Science in Education, we aim also to increase the desirability of a career in Science for all.

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Hands-on Science

Costa MFM

Introduction

In the Society of our days there is a major increasing need of an in depth quality education in Science and Technology.
Science teaching at school should be generalised aiming not only the sound establishment of a “Science” culture in our societies but also to guarantee a steady basis for the improvement of Science and its technological applications.
Urgent actions should be taken in this direction. By initiative of the author the “Hands-on Science” (H-Sci) network was created. The European Commission under the program Socrates, Comenius 3 action (project nº. 110157-CP-1-2003-1-PT-COMENIUS-C3) supports the network.

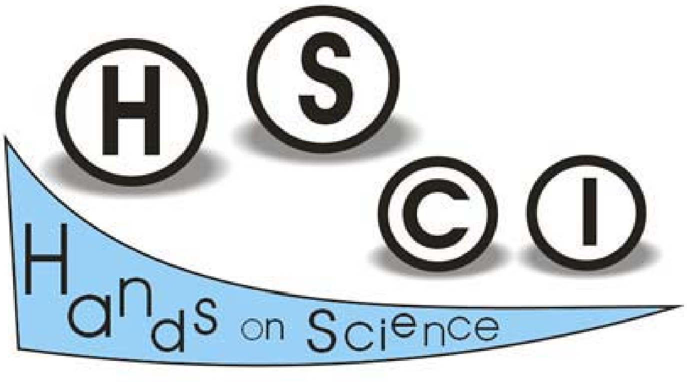

Figure 1. The symbol of the network

The activities of our network focus on the development and or diffusion at European scale of positive hands-on experimental practices on teaching science at basic secondary and vocational training schools. By leading the students to an active volunteer and committed participation in the teaching/learning process through hands-on practice and experimentation, making intensive use of the new instruments and resources of the Information Society.
Hands-on practices are being very successfully employed in Science Museums’ Clubs and Associations throughout Europe, as major motivational but also learning

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tools. The benefits of the use of these methods in the classroom are being illustrated for already some years in the USA and in some EU schools. It is now the right time to generalise the use of these practices in an effort to raise the levels of scientific literacy and expertise among our youngsters.

Science and Technology have always been issues of fundamental importance to the development of the countries and societies. Today this is, definitively, also true. No sound development can be foreseen without a strong S&T infrastructure. The fundamental basis of it is, indubitably, a well-prepared motivated reliable and flexible workforce. Scientific and Technological literacy is also of great importance for citizenship and democratic participation in a world where Science and Technology issues and demands have a dominant role.

The increase of literacy in Science and related technical expertise will induce the creation or development of high-tech industries or services' firms that are of fundamental importance for Europe's growth and development. Thus being a pro-active factor of direct impact on the inclusion of new, and less developed, country members in the EU. Not only a long-term effect is foreseeable but also an immediate impact by raising the expectations of the economic agents and of the society in general.

A clear picture on the status of Science and Technology Education in European Schools should be made available. As well a number of policy recommendations and tested pedagogic material will be made available. A network of experts on this topic will be established. A raised awareness of the importance of this theme will be established in steady basis.

Pedagogical and Didactical Approaches

The new stringent requirements of the modern society demand not only the gathering of specific knowledge but also and specially the ability of acting interactively to be able to find, analyse and solve new interdisciplinary problems.

The best way of achieving an adequate formation of our students on these issues is by inducing the students to an active committed participation in the teaching/learning process, through practice and experimentation [1]. Making use of the new instruments and resources of the Information Society.

Our pedagogic approach is focused on inducing an effective learning of science subjects and basic competencies as responsibility, method, self control and reward, critical reasoning and observation, commitment in collective group actions, interaction and proactive inter-dependence.

Hands-on activities are proved to be the most effective way of acquiring these competencies for the vast majority of child and adolescents [2]. Whenever advisable a constructivistic [3] approach will be used. It is sometimes necessary to allow the students to have a first qualitative conceptual contact with the issues of science. Conceptual learning will be integrated and used in our hands-on practices. We will use virtual simulations of natural phenomena always simple and inducing or requiring interaction with the students in a way that the qualitative perception of the concepts of Science may lead to a quantitative interpretation. The Physlets [4] first developed at the Davidson College in the USA are accepted to be a good tool that

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will be explored in this context, and exported to other fields of Science. Different approaches to this issue of the use of ICT including virtual simulations in Science teaching will be discussed and assessed. The use of ICT in teacher training will also be explored [5]. The produced guides will be formative summative and making constant appeal to critical reasoning, observation and active commitment of the pupils. They will be expert' reviewed and tested in-class, and receive students and school evaluation. The heterogeneity of pupil's interests, abilities, experiences and future wishes should be carefully assessed also by contrasting the responses between different countries, languages, minority groups, cultures and gender. This analysis, that will be published and widely publicised, with conform the development of the pedagogical materials and syllabus to be produced for different countries, populations and languages. We will try to establish bridges between the industry and employers, the schools and educators, and research institutions. Suggestions will be developed on how to establish this kind of links (local and international co-operation settings will both be considered). Syllabus and guides to be developed will also take into account this interaction.
The assessment of the network is considered fundamental. We will seek both internal self-evaluation but also from external educational government boards, Educators Associations, relevant local government entities, teachers and especially from students and their parents. Inquests and questionnaires will be prepared and delivered to the different evaluators. The experience of the ROSE' (The Relevance Of Science Education) project coordinated by the University of Oslo, will be taken into account [6].
Our pedagogical and organisational strategies follows the guideline determinations of the USA' National Science Education Standards (National Research Council, 1986) actualised and adapted to the actual, and local, social cultural and educational situation in the EU. We place a special focus on the pro-active commitment of teachers and educators in motivating, inducing and conforming the autonomous realisation of broadband hands-on scientific activities by keen and active pupils.

Goals and Outcomes

Our goals and field of intervention is rather wide. Below we list the main activities goals and outcomes of our network on the first 3 years of the project and beyond.

Main Goals and Activities

We expect this network to serve as starting point for the generalisation of the use of hands-on active learning of Science in EU Schools.

1. we will collect and sum up continuously knowledge, information, materials, ideas, curricula and experiences from past and ongoing Socrates (Comenius and others) projects in related fields;
2. collect and monitor results and expertise achieved in former and on going pedagogic research projects in Europe and abroad in hands-on learning at

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schools in the various fields of Science.

3. develop an instrument/strategy of data collection on students' (6 to 18 years old) opinions, experiences, interests, priorities and perceptions, in particular of the relevance of Science.
4. discuss and develop theoretical perspectives and practical approaches sensitive to the diversity of backgrounds
5. induce the presentation of a variety of COMENIUS 1 and 2, and MINERVA projects, and others (at national and multinational level) including in the contest of the 6th framework, involving members of the network and others. Those projects will allow the achievement of several of our most important goals.
6. assess discuss develop and test ways or better ways of using hands-on learning at the school.
7. describe good practices and transform these into better practices in Teaching and Learning Science.
8. induce an interdisciplinary integrated approach to Science learning through experimentation.
9. induce the discussion and exchange of ideas and experiences among the different participants on the network.
10. discuss and promote the issue of Science literacy for citizenship and Life-long learning.
11. create an open web based network, a privileged forum for sharing ideas and diffusing our works' results
12. by creating internet pages (including the study of the development of virtual laboratories and tools) and Internet-based teleconferences and courses in the different national official languages,
13. by creating an web-based discussion Forum to be used by and open to all the school teachers, educators, parents and responsibles for the local, National and EU Science and Education policies.
14. promoting exchange visits of schoolteachers and project co-ordinators between institutions in different countries.
15. organising international conferences and thematic workshops on this subject.
16. inviting the community to be involved in our discussions
17. promoting and delivering training courses for school teachers and educators in different languages and countries
18. establishing guides and guidelines, translated to national languages on new specific hands-on experiments.
19. promoting hands-on experimental in-school activities
20. promoting Hands-on-Science contests and fairs at school regional national and EU level.
21. to induce the establishment of Discovering Science Students' Clubs within the schools.
22. to contribute to the development and dissemination of new ICT and multimedia tools of free open equitable access to persons with disabilities and minorities.

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23. to contribute to induce and facilitate the access of women to Science.
24. to proactively contribute for a faster positive inclusion of the future new EC members.
25. to develop policy recommendations for the curricula' improvement
26. to create a network of teachers interested on this subject to serve as possible future co-ordinators of educational projects and pattern makers.

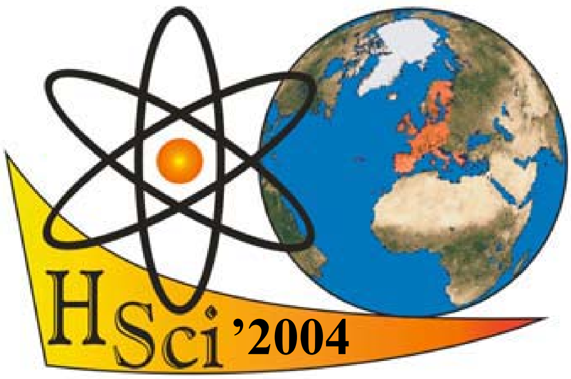

Figure 2. The network' first International conference on "Hands-on Science"

Figure 3. The "Ideas for Science Fairs" European contest is expected to involve many hundred students all over Europe.

We expect to have a positive impact in social inclusion of minorities. In particular in what concerns the gypsy community in Romania and immigrants and religious minorities in countries like Germany, Malta or Portugal. In some of our Schools there are a large increasing number of minorities that need special attention. The use of the kind of activities we propose that induces an active voluntary commitment of the students in concrete tasks can have rather positive effect contributing to a better integration of minorities in the School and in the community. Furthermore these activities lead to an organisation of the students in groups were each student will have a common appealing goal.

To the gypsy community in Romania will be given a particular attention. Lectures and demonstrations will be delivered to those communities in deprived areas in the interior of Romania.

We consider that hands-on teaching of girls in School age may contribute to define a clearer perception of Science on this group of students approaching helping bring more women to Science and Technology. The ways of achieving this goal will be discussed explored and assessed.

Close attention will be given to the possibilities and benefits of hands-on science activities in special education schools for children with disabilities. Pedagogical materials and strategies will be developed and in class tested. We expect to prepare other projects in a near future in order to deal with this specific problem.

The issue of Science literacy connected with the each day more important adults'

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and life-long education will also be addressed also in the sense that a positive appealing initial or basic contact with science may certainly lead to an effective sustainability of the interest about Science and Technology during life.
We also have as a major general goal to contribute to a faster positive inclusion of the future new EU members in an enlarged Europe.

Main Outcomes

1. Teaching recommendations
2. Syllabus proposals
3. Web-based discussion forums
4. Web-pages and sites
5. Virtual laboratories and experiments
6. Translated reports and written material
7. Guides and pedagogical guidelines in official national languages
8. Catalogue of projects
9. Catalogue of books and guides
10. Info folder about the network
11. Electronic newsletter
12. Teachings packages
13. In-school motivational activities
14. Three International Conferences and thematic workshops
15. Several training courses Comenius 2.1 project's proposals
16. Several Comenius 1 project's proposals
17. Internet based video-conferences and meetings in local national languages
18. Network of Discovering Science Student' Clubs.
19. Network of pattern makers in hands-on learning of Science.

Target Groups and Expected Impact

To our knowledge it is the first time such a wide network is established in Europe to address the issue of hands-on learning of Science and Technology. Taking profit of the new ICT technological developments in modern society we will support complement and integrate the Hands-on quantitative study of Science with Constructivism and Conceptual and Interactive Engagement qualitative Learning.
Indirectly the beneficiaries of our activities will be the Science' schools students not only in the involved countries but also in all EU current and up-coming member countries.
Specifically we will be targeting the following groups:

1. School' students (directly several thousand including those of Associated Schools)
2. Teachers and educators
3. Schools involved in the network (including a large number of associate members from hopefully all EU countries)
4. National coordinators of the network (10)

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5. Education boards (4 network members)
6. Teacher training Institutions (10 network members)
7. Research institutes (12 network members)
8. Responsibles of National and Trans-National educational programs
9. The local communities and the industry

The impact of our activities depends on the target groups:

1. The network participants will get a clear idea of the state of the art on hands-on learning of the different subjects of Science.
2. The network participants will be able to serve as pattern makers in their schools, communities and countries in the subjects of hand-on experimental learning of Science.
3. The network participants will establish an enlarged number of international contacts that will enlarge their perspectives as educators but also as citizens of an enlarged European Union.
4. Raised awareness of the importance of international partnership among teachers, schools and governments.
5. Schools and educators will have a proven idea of the true advantages and possibilities of the pedagogical use of hands-on experimentation in the teaching and learning of Sciences.
6. Pupils will have raised knowledge on a number of topics and will have a new international perspective about science, teaching and education.
7. Students of the participating schools (the networks ones and other to be associated) will acquire new competencies and be aware of its importance.

Partnership Composition

The “Hands-on Science” network involves several Universities, Research Institutions, National Government Boards, Private companies, Colleges and Schools and School’ Associations from Portugal, Greece, Spain, UK, Slovenia, Romania, Germany, Belgium, Malta and Cyprus, and the CoLoS (COnceptual Learning Of Science) pedagogic association.
The network counts with the formal involvement of 29 Institutions of different types covering all education levels from elementary secondary, special education, technical and university levels. Also a large number of associate member are already involved from the participating countries and from France, Denmark, Norway, Holland, Slovakia, Austria, Belarus, Bulgaria and Russia (observer). Further associate member will be accepted along the development of the network activities, in specific task forces or thematic groups.
Different institutions working in different environments with distinct cultural and socio-economical backgrounds – in large towns, medium sized towns, and small villages, some in rural or industrial areas- covering a large varied geographical area from the Iberian Peninsula, the Mediterranean, Southern Northern and Central Europe to the Eastern Europe. They will focus their activities in exploring and promoting the use of hands-on experimentation teaching by extensively employing advanced ICT tools, or simple hand made materials, in integrated interdisciplinary

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approaches or analysing the issues in a more sectioned way. Different approaches, different feelings, the same conscience, the same objective: to evolve to a positive approach of participated active hands-on experimental learning of Science at school level.
All partners have previous experience on exploring and or developing innovative educational practices and materials in a non university level and many are or were involved in national projects of these kinds and on international collaborations within the EU or with EU and North and Latin American' or North-African Institutions.
Some of the participating schools have relatively large (up to 30%) groups of pupils from minority groups (language, race, religion) and are experienced in developing pedagogical approaches to deal successfully with the problems that situation poses.
A number of schools are experienced in Distance Learning and most have already proper facilities (some financed through EU projects). Several network member institutions had or currently have members of their staff participating in curriculum development efforts in science and technology organised by the respective Ministries of Education, Science and or Culture.
The CoLoS consortium brings together research teams from many US and European Universities (from the DE, UK, IT, RU, SI, FR, ES, PT). It aims to promote the development of innovative teaching methods in science and technology focusing on: learning and understanding fundamental concepts in science; the integration of qualitative and intuitive understanding with quantitative methods; and the use of simulation and network-based material.
A number of different Schools and Institutions will be involved in the Network' activities as associated members. Among those a few will a role focused on evaluation and or dissemination of the network activities and results. The associated schools and institutions will not only be informed of the network activities, have privileged access to web based network and to the produced reports and materials, as they will be asked to participate in the activities of the thematic groups as extensively as possible.
A numbers of Observer members from countries outside the EU will be accepted and welcomed.

Implementation Strategy and Plan of Activities

Our network is a relatively large one either in terms of the number of partners and countries involved, or by its theme involving all fields of science all levels of School teaching with an extensive range of general and specific goals. In fact this network will be the starting point of a significative number of projects (Socrates and others) addressing specific topics or goals.
In order to maintain the network with a manageable but sufficient size in order to fulfil all requirements and develop its activities efficiently, we proceed with a selection of partners on view of their expertise and previous experience in co-operation projects particularly with other members of the network' team. A relatively large group of associated members was established enhancing the impact of our activities.
We decided that the network needed a 3 full year's period of activity to achieve the

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direct goals and outcomes and specially to guarantee its sustainability in the years after the formal end of the project. An efficient decentralised and hierarchically organised system of administration of the Network on all its aspects will be established.
The network Cooordinator (the author) will ensure the proper efficient development of the network. A Steering Committee formed by the all the National Coordinators and the Network Coordinator will meet (frequently by video-conference) as frequently as needed every year in order to: analyse the development of the work; assessment of results; writing down reports and further support material; proceed with data diffusion and public relations.
In regular basis each National Coordinator will contact all the responsibles of the member institutions of their country recalling their work results. A short report will be issued and delivered to the Network Coordinator that will disseminate it by the entire network members for discussion and improvement. Whenever final conclusions, among the Network, are achieved they will be published in the web site in order to extend the discussion to the community. Boards or offices of the National and supra-national Educational institutions will receive that information directly.
Most of the meetings will be (whenever possible) made in the form of web based video-conferencing. Most of them will be open to all Network Members that often will be specifically invited to take part on the meeting. The in person contact between the Network members is considered very important and will be made whenever possible also during the exchange visits and workshops to be organised throughout the different Partner Countries but also on the General Network Meetings that will take place during the Annual International Conferences.
At least once a year of activities the Network Coordinator will travel to Brussels in order to meet the representatives of the Socrates Program to present and discuss results, reports and activities schedule for the following year. The eventual participation of National Coordinators could be considered.
Annual International Conferences will be held on the middle of each project's year and will be attended hopefully by the entire network members. Furthermore it will be open to all scientific and educational community (including students and their parents). The community will be invited to participate not only in conferences and thematic workshops but also in courses and motivating/promoting activities in the classroom or at School.
This network is organised in a top-down/ bottom-up structure. This means that not only the Network Coordinator and National Coordinators will induce actions produce reports guidelines and induce discussion and interaction. Also all the Network Members on his thematic groups or taskforce or individually through his group will present suggestions, initiate discussions prepare reports and organise local or multilateral activities.
The General Network Meeting presided by the Network Coordinator (once a year during the annual conferences) is on the top of the hierarchy of our structures and to which the Steering Committee will report.

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The network workforce will be divided into thematic groups and fourteen main task forces:

T1. Management

T2. Data collection and analysis

T3. Meetings, workshops and conferences

T4. External projects promotion and integration

T5. Impact, evaluation and monitoring

T6. Reports and publishing

T7. Public relations and dissemination

T8. Web based networking

T9. Tools and practices for HSci learning of Science

T10. Virtual and multimedia hands-on material

T11. Training of teachers

T12. In school activities

T13. Exchange visits

T14. Cross culture, equal opportunities and inclusion

Although all fields of Science will be covered by the network activities, a few topics will be specifically addressed in: Physics, Ecology, Chemistry, Geography, Biology, Archaeology, Robotics, Maths,.... Interaction between these thematic groups will occur.

Transversal thematic workshops will be organised: “The access of Women to Science” in Germany in June 2004, “The challenges of EU’ enlargement on Science literacy and Development” in Malta, fall 2005; and “Science Literacy and Life-long Learning” in Romania in July 2006.

In January 2004 we launched the 1st European Contest on “Ideas for Science Fairs” with which we hope to induce the generalisation of the organisation of Science fairs in the Schools.

During each annual meeting a workshop will be organised where we will present our work and discussing it with industries’ representative and of the community. Their ideas and demands will be organised and will condition the further development of our work.

Several Comenius 2.1. projects will be presented by network members in order to develop a number of training courses in the different languages and participating countries. Most of them having an informal interactive structure aiming to allow the teachers/educators to feel the advantages of this pedagogical approach. Practical tools will be giving to the teachers in order to allow them to immediately begin introducing hands-on activities in their classrooms. Other topics will surely appear along the way. By the moment and already for the next call we expect to present 5 projects on “Elementary Optics”, “The use of virtual interactive simulations in science teaching”, “How to establish an In School Science Forum”, “Robots. On the way to the future”, “Feeling Life and ecology”. On these topics and in others like “All different all the same” involving “regular” and special education schools in Portugal, Spain and Greece, or “The world of photonics” different Comenius 1 project proposals will be made.

The schools involved on the project will play the most important role. However in the network close to each one of them we intend to have a higher educational institution working close together. Several motivational activities will be organised in the different countries inside the school in extra-curricular activities like informal seminars, Science fairs and contests, but also as in-classroom intervention were

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the students will execute a number of hands-on experiments. A general set of experiments covering the different disciplines of Science (ecology, light sound and waves, geology the earth and the environment, biology animals and plants, genetics and reproduction, speed and mechanics, electricity and energy, sun and space, chemistry, shapes and forms, …) and education levels (up to 10 years old, 10-13, 14-16, 16 to 18) will be studied and supplied to the schools for assessment of the materials themselves and different approaches of its practical in class use.
In Romania the local partners with cooperation of members of other countries when possible will prepare and execute a number of informal courses and demonstration sessions in rural and particularly poor and neglected areas, including gypsies' communities in the interior of Romania.
Web based meetings and teleconferences will be used as extensively as possible. An ISDN multipoint videoconference system will be established. The use of virtual hands-on learning tools will be explored. Different approaches will be implemented and tested. Translations and adjusts will be made at Country level. The Science Fairs and Students' Science Clubs that will be organised will have virtual versions. A suitable and simply platform will be created allowing a straightforward organisation of virtual web-based Science Fairs and students' a Science discussion e-forum.
The careful assessment of the teachers and students feedback on the Project's activities and product' outcomes will be made and is considered fundamental.
We will seek an enlarged involvement of Industries and of the work-world in general in order to get their feedback on educational and special competencies needs. We also aim to gather a cluster of companies (including major industries that will be invited to attend our meetings and assess our activities and outcomes) able to ensure the development and financing of the networks' activities after the official expected end of the H-Sci network.

Evaluation and Dissemination

The assessment of the network is considered fundamental. Internal self-evaluation will be made in a country and task basis. At least twice a year the Steering Committee will access the evolution of the network activities and establish corrective measures whenever needed. The evaluation will be made in two levels: in what concerns organisational matters, and on the evaluation of the quality of the pedagogical material and activities developed. Reports will be generated and publicised. By the end of each year reports will be presented to Educational government boards, Educators Associations, relevant local government entities, teachers, students and their parents. Their assessment has a major importance. Inquests and questionnaires will be prepared and delivered to the different evaluators.
In the network global web site there will be a space for evaluation and discussion of progress and results open not only to the network members but also to all interested. National web sites, dynamically linked to the global website, will include a space for pupil's opinions and intervention. A data processing strategy will be

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established during the first months of activities of the network being adjusted as necessary. The strategy will be made available to all interested for use or discussion.
Acquired data will be statistically analysed and conclusions drawn. The network will also request access, and analyse and process the corresponding data, to the current exams and evaluations on the schools and students involved in activities developed by suggestion or authorship of the network.
The Project and Projects' activities and outcomes will be widely publicised.
Apart from the International Conferences and workshops the results of our activities will be presented in different conferences and congress in relevant subjects. As well several papers will be published in International Journals.
A network of pattern makers on these subjects will be established involving all countries participating in the Project.
Several EU project proposals are expected to be presented in the future based on the present project' results. It will aim to enter also the vocational training market, for life-long education in optical and optics related fields, mainly to support the working force re-conversion to jobs related to the expanding applications of Science.
We count with the support of several National Governmental boards or institutions to help us publicising and disseminating our activities and outputs. Also on the evaluation of our activities and outputs he count with the cooperation of: the Slovenian Board of Education (formal partner of the network); the Ministry of Science and Education of Romania; the "Unidade Ciência Viva" of the Ministry of Science and Universities in Portugal; The DCL company at EU level; and the CoLoS association at European level. Several members with the status of observers will have an important role as evaluators of our network development.
The Internet based e-network established linking all the participating institution will be another way of dissemination of our activities and outputs.
The opinion of all the students involved on our network activities will be expressed in volunteer anonymous inquests that will be prepared. The results of the inquests will be statistically treat and the main conclusion taking in great account.
The monitoring and evaluation on the national (Slovenian) level will be accomplished through direct involvement of the Slovenian Board of education.
The assessment of all our project output by the scientific and educational community during the scheduled annual conferences will represent a major contribution to the evolution of our work and to the establishment of our final conclusions.
The DCL firm will consider the possibility of production and commercialisation of any educational material we may develop.

Conclusion

The pedagogical usefulness and effectiveness of in-class hands-on experimental activities is clearly proved in different school levels and disciplines.
We intend to further prove and make this evident contributing to invert decline of interest among young people for science studies and careers.

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Our "Hands-on Science" network aims to strategically induce the creation of a realm of learning that will give the students the competitive edge in the new Knowledge-based Economy. We plan to grow steps in the sense that schools may in fact become incubators for nurturing promising scientists and pro-efficient technicians and professionals in Science and Technology.

"We learn how to do things by doing the things we are learning to do"

(Aristotles)

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References

[1] Costa MFM, The importance of experimentation on teaching the basics of optics at elementary and high schools, Proc. Soc. Photo-Opt. Instrum. Eng., 3190: 228-232, 1997.
[2] Kolb DA, Experimental learning: Experience as source of learning and development, Prentice Hall: Upper Saddle River, 1984.
[3] Gatt S and Vella Y, Constructivist Teaching in Primary School Social Studies, Mathematics, Science, ICT and Design and Technology, 2003.
[4] Christian W and Belloni M, Physlets: Teaching Physics with Interactive Curricular Material, Prentice Hall's Series in Educational Innovation, 2001.
[5] Michaelides PG, An affordable and efficient in-service training scheme for the Science Teacher, in Proceedings of the International Conference Computer Based Learning in Science, pp.: 792-799, 2003.
[6] http://folk.uio.no/sveinsj/ROSE_abstract.htm

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State of the Art of Science Teaching

Michaelides PG

Introduction

Education reforms have been effected or are under way in most of the European and other countries during the last years. Although the extent and the kind of the reforms vary significantly from one country to another, they all share as a common factor the increased significance of Science Education which becomes a major constituent of school curriculum, comparable to language. This bust resulted in a plethora on works, empirical and other, related to Science education. Many works are also published on the INTERNET [1].

Science teaching which constitutes a major part of the contents of Science education has also attracted educators and researchers. A simple comparison on the quantities of articles in scientific journals on Science education and the publication of books dedicated specially to the different aspects of Science education shows a significant increase over the past decade. The increase in not only quantitative, providing useful empirical data but it also extends to more general aspects including the teaching approaches adopted, the underlying learning theories, the teaching means and the use of new technologies (especially informatics), and also, other parameters that may affect the effectiveness of Science Teaching.

A Short Commentary on the Literature

Until some time ago, Science teaching and, more generally, Science education were dealt mostly as an adaptation (more or less similar to the teaching of all the other subjects of the school curriculum) of the general pedagogy which attracted the research emphasis on teaching. In current days, possibly because of the importance assigned to Science teaching, specific large extent studies are undertaken providing a plethora of recent data as candidates for inclusion to this, necessarily brief, work. Now, the expression "state of the art" may take different overlapping and parallel meanings:

- Current or contemporary trends in the field,
- New developments in the underlying theories,
- New approaches using or adapting already known models,

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- Recent empirical data from relevant activities,
- Use of new equipment and or technology,
- Empirical results obtained recently,
- Etc.

There are many good works in every one of the above classes and it would be rather unfeasible to single out and present even representative works (not mentioning the great subjectiveness such a task may have). Consequently, this work presents, for the interested reader, a more or less extensive bibliography of collected works on available sources about research and field activities on Science teaching and focuses to some of the most common characteristics the current works on Science teaching exhibit.

Empirical Results

Works under this class describe the teaching of a specific topic from the Science subject matter of the school. The teaching is presented and the data are discussed in terms either:

- The (social, ethnic, economic or otherwise) school context,
- The application of a specific learning strategy,
- The contest of a specific problem with the Science topic discussed, e.g. misconceptions, alternate conceptions, specific understanding difficulties, etc.,
- The comparison between different teaching approaches,
- The use of new technology, especially computers,
- The use of an innovative experimentation,
- Etc.

Taking into account the specific terms under which the study has been performed, the, usually sound, empirical data provided are useful to the development of teaching strategies, to choosing a specific type of instruction, etc. Examples of this type of work appear in all journals, either specific to Science education or to education in general. The publications from schools and from teachers associations always provide valuable such data from actual school operation and quite often contain studies of a high scientific quality [2]. Specialized International Conferences are also a rich supply of such data (see for example [3], [4]). Local conferences provide also similar data with the advantage of addressing peculiarities of a specific education system.
Summer schools or special interest workshops is another valuable source of education data on a specific area or region.

Surveys and Specialized Studies

Surveys refer to various parameters of the education system of a region. They are usually carried out within the activities of international bodies e.g. OECD [5],

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UNESCO [6], EU [7], or sponsored by (local or state) governments. Their focus is mainly on economic and on policy matters. However, recently their content has been extended to include specific chapters directly related to Science and Technology education [8-15]. These data provide useful information on developments in the regions considered.
Lately, another source of this specific type of data initiated within the European Union by Thematic Networks (or other Community funded actions) on Science and Technology [16-18]. Usually these are initially fostered by EU within the context of increasing the S&T Literacy (STL), a priority action.
Because of the importance Science teaching and, more generally, Science education receives in most of the European and other states, many reputed publishers include in their publication collections of refereed relevant studies produced in a regular basis (see some examples later).

Content

Works on Science teaching from sources like the ones mentioned earlier were selected and their contents were analyzed in terms of:

- The theme and/or type of the work,
- The underlying learning theory, if any, in relation to skills, dexterities and attitudes to be attained,
- The type of instruction used and the type of assessment, if any,
- The subject matter chosen, its sequence into topics and its type (traditional versus modern Science),
- The target group,
- The experiment and, more general, the practice work involved, if any,
- The equipment used,
- Other related issues.

Although this analysis was not extensive to include all different aspects in these categories, there were interesting findings.

Theme

The works examined were referring to different issues of Science teaching, e.g. the application of a learning theory or of a specific type of instruction etc (see above in 3. Themes). Many were also referring to related issues that affect Science teaching or provide a context for it such as the Science teacher's competence and how to develop it [19-21], the curriculum aspects and how to achieve them, existing or desirable objectives of Science education, the influence of the social environment of the school or the pupils [22-23], etc. It should be noted however that some of the works examined refer to issues related to Science teaching without a focus theme. This was more evident in works describing actual school practices referring to experimental or practice activities.

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Underlying Learning Theory

Although learning may occur spontaneously (every day's experience) or even without teaching at all, learning theories are fundamental in choosing an appropriate teaching strategy and enhance significantly teaching effectiveness when they are understood by the teacher and applied appropriately. This is more than true for Science where in addition to cognitive skills (simple and complex) other practical skills and dexterities are also to be attained. In quite a few of the works examined, a specific learning theory is missing and it cannot be inferred from the whole teaching architecture. As empirical evidence indicates, most of the teachers lack the necessary knowledge and if they possess it, they tend to repeat the teaching they themselves have been exposed to than to transform their knowledge into school practice and adventure on new teaching approaches. The scientific knowledge they have learned on this subject seems abstract and remote to school reality. The importance of Science education assigned by recently introduced national curricula in almost all countries revealed the necessity for an effective Science teaching and the requirement of a learning theory. To this end Piaget's work provide an expected choice [24] and constructivist teaching emerges as the theory environment for Science teaching with many relevant works appearing. Although in most of the cases the theory is applied correctly, in actual school instruction the active evolvement of the students with an appropriate time for reflection and (re)construction of their (new) cognitive schemes leaves large margins of improvements. In most cases the teacher "demonstrates inconsistencies", "explains or proves the theory" and "builds the model". The reasons may be attributed to the limited school time allocated or to unawareness of its importance. This is a problem attracting attention (see for example [25]). A useful source of related issues may be found also in [26].

Type of Instruction Used

Empirical data on school operation show that narration, although still practiced to a large extent, diminishes. Instruction is at least enriched with audiovisual means. Experimentation at least as a demonstration quite often performed by the students themselves is constantly increasing. Teaching actions requiring the active student's participation (i.e. essays, observations) either at atomic level or in group work appear frequently [27]. Teaching by project assignments and experience teaching are constantly increasing. Assessment is improving and seems that is considered, at last, an integral part of the teaching although there is a lag in formative assessment. When formative assessment is included in teaching usually means a summative assessment on part of the lesson of the day and, if achievement results are low, the teaching is repeated in the same way (see more in [28]).

Subject Matter

The management of subject matter is almost within the traditional analytical way imposed in the course outline of the Science curriculum, a rather expected outcome, even when the curriculum permits flexibility. Encouraging is however that

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increasing advocating of a more synthetic (e.g. study of a phenomenon in total not its partial aspects) or of an interdisciplinary approach appear and relevant research and field work started to appears (see an example in [29]). Real life observations and their connection to the "theory" of Science disciplines only recently has attracted attention and started to enter classrooms.

Target Group

Apart from a minority of works where a target group is not clearly defined or it is stated to cover a wide range of grades (ages), the majority of the rest addresses mostly primary education, may be because pedagogy is associated with childhood. Middle and then high school general education follow (in this descending order) while technical vocational education is almost absent despite its significance in a technology based society. Higher levels of education are addressed mainly in pre- and in- service Science teachers. Practical skills, so interlaced with Science education, need still a proper attention and a systematic study (see more in [30]). Almost always the study is restricted to (complex) cognitive skills (e.g. problem solving). Within this context, conceptual change, scaffolding and related methods are used but quite often in a controversial way.

Practice Work

Experimentation has been made compulsory in most of the curricula introduced recently and is increasingly included in school Science teaching. Problems still remain and include:

- The type of experiment(s) used (demonstration or testing, by the teacher or by the students,…)
- The equipment used (simple or modern, in the classroom or in special laboratory, actual experiments or simulated ones,…) [31].
- The role of experiment within the teaching process.
- Reporting on experimental findings.
- Etc.

Most problems here may be traced to the downgrading of practice work that prevailed and the lack of experienced teachers. Despite the progress made, the field is open to the investigation, the research and the teaching with the main problem being the smooth and consistent incorporation of experiments into the teaching practice. Also studies on this field will provide useful data about the outcome of students' practice of science and may help to understand better the influence of practice work to conceptual associated with cognition.

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Perspectives

Science teaching aims at a more efficient Science education. Efficiency however depends strongly on the objectives attributed to Science education an issue directly related to the reasons Science is included in the school curriculum. These are:

- Cultural. Science is a cultural asset of human civilization and has its place especially in compulsory education.
- Utilitarian. Science is the basis of technology and thus a sine qua non for technology dependant societies and a
- significant means to welfare for the rest.
- Personal. Science poses inherent advantages to the cognitive development of young persons and consequently it is important especially to the primary school curriculum when cognitive skills are developed [32].
- Social. With so many decisions in technology dependant societies directly influenced by Science and Technology advances, Science literacy is crucial to democracy as an active participatory system [33].

Depending on the values and the perspectives of the context society ([22], [23]) different priorities may be assigned to the reasons above affecting thus the emphasis of Science teaching. Or:

> The education we desire for our children must depend upon our ideals of human character, and our hopes as to the part they are to play in the community. A pacifist will not desire for his children the education which seems good to a militarist; the educational outlook of a communist will not be the same as that of an individualist. To come to a more fundamental cleavage; there can be no agreement between those who regard education as a means of instilling certain definite beliefs, and those who think that it should produce the power of independent judgement. Where such issues are relevant, it would be idle to shirk them. At the same time, there is a considerable body of new knowledge in psychology and pedagogy which is independent of these ultimate questions, and has an intimate bearing on education. Already it has produced very important results, but a great deal remains to be done before its teachings have been fully assimilated. This is especially true of the first five years of life; these have been found to have an importance far greater than that formerly attributed to them, which involves a corresponding increase in the educational importance of parents.
>
> (Bertrand Russell,
> On Education, Especially in Early Childhood,
> 1926) [35]

If the priority is Utilitarian, facts methods and techniques would be pursued by Science teaching. If the priority is Personal, complex cognitive skills as e.g. problem solving must be pursued. If the priority is social, project work and group work are useful resources. Usually a balanced mixture is aimed at. Our societies highly value

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the personal and social reasons also have declared an interest on the Utilitarian one. Consequently, Science teaching, especially in compulsory education, has to be adapted appropriately in order to improve [34] (or at least to not deteriorate) the quality of our societies. Towards this aim Science teaching must adapt appropriately. Areas of improvement include:

Syllabus. An update is necessary. After a century since relativity and quantum mechanics it is about time for them to reach schools [36]. These together with Statistical physics and recent developments must reproduce the syllabus in a coherent and consistent way. The up to now practice (in tertiary education also) to add separate additional chapters after traditional Science has been taught only confusion provokes.

Inquiry. Open type questions and problems are necessary to complex cognitive skill development. They should, however, be accompanied with scientific discipline. Physics by inquiry is a valuable resource [37].

Experiments. They should be performed, especially in smaller ages with simple materials. Self-made equipment presents inherent advantages and helps towards a better understanding of the basic notions [29]. They should be incorporated smoothly to the teaching activities with the skill of planning an appropriate experiment to test a hypothesis to be an explicit aim. The distinction of observational and/or experimental data from their interpretation and the corresponding theory is very important [43].

Modelling. Science teaching must develop reasoning (logic) [38]. The creation of models [39] is a very advantageous process, may be used more generally and should constitute an explicit objective of Science teaching.

Teaching. Everyday observation may be related to Science [40]. Combined with what children think [41] is very advantageous and leads to a better understanding and appreciation of Science.

Teacher education. A matter of urgency. Polymorphic practice [42], new and flexible methods of training [44] are valuable resources.

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Notes and References

[1] A search on Science education resulted in more than 300000 hits on more than 50000 sites. Narrowing and restricting the search still leaves more than 50000 results. Although most of them are simple description of activities, a few have a significant value.

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[2] See for example the “Handbook of Research on Teaching” 4th edition published in 2001 by AERA – the American Educational Research Association (http://www.aera.net/).
[3] CBLIS – Computer Based Learning in Science is held biennially and focuses in the use of Informatics to various aspects of Science Education. The 2003 (6th) Conference was held in Nicosia, Cyprus. The 2005 (7th) Conference will be held at the University of Zilinska in Slovakia, see links:
http://www.ucy.ac.cy/cblis2003/ and http://www.student.utc.sk/~jasomja/cblis/
[4] EERA – European Education Research Association (http://www.eera.ac.uk/) operates the annual European Conference on Educational Research (ECER) in which Science education is represented. The 2004 conference will be hosted by The University of Crete in Rethymno at Sep. 20-25, 2004.
[5] OECD - Organization for Economic Cooperation and Development outlines its publications and activities in various economic sectors. Its publications include regular indexes on Education with specific chapters on Science and Technology education and corresponding Trends and Achievements, Outcomes of Learning, etc. Many of the publications are also available electronically. The OECD PISA activities (Programme for International Student Assessment) are well known (http://www.oecd.org/home/).
[6] UNESCO - United Nations Educational, Scientific and Cultural Organization was established in 1946 (www.unesco.org). Many of UNESCO’s publications are available electronically.
[7] On the European Union – EU site (http://europa.eu.int/index_en.htm) there is a plethora of data on Science and Technology education.
[8] OECD- Science, Technology and Industry, Scoreboard, Benchmarking, Knowledge-Based Economies, a regular publication.
[9] OECD – Education at a glance, a yearly publication with indices on Science and Technology issues including Learning outcomes and Science achievements.
[10] OECD - Investing in Education, Analysis of the World Education Indicators.
[11] OECD - Schooling For Tomorrow, Learning to Bridge the Digital Divide.
[12] OECD - The Appraisal of Investments in Educational Facilities.
[13] UNESCO Handbook for Science Teacher.
[14] New UNESCO Source Book for Science Teaching.
[15] EU – database. It contains a wealth of documents on Education and Training (see Url in [7]).
[16] ESERA – the European Science Education Research Association that also operates a biennial conference. Selected works from the 2001 3rd International Conference may be found in Science Education Research in the Knowledge Based Society by Dimitris Psilos et al. (Eds.), KLUWER Academic Publishers, 2003 (http://www.physik.uni-dortmund.de/didaktik/esera/home.htm).
[17] http://www.biol.ucl.ac.be/STEDE/, STEDE – Science Teacher Education Development in Europe.
[18] Hands on Science operating this Conference (http://www.hsci.info/).
[19] Cheng YC, Chow KW and Tsui KT, New Teacher Education for the Future International Perspectives, KLUWER Academic Publishers, 2001.

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[20] Brophy J (Ed.), Advances In Research On Teaching, in Teachers' Knowledge Of Subject Matter As It Relates To Their Teaching Practice, JAI Press Inc. 1991.
[21] Sandra K (Ed.), Science Teacher Education: An International Perspective, KLUWER Academic Publishers.
[22] Christophorou LG, Place of Science in a World of Values and Facts, Kluwer, 2001.
[23] Kumar DD and Chubin DE (Eds.), Science, Technology, and Society: A Sourcebook on Research and Practice, Kluwer Academic Publishers, 2000.
[24] Jean Piaget (1896-1980) a Swiss biologist with many published papers in the field. However he is known for his works in developmental and cognitive psychology. He started psychology studying his children's intellectual development and is best known for his theory on the stages of cognitive development. He was interested in intellectual development of young persons and not in Science teaching and used topics from natural sciences (field he understood well) for his empirical observations on how children were acting. As a result his works became a supportive host to Science teaching.
[25] Gatt S and Vella Y, Constructivist Teaching In Primary School, Social Studies, Mathematics, Science, ICT, Design And Technology, Published by Agenda - Malta, 2003.
[26] Jarvis T, Children and Primary Science, Nichols Publishing, 1991.
[27] There is an increasing tendency to use group work almost exclusively. While this type of teaching action seems appropriate for lower grades atomic works may be more advantageous for personal and vocational development especially for practice (psychomotive) skills.
[28] Bell B and Cowie B, Science & Technology Education Library, in Formative Assessment and Science Education, Kluwer Academic Publishers.
[29] Michaelides PG and Miltiadis T, Science Teaching with Self-made Apparatus, paper to be presented in this Conference.
[30] Leach J and Paulsen A (Eds.), Practical Work in Science Education: Recent Research Studies, Roskilde University Press, Kluwer, 1999.
[31] Complex equipment may be necessary in high grades (ages) experimentation where the phenomena under study may require it or the measurement accuracy should be rather high. Their complexity however may hinder the principles of the phenomenon under study especially in lower grades (ages) where a conceptual understanding of basic principles is more appropriate. Simulations may be appropriate for an easier understanding of the workings (theory) behind the phenomenon under study or for difficult to operate situations (e.g. volcanoes, nuclei, etc). They are also useful to the manipulation, process and multivariate presentation of the data obtained. Their use however deprives the experience of a direct observation or of the planning and execution of an experiment and they are not usually appropriate to smaller ages when complex cognitive skills are to be attained.
[32] In a Piagetian context children in primary education are in the stage from concrete operational to formal. Natural phenomena (at least the ones in primary Science) are directly observable by the senses (or with the help of

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simple easily understood equipment) thus more easily perceptible than the phenomena (objects of study) in other disciplines where an abstract notion is necessary for their perception (for example migration apart from the observation of a person relocating him (her) self the subjective notion of permanently moving – making a new home- is also required). Because physical phenomena are usually perceptible by all normal persons they may provide a common reference system of notions and this was called by Einstein in his "Lectures at Princeton" truth).

[33] Democracy as we know it is based on active participation of the citizens to the decisions taken acting on their own capacities and not as followers of a "gifted leader" (as sheep under the herdsman). As an increasing number of decisions is dependent upon Science and Technology (S&T) developments, in order for citizen for the citizen to be able to participate on his (her) own he (she) not only should be S&T literate but also he (she) must have cognitive skills permitting decisions on incomplete knowledge, i.e. also in areas he (she) is not an expert. Otherwise science will be mixed with religion as in the Dark middle ages or in some places (for example contemporary USA – see http://www.ncseweb.org/ where Science education, especially de theory of evolution became a legal matter competing with religious doctrine). Note 1: the effective Science and Technology education has been declared by UNESCO "democratic right", a right to democracy.

[34] Gutwirth S, Smets S and Van Langehove L, Science, Technology, and Social Change, Aerts D (Ed.), Kluwer Academic Publishers, 1999.

[35] Bertrand Russell (1872-1980) one of the greatest philosophers. Current Logic in advance from Aristotle is heavily based on his works (Russell's paradox). He is widely known for his peace initiative during the "cold war" period. He was a prolific writer of scientific works some of which were written in jail where was imprisoned because of his political activity. He was also author of many articles addressed to general public(http://www.humanities.mcmaster.ca/~russell/)

[36] Kalkanis G, Which (and How) Science and Technology Education for Future Citizens?, pp.: 199-214 of Vol. II of the proceedings of the University of Cyprus, 1st IOSTE Symposium in Southern Europe – Science and Technology Education: Preparing Future Citizens, Paralimni- Cyprus, 29/4-2/5, 2001.

[37] McDermott LC, Shaffer PS and Constantinou CP, Preparing teachers to teach physics and physical science by inquiry, Phys. Educ., 35: 411-420, 2000.

[38] Viennot L, Reasoning in Physics: The Part of Common Sense, Kluwer Academic Publishers.

[39] Gilbert JK and Boulter CJ, Developing Models in Science Education, Kluwer Academic Publishers, 2000.

[40] Michaelides PG, Everyday observations in relation to Natural Sciences, in Learning in Mathematics and Science and Educational Technology, pp.: 281-300, University of Cyprus, 2001.

[41] Cobern WW, Everyday Thoughts about Nature, Kluwer Academic Publishers, 2003.

[42] Michaelides PG, Polymorphic Practice in Science, Proceedings of the 1st Pan-Hellenic Conference on the Didactics of Science and the introduction of New

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Technologies in Education, University of Thessaloniki, Thessaloniki, pp.: 399-405, 1998.
[43] Michaelides PG, Understanding difficulties in Science observations, oral presentation, 2nd Pan-Hellenic Conference on the Didactics of Science and the introduction of New Technologies in Education, University of Cyprus, Nicosia, 2000.
[44] Michaelides PG, An affordable and efficient in-service training scheme for the Science Teacher, Proceeding of the 6th International Conference on Computer Based Learning in Science 2003, University of Cyprus, Nicosia, Cyprus, pp.: 792-799, 2003.

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Learning Optics at Basic Schools by Experimentation

Costa MFM

Background

The main goal, the work of the physicist is to discover to understand and to explain the physical world.
To observe, to see critically, is the first fundamental step in this process. The student must not only to understand this deeply, as they must to be taught to see, to observe. This should be the first concern of a physics/science teacher.
We may even argue about the interest of explaining, transmitting the concepts if the student is not able to “see” the problems, the situations and is unable to distinguish/discriminate the processes, the problems involved that need to be solved or explained in order for the situations to be understood. It is definitely of utmost importance to early teach the students to observe but also to raise questions, to perform critical analysis, to build new situations and scenarios.
In order to captivate the students attention and interest on physics (and science and technology in general) it is common practice among the most concerned teachers to make the presentation or demonstration of some experiments, as spectacular as possible. A high degree of sophistication is often sought in order to increase the impact among the generally alienated students. The problem is that it is more and more difficult to find new situations that could surpass the ones all and every student already saw repeatedly on TV or cinema. Furthermore they tend to accept as enough the ideas/explanations (usually inaccurate and often even wrong and misleading) they receive in such a way. Moreover they do get themselves definitely bored when attempts are made to discuss and explain those subjects. The major problem with this process is that the “information” is received fast and in an extremely passive way. They see, they ear but never critically. And in that way no meaningful knowledge can ever be attained!
So,... what to do? Let’s turn into the basics, to “simple” things, everyday situations, simple old fashion apparatus. And, above all, let’s give time (we should never forget teaching takes time and learning takes much more!) the students to see, to discuss, to play with, to enjoy, to have fun, to feel the thrill of discovery, to wonder themselves with the world of physics... Nice words! ... In reality... it do pays the effort!

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Increasing students' specific knowledge is important. But above all science demands work, responsibility and method. It is precisely this, the most important thing the science teaching should give to the students.
Hands on, experimental work is surely be the best way to achieve those goals. Furthermore in classic lectures students have an attention span less than 15 minutes. The introduction of, even if small, practical hands on activities or some practical problems to be discussed in class, do allow a much more effective extensive use of the class time.
We cannot expect that all of our students will become scientists or fellows truly interested on these subjects, but it is our "obligation" to try to make that number the higher the possible [1-7].

Introduction

The generic objective of the "Ciência Viva" ("Science Alive") program (8) created in 1996 by the Portuguese Ministry of Science and Technology was to improve and enlarge the use of experimentation on teaching science classes in basic and secondary schools.
Our specific objectives arose from the huge deficiencies in the knowledge of the even very basic concepts of optics I first noticed on my classes of geometrical optics at the undergraduate course of Applied Optics (optics branch) at the University of Minho. More than one quarter of the students stated that they have not hear about optics ever in classroom (for instance in the 8th grade the optics subject is optional and most frequently not taught at all) before entering the university! Only a few students have shown an acceptable understanding of the meaning of index of refraction. A higher number of students recognized the lens maker formulae. But... could not solve a simple minor problem with it, nor could even explain what they think the terms image and object are or mean!
Our specific goal was thus to complement the formation of the basic and secondary schools' students in the field of Elementary Optics.
My objectives found a good receptivity among several teachers of five Minho's basic or secondary schools EB, 2/3S de Celorico de Basto (EBSCB), Fermentões (EBF), Alberto Sampaio (ESAS), Vila Verde (ESVV) and CENATEX. All schools of different type operating in different contexts. The ESAS is an average size secondary school located in the centre of the town of Braga the District capital of Minho. The ESVV is a basic and secondary of a small fast growing town in the suburbs of Braga. Settled in the outskirts of a large industrial town the activities on the basic school of Fermentões are strongly conditioned by a rather difficult social environment. On the other hand the EBSCB in a countryside environment have very nice operation conditions with teachers and students extremely cooperative and enthusiastic. Finally the secondary school CENATEX is a professional school in technological subjects.
In the overall more the 1200 were directly involved ages from 12 to 18 years coordinated by around forty school teachers in a large number of different types of activities.

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A Brief Overview of the Experimental Projects and its Results

The two first projects (ESVV and ESAS) back in 1997/98 have established the basic ideas and strategies on teaching the basics of optics to this kind of students.
A small set of hands on simple experiments (however with an increasing complexity) was prepared together with a small activities' guide (3-6). A permanent appeal is made to an active critical posture. All of the sessions' evolution relies essentially on the observation. The students should see, discuss and get their own conclusions and whenever possible to establish what to do next. They are encouraged to step out of the guide's proposals and follow their one path to reach the goals. Time was rather short and the students were not used to this kind of action. Thus all the actions were not fully accomplished. This was definitely not considered a major drawback. Each student has his own pace and we should also understand that. Rushing things it is not a good strategy at all.
The students begin looking and discussing different sources of light from the sun to sodium fluoresces. Light dispersion with Newton prisms was next. A short analysis of the human visual system was performed. The colour vision and colour matching were then introduced. Definitely enchanted students performed several simple experiments. Some optical illusions have been observed and discussed. Next they entered the domain of the basics of geometrical optics. Simple ray tracing experiments were done. The mirrors and lenses were introduced. The microscope and the telescope become rather popular! Other topics like spectroscopy, optical sensors, diffraction concept, holography and fibre optics were also included.
Along the years the material, guides and experiments involved were improved and enlarged trying to establish bridges to other fields of knowledge in an interdisciplinary way. Not only the very basics of light and optics are object of our projects (EBSCB and EBF). We also included more advanced approaches to topics like optical sensors, fibre optics and telecommunications (CENATEX) in interdisciplinary ways involving not only physics teachers and students but also electronics or chemistry teachers and students in a project were the focus is on the spectroscopy and its applications (EBSCB).
The very positive way the project evolved on the classroom's experimental activities was confirmed by the assessment of the students' knowledge improvement on these matters. But, above all, the interest of this kind of actions was marked by the students opinion expressed on voluntary surveys the students filled by the end of the action. 98% of the students was very pleased with the action and expressed their desire of seeing it continued. An important majority stressed the importance of hands on experimental work on learning physics. But perhaps more important is that the students soon began organizing their own activities. For instance every Wednesday afternoon (even on holidays) the physics lab of the EBSCB is open to the students that organize autonomously and work almost entirely alone, on themselves.
Even with younger students (8) from pre-school or elementary (5 to 8 years old) this kind of action has a striking positive effect. The basics of some subjects are easily understood: addition of colours (often older students take longer to understand the process because they are used to the subtractive ink's colour mixing), reflection of light and internal total reflection (a piece of sweet flavoured jelly may act as an

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wonderful... light guide!), refractive bending of light (the coin in the bottom of a plastic cup; a trip to a rivers' shore may become an highly productive and pleasant experience!).
Confirming what I said above in the introduction even the younger children insistently request to see and play (literally!…) with lasers. Constant references are made to TV films or cartoons. Fibre optics is also mentioned and when in use they become very popular. Not only the students see that light can go from one side of the fibre to the other even if highly bender as they also realize the fibre can be used to see objects in the other end away.

Conclusion

Perhaps more important than knowing concepts or theories is to know how to get them. It is necessary to teach and predispose the students to observe, to think, to reason, to analyze critically and interactively problems and situations. More important than the final concepts, is to know, to feel, to interiorize the paths or processes of, or to, understand them.
Once more it was clearly proven that the pursuit of experimental hands-on work by the students on or off the classroom it's a powerful way to helps us science teachers to reach our basic goals.

References

[1] Costa MFM, Teaching Applied Optics at the University of Minho, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 357-361, 1995.
[2] Narayana SP, Put the real world in the physics curriculum, Physics Today, 48: 15, 1995.
[3] Prasanis AS, Teaching Optics in the Optics Age, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 318-330, 1995.
[4] Schuch JH and Wu ZL, Getting students to see the light, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 309-315, 1995.
[5] Nofziger MJ, Optics curriculum for middle school students, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 213-224, 1995.
[6] Williams G, Laser experiments for the secondary school classroom, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 230-246, 1995.
[7] Wilder C, Elementary laser optics? Yes!, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 193-197, 1995.
[8] http://www.cienciaviva.pt/

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Teaching Concepts of Physics and Appointing the Nature of Science through Historic Scientific Experiments

Dimitriadis P and Paptsimpa L

Introduction

The aim of a modern educational process is to prepare and enable citizens (European Commission, 1995; AAAS:1989; AAAS:1993; Millar, 1997:101):

a) to understand basic principles and concepts of science;
b) to follow the scientific methodology in dealing with their daily life problems and to apply scientific knowledge for taking personal and social decisions;
c) to perceive science as a human achievement;
d) to conceive the value of scientific knowledge as well as the limits of its power.

After many years of interest in the scientific literacy of citizens, researchers in the field of natural sciences education keep on seeking an effective way of approach by the trainees not only of the acceptable scientific knowledge (i.e. the final results of the scientific exercise) but also of the methodology of science, that is the way of scientific work (De Boer, 2000; Hurd,1988; Laugksch, 2000; Lederman and O' Mailey, 1990; Akerson, Abd-El-Khalick and Lederman, 2000; Lederman, 1999). Scientific theories should be presented in such a way that would place emphasis on the fact that these theories constitute sets of inter- related concepts and that every theory offers a framework to understand and comprehend an empirical field (Millar, 1998).

Objectives

One of the most important questions concerns the extent to which an indirect teaching approach on the nature of science (NoS), including lectures, discussions and incorporating scientific activities like experiments, projects, research etc., should be used. Answers to the aforementioned question differentiate to a great extent (Palmquist and Finley, 1997; Lederman and O'Malley, 1990; Moss, 2001; Rydder et al., 1999), (Bell, Lederman and Abd-El-Khalick, 1998; Bell, Lederman and Abd-El-Khalick, 2000; Akerson et al., 2000; Bianchini and Cobern, 2000). The

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proposal presented in this paper is based on the framework that connects the experience of ‘doing science’ to the direct and explicit teaching of the NoS features through the use of elements from the history of science (Akerson et al, 2000, p.297).
The history of science should be incorporated in a way that allows the presentation of the historical evolution of scientific standards and physics’ concepts, which led to the formulation of the theories that constitute, at present, the foundations of scientific knowledge. Elements from this historical evolution should be included both in the curricula of the various educational grades (AAAS:1993) and in the teachers’ training programs (Dimitriadis, P. et al., 2001). In addition, the historical, geographic and social context within which these theories were developed should be made known to the students. By presenting the biography of the scientists who participated in the development of the scientific theories, the social character of science is better perceived and its nature as a human achievement is properly highlighted.
It is evident that out of the total of the scientific ideas one should select and present the more useful and significant parts of achieved scientific knowledge, like particle structure of the matter, the fundamental interactions, etc. Moreover, each thematic unit chosen to be taught should give answers to fundamental questions that concerned the scientists who participated in the formulation of the respective theories. More importantly, however, these questions should generate the interest of students and drive them to further study the specific topic. Thus, for example, the following questions could be asked:

a) How do matter composing particles interact with each other?
b) Could the particles forming the matter be created or disappear?
c) Where does the stellar energy to which we owe our existence come from?
d) What makes the stellar bodies move and how is their movement determined?
e) Can we predict whether a stellar body approaching the earth is going to collide with it?
f) Which is the cause of the movement of terrestrial and celestial bodies?

In this particular case, we choose to present certain basic experiments that are considered as milestones in the development of the concepts of physics, since the methodology followed and the way in which these experiments have been performed have contributed to the establishment of scientific methodology. These experiments should be presented in such a way that the steps of the scientific method are explicitly demonstrated. Experiments like these could constitute the basis for teaching in class the key concepts of physics, like those of inertia and gravity, the laws of Newton, etc. The teaching approach is addressed to middle school students and students of the first grades of the high school.
The basic thematic units we choose are the following:

a) The Newtonian mechanics.
b) The theory of electromagnetism.

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c) The structure of the matter.

We present these topics in close relation to the historical experiments performed, respectively, by Galileo, Faraday and Rutherford.

Educational Software

Our purpose is to build up a collection of web pages within the European School's of Brussels III site. The didactic material included is addressed to both teachers and students and will have the form of hypertexts, visualizations of the simulation models and static pictures related to the theories. Work sheets will be available in a later stage.
Information and communication technologies are essential in meeting the objectives of the network. Since we strive to encourage students to become familiar with some historic experiments, an ICT platform is needed to facilitate this. The development of this software has the following general objectives:

a) To assist in creating proper solutions for problems arising during the teaching of the respective concepts, like facing the students' misconceptions
b) To be used by students in order to absorb and comprehend the respective concepts.

Such software packages contain:

a) The presentation of experiments as performed by the scientists who conducted them or their inspirers, along with the questions for which answers were sought when performing these experiments;
b) The technical problems that had to be faced by those who designed these experiments;
c) The established perceptions that were overturned by carefully analysing and interpreting the experiments' results;
d) The presentation of the geopolitical context in which the aforementioned ideas had been developed;
e) Simulations / visual representations of the experiments, highlighting the basic parameters of the phenomenon and their inter-relationships;
f) Study / teaching plans and worksheets.

An important feature of this software is the multimedia worksheets, which have the following characteristics:

a) Multiple representations of instructions in picture, video and/or text format.
b) The possibility to highlight the information acquired at the empirical field. For example, there is a possibility to observe a fast developing phenomenon in slow motion, so that the student can watch each different picture thus becoming able to describe in detail each different step of the experiment.

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c) Model creating capabilities for the natural phenomena the students are studying in the course of the empirical activities.
d) Presentation of the scientific model for the particular natural phenomenon properly adapted to the students' cognitive level.

In this way, students analyse in detail their empirical data and identify the basic characteristics of the phenomenon, resulting into the scientific model that describes this phenomenon. Thus, the student realises that making models of the natural systems is a basic element of scientific methodology (Arbanitakis D, Dimitriadis P, Papatsimpa L, 2001).
Computer based techniques like hypertext and visualization of simulation models serve as a means to overcome basic obstacles in learning processes.
The first drafts of the didactic material are created using the authoring environment of Macromedia's Flash MX which can provide Web pages of sufficient quality. The Action Script included, is quite powerful in supporting the simulation models presented (and at the same time quite easy to understand). We investigate the possibility of using other products, if necessary, in a later stage.
Some of the animated pictures are built by using Animation Shop by combining static pictures – frames, created under the Paint Shop Pro. It is an environment providing tools for image manipulation.
The outcomes will be available to schools worldwide. Initially only the partner schools will actively participate in providing and testing the educational material.
Once the final version of the web-site is fully operational, all schools that have access to the WWW will be able to view and study the information presented, and will be enabled to actively participate in the process of exchanging ideas and providing additional information.

Teaching Methodology

Students were working in groups of two persons on the basis of the worksheets under the guidance of the teacher. The worksheets were developed on the basis of guided research. By using electronic worksheets, the teacher was able to easily enter into a Socratic dialogue with the students who were, thus, assisted in dealing with their preconceptions on the specific phenomenon. The teacher is supported in introducing the scientific model through the use of simulations or visual representations of the natural process, simple modelling of real objects (e.g. the material point) or forces, shown by the video projector. The teacher, using suitable slides, guides the students to identify the common characteristics of activities conducted in the classroom or of the phenomena they watched on the video screen, so that they can draw conclusions and use the scientific terminology.

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Thematic Unit 1-Unifying Earth with Heaven, the Newtonian Synthesis

This thematic unit refers to the laws that were formulated by Newton. These laws govern the movement of both celestial and terrestrial bodies, the law of the universal gravity, as well as to the great influence of the aforementioned views on shaping the socio- philosophical ideas of the 17th and 18th centuries.

The Newtonian perception of the world created such a great response that it also influenced fields beyond Physics and Astronomy. Physics' principles and the mathematical way for calculating their impact provided the model for all subsequent scientific development. It consolidated the perception that natural phenomena can be explained in terms of mathematics and physics, and that nature can evolve without the intervention of external actions, like God, although Newton himself considered that the verification of his theory certified God's existence. It also influenced significantly the social beliefs of that time and signalled the beginning of formulating various social systems theories. A lot of people considered that it is possible to design and operate a system of government in a way similar to the Newtonian solar system, which under the influence of different forces/factors would soon reach a stable state of equilibrium.

Moreover, the development of Newtonian mechanics is a characteristic example of a scientific theory that was progressively built by following the distinctive steps of scientific methodology, that is:

A. The validation of different scientific statements through a multiple process of experimental confirmation, the use of parameters to describe natural phenomena and the identification of quantitative relations among these parameters.

- **Galileo** designed and conducted experiments with admirable for his time accuracy, in order to confirm Aristotle's postulations (which were the prevailing ideas of his era) on the bodies' movement and fall. He was, thus, lead to defining the law of inertia, as well as the laws of movement under constant acceleration and of movements influenced by the resistance of the air (projectile motion).
- **Huygens** studied collisions and, taking into account the notion of relative movement, concluded to the principle of maintained thrust.
- **Keppler**, elaborating further the very accurate astronomical observations of T. Brache, concluded to the empirical laws governing the movement of the planets.

B. The synthesis of individual scientific true statements – Identification of a small number of principles explaining the experimental results.

- **Newton introduced**:
  The notion of mass as a measure of inertia,
  The notion of force and its qualities (the action-reaction axiom),
  The three laws governing movements,

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The law of universal gravitation, and explained the empirical laws on the movement of planets, based on the 2nd of his laws and the law of universal gravitation.

By selecting the above topic we can:

- highlight the role of observation and experimentation in the scientific methodology, the clash of scientific ideas that lead to the Newtonian perception of the natural world, as well as the influence of Galileo's and Newton's theories in shaping the modern concepts on the movement of terrestrial and celestial bodies;
- present the whole of Newton's synthetic theory integrating the applicability of the same laws on the movement of terrestrial and celestial bodies, a set of ideas that is one of the most important ones in mankind's cultural heritage;
- familiarise the students with the above set of concepts, a fact that will help them in seeking for answers on the fundamental questions of mankind concerning the universe, its creation, its size, its evolution, etc. Almost all human civilizations, from antiquity to today, have been concerned with similar questions, which stimulate the strong interest of present students.

Educational Objectives

We distinguish two types of educational objectives: Those concerning the comprehension of concepts and those referring to obtain skills in relation to:

Physics

The student should:

- Be familiar with the basic concepts of Mechanics: mass, momentum, acceleration, force;
- Recognize them through specific activities (like the use of air-table fabricated by simple materials and a simple tribometer, as well as that the force of friction makes bodies decelerate and finally stop);
- Qualitatively associate the concept of inertia to perpetual movement
- (Galileo's experiments);
- Qualitatively associate the concept of acceleration (how fast or slow a body starts or stops) with the body's mass and the force exerted upon it;
- Describe the qualitative characteristics of his every day experiences using Newton's 2nd law;
- Identify in simple activities conducted both in the classroom as well as in his daily life the bodies upon which a force - and the reaction - is applied by relating the application of these forces to the change in the bodies' movement;
- Use the terms action/reaction to explain phenomena he / she observes in his / her daily life;

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- Know that gravitational interaction is exerted from a distance between all bodies with a mass, thus being of a universal character;
- Know the law of universal gravitation and qualitatively explain on the basis
- of this law the movements of planets, stars, comets, tides, etc.
- Be acquainted with the three laws of Newtonian Mechanics concerning the movement of bodies and comprehend that they are universally applicable.

History

The student should:

- Know the scientific achievements of Europe during the Middle Ages and the Renaissance;
- Appreciate the role of the church in shaping the society and the ideas during the Middle Ages;
- Comprehend the importance of Renaissance for the European development in the modern times.

References

[1] Adb-El-Khalick F and Lederman N, Improving science teachers' conceptions of the nature of science: a critical review of the literature, International Journal of Science Education, 22: 665-702, 2000.
[2] Akerson VL, Abd-El-Khalick F and Lederman NG, Influence of a reflective explicit activity-based approach on elementary teacher' conceptions of nature of science, Journal of Research in Science Teaching, 37: 295-317, 2000.
[3] American Association for the Advancement of Science (AAAS), Project 2061: Science for all Americans, AAAS: Washington, 1989.
[4] American Association for the Advancement of Science (AAAS), Benchmarks for science literacy, AAAS: Washington, 1993.
[5] American Association for the Advancement of Science (AAAS), Project 2061: Science for all Americans, Historical perspectives, AAAS: Washington, 1993.
[6] Arbanitakis D, Dimitriadis P and Papatsimpa L, An interactive multimedia programme for the primary school teacher: A new tool for the implementation on information technology in the teaching of science, 5th Panhellenic conference (with international participation): Didactics of mathematics and informatics in education), Thessaloniki, Creece, 12-14 October 2001.
[7] Bell RL, Lederman NG and Abd-El-Khalick F, Implicit versus explicit nature of science instruction: An explicit response to Palmquist and Finley, Journal of Research in Science Teaching, 35: 1057-1061, 1998.
[8] Bell RL, Lederman NG and Abd-El-Khalick F, Developing and acting upon one's conception of the nature of science: A follow-up study, Journal of Research in Science Teaching, 37: 563-581, 2000.

ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

[9] Bianchini JA and Colbrurn A, Teaching the nature of science though inquiry to prospective elementary teachers: A tale of two researches, Journal of Research in Science Teaching, 37: 177-209, 2000.
[10] DeBoer GE, Scientific literacy: Look at its historical and contemporary meaning and its relationship to science education reform, Journal of research in Science Teaching, 37: 582-601, 2000.
[11] Dimitriadis P and Papatsimpa L, Educating of primary teachers in history, philosophy and methodology of science with a constructivist approach, Proceedings, ESERA, 3th Inter. Conf., Thessaloniki, Greece, pp.: 356-358 2001.
[12] European Commission, White paper on education and training: Teaching and learning-Towards the learning society (White paper), Office for Official Publications in European Countries, Luxemburg, 1999.
[13] Hurd PD, Scientific literacy: New minds for a changing world. Science Education, 82: 407-416, 1998.
[14] Jenkins E, Scientific and Technological for Citizenship: What can we learn from the research and other evidence?, 1998. http://www.leeds.ac.uk/educol/documents/000000447.doc.
[15] Laugksch RC, Scientific literacy: A conceptual overview, Science Education, 84: 71-94, 2000.
[16] Lederman NG and O'Malley M, Students' perceptions of tentativeness in science: Development, use, and sources of change, Science Education, 74: 225-239, 1999.
[17] Matthews PM, Contemporary Curricular Developments, Science Teaching, Routledge: London, 1994.
[18] Millar R and Osborne J, (Eds.), Beyond 2000: Science education for the future, Report of a seminar series funded by the Nuffield Foundation, King's College: London, 1998.
[19] Millar R, Science education for Democracy, in Levinson R and Thomas J (Eds.), Science Today, Routledge: London, pp.: 87-101.
[20] Moss DM, Examining the student conception of the nature of science. International Journal of Science Education, 23: 771-790, 2001.
[21] Palmquist BC and Finley FN, Preservice teachers' views of nature of science during a post baccalaureate science teaching program, Journal of Research in Science Teaching: 34, 595-615, 1997.
[22] Ryder J, Leach J and Driver R, Undergraduate science students' images of science. Journal of Research in Science Teaching, 36: 201-219, 1999.

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Physical Virtual Laboratory

Păuşan E and Iliescu M

Introduction

As teachers, we confront with students who have needs and distinct problems, which request the method diversification which should help each of them to have a chance in a society who wants to be integrated in the European Union. This means more than knowledge acquisition, and their integration in a coherent system, and also practicing the investigation and learning techniques.

Fighting for using the information technology and communications in the modern school, we'll remember since the beginning that through the proposed activities we want to establish equilibrium between the formative and informative process. By develop the informational network are opened gates to a knowledge which is built step by step, by facing permanent models with reality, by facing the opinions with dialog.

Projecting our activities, so that the students to be used with the permanent confront of models and real systems, we could minimalism one of the important risks existing in an informational society: people next by a computer could become a prisoner of a virtual universe, model type, less and less open minded, less and less involved in day by day life. That's why is important to structure an educational environment in which the personal experience to be the before the theoretic act, abstract, having as main objective step by step formation of an equilibrate personality.

Studying per Model - a Stage of Scientific Research

Studying physics we define models for different physic systems, confronted with the real systems, is an important stage of any scientific research. That's why simulation software and the laboratory experiment could be components of a cluster that allows developing of activities for which is important the finalization because of the perspective offered by confrontation between model and real system. In the interior of simulation software cluster exists a relationship in both ways:

- Projecting a simulation software will be realized transfer per model of the obtained information after studying the real system, being an argument for a

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proposal that this kind of applications to be realized also by the students (represents also another way to solve a physics' problem, agreed by them);

- The reverse relationship, simulation software – laboratory experiment, starts from two aspects: simulation can have an anticipative character, could be identified optimal conditions of the laboratory experiment progress; another aspect is related to the need of validation of different suppositions regarding the real system, and based on a simulation, many times, we could obtain answers for a new experimental research.

Labview Simulation

Having classes/ groups of students with different problems, could be efficient that different simulation software to be realized by the teacher, because he knows students difficulties. This type of applications presents an important advantage: possibility to visualize the way how a model is acting in the conditions made by the user. Also could be pointed out in short period of time more particular situations, being offered through a single application for a package of problems for a known problem. Learning sequences, which that be built using the interactive applications could be selected by the teacher, but exists also the possibility that this could be generated by the student, discovered new aspects, which are properties of systems. It could be then asking questions, for which the answer it can be found exactly in this applications. In other type of situations we could rely on different software in order to allow to the student practicing in his own way of work.

Applications made by us using LabView includes also working tasks, the virtual experiment being proposed, usually, to determine the value of a measure necessary to describe the evolution of the system. Having as objective student confrontation with different investigation methods, following also practicing in their own way, we projected the applications that so by using them the student can go over the main stages of the experiment, knowing the method principle, working way, recording of the experimental data, projection of an algorithm for data processing, making conclusions.

Applications presented in Figures 1 and 2 offer different experimental methods in order to determine the compliance constant of a resort, being selected projection solutions so that the virtual experiment to be equivalent with the real one. For the applications, which present the equilibrium method, user will select different values of the mass of the body, which is hanged of the resort, for a specific value of the compliance constant, the system configuration is modified accordingly. User will read on the rule value of resort strain and will fill in a table this value, and in the second table will be recorded masses of bodies, hanged one by one by the resort. Application diagram will display the experimental points, and also the sequential order of these points, being necessary that the student make a correct analyze of the diagram and to extract the useful information.

"Demo" section of the application presents to the student the theoretic curve of the resort strain that depend on the value of the straining force, being also presented the method based on which could be obtained the solution of the proposed problem. To have in target practicing of the way how it could be obtained an

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experiment conclusion, analyzing the recorded data, is important to take into discussion and to be presented to the students different processing possibilities, in the above mentioned application being used the smallest square method.

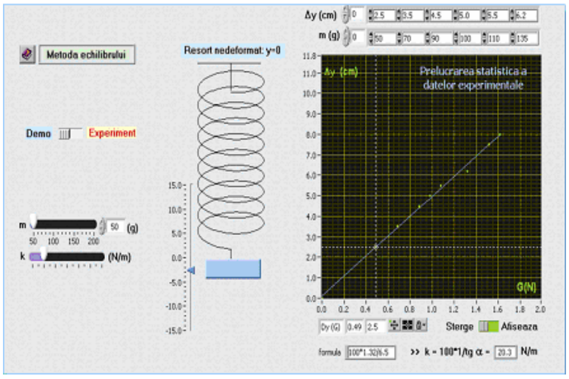

Figure 1. Sequence from the frontal panel of the application "Determining the compliance constant of a resort (equilibrium method)"

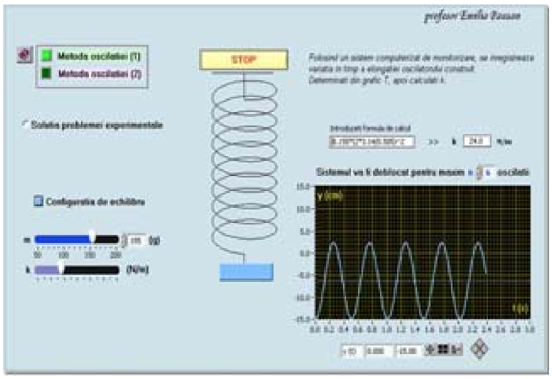

Figure 2. Sequence from the frontal panel of the application "Determining the compliance constant of a resort (oscillation method)"

By projecting the application presented in Figure 2, we wanted to prepare another laboratory experiment, in which data are acquired using the computer. To realize this kind of experiment it was necessary student accommodation with the way of data processing and extraction of the information.
Using this software, the student will initiate oscillation by pulling out the system from the equilibrium configuration, application displaying variation graph during time of the oscillator elongation, in the same time with the simulation of evolution of the modelled system.
Information extracted from the application diagram allows determining period of oscillation; this value is necessary to calculate the compliance constant of the resort (in section of the front panel, for the sequence "Experiment", are inserted controls that allows introduction of calculation formulas, their results being analyzed by the program).
Using different simulations will be permanently followed, when it's possible, the real experiment, student will be confronted with questions like: "why in these conditions the system behaves this way?", how can we check in the laboratory this kind of behaviour, which is the best methods for the real system?", in what kind of conditions system properties are easy to be pointed out?", "why the model doesn't behave in the same way with the real system?", etc. Confronting behaviour of a model with a real system will be identified properties that make the difference between the two systems. Is also pointed out the necessity to built a chain of models in which the information will be amplified, easier models are as a particular case of the superior models.
Being proposed to the students realizing this kind of applications, they solve a physics problem, practicing in the same way many competences. It is recommended, for this kind of proposal, using LabView program, which is accessible also to the teachers and students, because of the offered facilities.

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Remember that the programming language used is a graphic one, extremely intuitive, and the functions allow realizing complex applications.
Although, the possibility to make a hierarchic projection offers flexibility, being possible to be built independent application, this could be then integrated in software. We choose first applications which have been presented in order to be exemplified also this aspect, the resort built based on an independent application being useful to realize many applications, which proposed distinct problems.

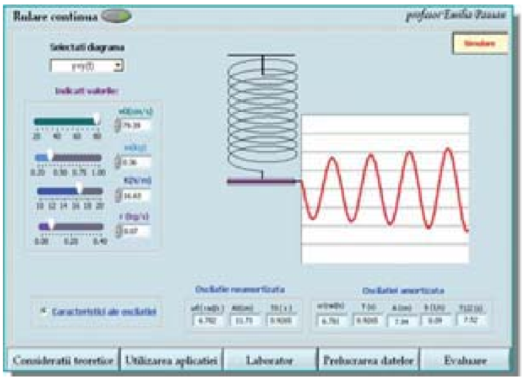

Figure 3. Application "Linear oscillator"

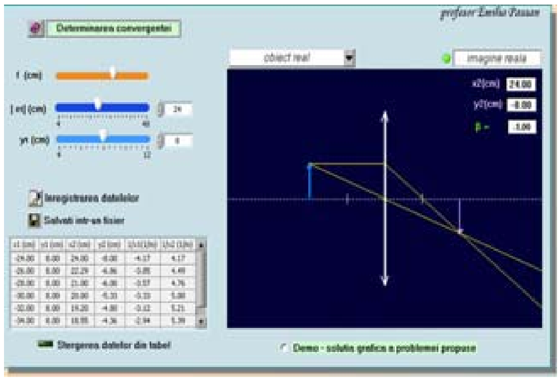

Figure 4. Sequence of the application "Convergent lens"

Simulation of system behaviour allows in a direct way confrontation of the model with the real system. In classic way, we describe the behaviour of physics system by value tables, by mathematics formulas and/or by graphic representations. Not always and not for every student realizing and interpreting the mathematic calculations, and graphic representations, is easy to be realized. He needs time to accommodate with these, and the rhythm of each student is not the same. This aspect is an important item for projection of different applications, in the following presentation is presented software, "The linear oscillator" (Figure 3). This allows to the student visualization of model behaviour, being also presented time dependence of different measures, which describes the oscillation (in the meantime the application presented in Figure 2 offers to the student only the information useful to solve the proposed problem, this new application allows a detailed study of the linear oscillator behaviour). Graphic representations are built simultaneously with the system evolution, equivalent to the recording of an electrocardiogram, which allows that the signification to be easily understood.
By processing the experimental data could be obtained characteristics of the oscillation: period, frequency, value of damping coefficient, etc. Remember also the fact that presented application in Figure 3, in which is simulated behaviour of the linear oscillator, includes as a particular case the simple model of the harmonic linear oscillator, being pointed out to the student limits of this model, corrections being made by a superior model.

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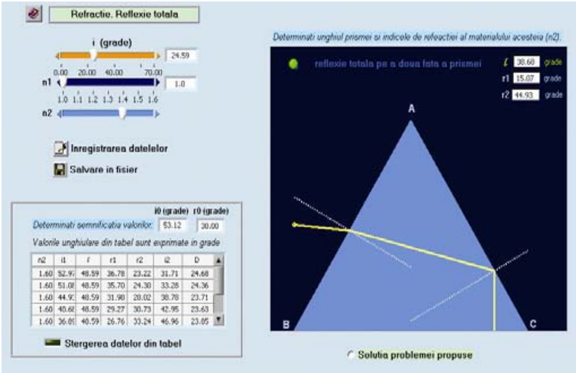

Figure 5. Sequence of application "Optial Prism"

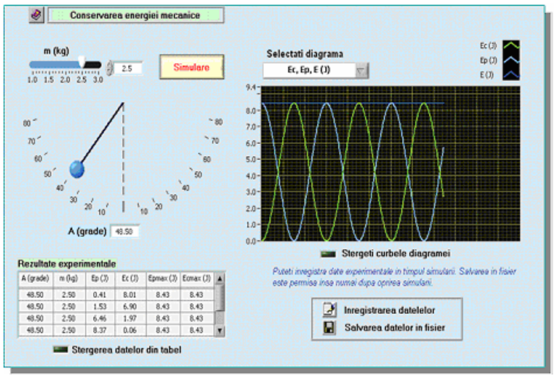

Figure 6. Sequence during the application "Gravitational pendulum. Conservation of mechanic energy"

In physics study, it frequently modelation by graphic constructions and using an interactive application it proves to be more efficient than using the plans. Using a similar application as the one presented in Figure 4, student will be familiar with the graphic drawing that allows visualization of image characteristics in a convergent lens, having the possibility, that in short period of time, to surprise different aspects, obtaining a big number of particular cases. This application proposes also to make a virtual experiment in order to determine the convergence.

Based on this kind of application, before realize the laboratory experiment, student will be familiar with the working way, with the data processing possibilities, discussing the solutions presented by students being important especially for making a successful laboratory experiment.

The application presented in Figure 5 propose to study the refraction phenomenon in a prism, could be pointed out particular cases of interest (in the illustrated sequence is presented the total reflection on the second part of the prism). This application proposes also to realize a virtual experiment in order to determine the prism angle and also the refractive index of the environment when the prism is installed. To solve the experimental problem is necessary a correct use of the application information, based on the studying laws, could be identified also particular cases that helps the student for the real laboratory experiment.

Graphic representations of different application presents important information for the proposed theme, by a correct interpretation of these data could be obtained connections between different measures, or to be deducted physics laws. In Figure 6 is presented software built on order to point out mechanic energy conservation. Simultaneously with the evolution of the modulate system (gravitational pendulum which could be pulled out from equilibrium configuration), is presented in diagram: application of time variation of kinetic energy, a potential energy, being given also the sum of these two components. User has also the possibility to record in a file experimental data, these being presented in a table in the front panel of the application.

Advantage of using simulation software is very good seen by applications in which are simulated system behaviours that cannot be studied in a school laboratory. In Figure 7 is presented this kind o software propose a classic problem of particles

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loaded with electric charge who enters in an uniform magnetic field, their speed being oriented under different angles comparing with the field lines. This application has integrated a self-evaluation sequence, being proposed to the student in classic way, a physics problem. Variables of the application are projections of particle speed on Oz and Oy axes, as we l as value of induction of the uniform magnetic field in which the particle enters (field lines being parallel with Oz axe), application displays oscillation characteristics (period and beam of helicoids). As working action, student has to determine the particle type, particle's load, as well as some oscillation characteristics (oscillation period and pulsation, helicoids step).

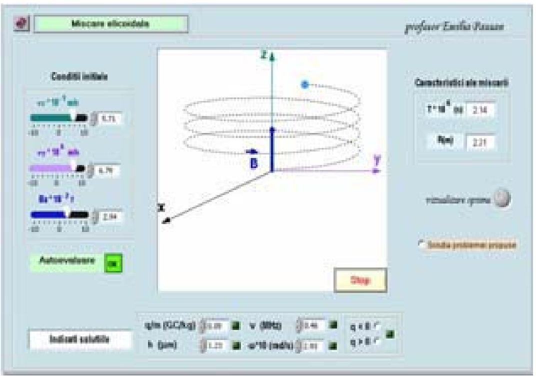

Figure 7. Application "Electrification of particles in a uniform magnetic field"

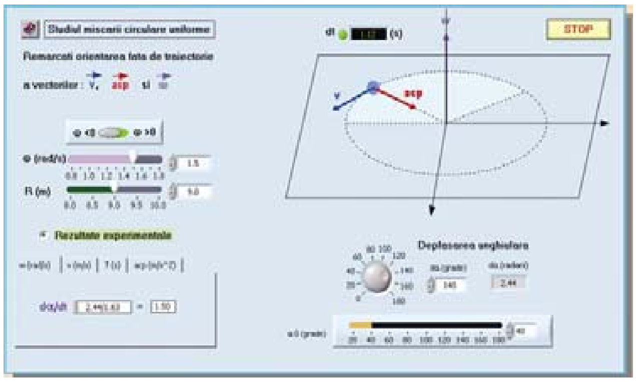

Figure 8. Application "Study of uniform circular oscillation"

A part of the applications requests also to find solutions in order to realize the three-dimensional effects (see applications presented in Figures 7, 8 and 9). Generally, we proceed to define a perspective and to include this one in the software algorithm, could be used also other solutions, LabView program offers controls ActiveX type and 3D diagrams.
Presented application in the above mentioned diagram, offered also to be seen a three-dimensional effect, points out, that for an uniform circular oscillation, are realized angular movements in equal periods of time. User will select value of the angled movement and its position on the trajectory, the application displays time period in which the angular movement is realized. There are also presented linear velocity vectors, angular velocity, and centripetal acceleration vector. Modification of the rotational sense is accompanied by the corresponding modification of velocity vectors, being requested to the user to established connections between represented vectors during application.
Using the same projection method in order to realize three- dimensional effect, was built another application, which completes the one prior presented, being proposed the classic problem of conic pendulum (see Figure 9). This new application points out system actions, which guides to a uniform circular oscillation, rising this way problem of this kind of oscillation. Generally, for each unit for which have been projected different applications, we realized also evaluation/ self- evaluation tests. In despite of tests integrated for some applications, tests projected for the

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evaluation made at unit content level have been realized as well as pointing sequence to be displayed after fulfilling all tests items (Figure 10), in this sequence being presented also solutions indicated by user, and also correct solutions.

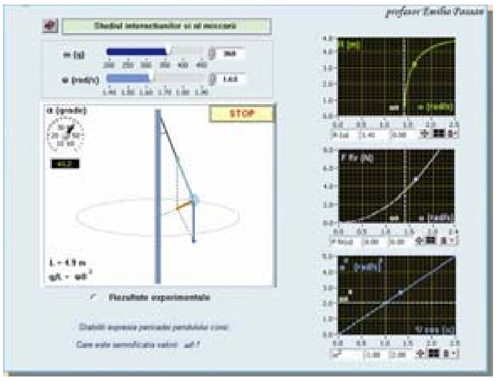

Figure 9. Application "Conic pendulum"

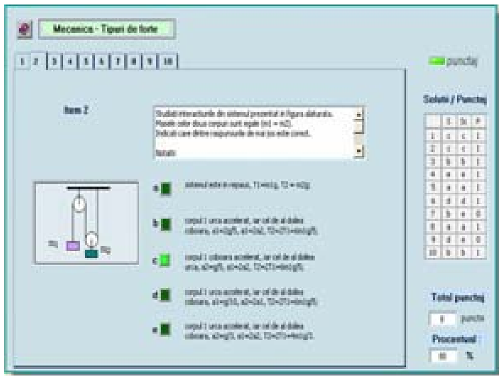

Figure 10. Test for self-evaluation, projected for the content unit "Mechanic interactions. Type of strengths"

One of the items of the presented test proposes the experimental data interpretation, student having the possibility to use, during test, an application for data processing. This type of item have been proposed to check the modality use by the student to extract the requested information based on graphic processing that could be realized using the software (is requested determination of the value of resorts' elastic constant, being presented experimental data obtained based on a laboratory experiment: values of resort strain and straining strengths).

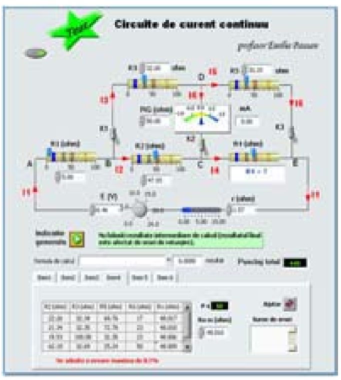

Figure 11. Test for self-evaluation projected for content unit "Direct current circuits"

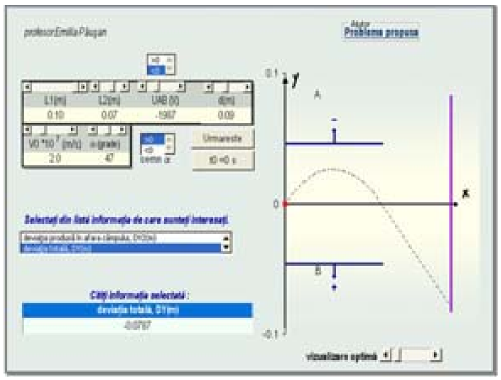

Figure 12. Sequence of application "Electrified particles in uniform electric field"

Most evaluation/ self-evaluation software, projected for a content unit, has an item in which the student is asked to realize a virtual experiment to determine the value of physic measures, system characteristics of the proposed system. In Figure 11 is described a test for the content unit "Direct current circuits", item 4 of the application

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requests to determine the electric resistance of one of the circuit resistors, could be used a zero method (user will modify values of electric resistance belong to other resistors of the bridge until the galvanometer will indicate zero value – this way the bridge being equilibrated). Theoretic knowledge of the proposed theme is verified, but also how these are used to project and realize a laboratory experiment.
Even the simplest applications, which could be realized using LabView, we propose interesting problems for school hours. Based on interactivity and didactic strategy included by projection, this type of applications could be integrated in a physic case that could be used by a student also in school and home.

Simple Solutions, Easy to Reach, to Realize Interactive Applications

Reminding that physics' teacher could realize small applications, being necessary a good algorithm, which can be then demonstrated in many programming methods, is proposed a simple projection solution of an interactive physics application, using Excel program from Office package.
Applications for classic problems could be easily realized based on this program. For exemplification is presented in Figure 12 an application in which is simulated behaviour of electrified particles in electric uniform field. User can modify distance between plates of capacitor, distance from this to the screen, speed value and orientation of particles that enters in field, electric voltage applied to the capacitor, as we l as the polarity. This way could be obviously see particular cases, the application displays useful information to describe the evolution of the modelate system.
Proposal to use Excel, which is optimal for the students who don't know a programming language, is easily proven. Near the obtained interest by proposal to project physics application, is not necessary to create to the student a problem, which is harder than the initial one. Here is the biggest advantage of using Excel: is extremely easy to use and, practically, high-school students are use with the base elements of it. This way, accent will be on a good algorithm and a good knowledge of physics laws and principles, without their applications have no content. More than that, interest for correct functioning of an application will make them to open one more book, or to ask more questions, and team activity is a useful exercise.

Conclusions

We proposed in this document to expand the physics case with a new component, necessary to make the model study, which includes simulation software. These proposals are proved by the fact that simulation software allows:

- Visualization the model behaviour, in users' conditions;
- Pointing out, in a short period of time, of more particular cases, which are important for the study of the proposed theme;

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- Simulation of some experiments, having as target accommodation with the experimental method, as well as different possibilities of data processing, or of the experiments that cannot be realized in a school laboratory.

By student involving to realize simple simulations on the computer, following all the stages starting with the hypothesis, developing the mathematic formalism, to the model confrontation with the real system, is good to remind that:

“Hypothesis has to be considered only as an asset, never as a target”

(T. Huxley)

Or that
“Writing adequate postulate is always possible to be realize mathematic systems, as Euclid did, but we cannot realize a world mathematic, because sooner or later will be forced to see if the axiom are valid for the objects from nature”

(Richard P. Feynman).

So, it’s important not to forget: Computer is an instrument which can be useful or not, it is depends the scope in which we are using it. New characteristics could be given to this modern instrument, and the evolution of today society offers new methods, instruments and solutions.

References

[1] Munteanu M, Logofătu B and Lincke R, LabView virtual instrumentation, Credis: Bucharest, 2001.
[2] Munteanu M, Logofătu B and Lincke R, Applications of LabView virtual instrumentation, Credis: Bucharest, 2001.
[3] Savu T and Savu G, Informatics – Technologies assisted by the computer, manual for 10th year of study / technique profile, ALL Educational: Bucharest, 2000.
[4] Garabet M, Voicu A and Păuşan E, Information and Communication technology in modern school, Credis: Bucharest, 2003.
[5] Păuşan E, Physics interactive applications. Excel, Credis: Bucharest, 2003.

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Science Teaching with Self-Made Apparatus

Michaelides PG and Miltiadis T

Introduction

Literacy in Science and Technology (STL) is fundamental for the welfare of modern, technology dependent societies. As more and more of the regulations of modern, technology dependent societies are based on the advances in Science and Technology, the basic constituent of democracy, i.e. citizens' participation, requires STL. In this sense, STL becomes a "right to democracy", a view also pursued by UNESCO. Within this framework Science Teaching in general education should be based on principles and methodology rather than on factual knowledge [1] and poses specific demands on the skills and knowledge of the Science Teacher [2]. A sound knowledge of the basic principles is considered, in general, a prerequisite for the Science teacher. Although teachers in Primary Education, at least, lack this knowledge, our experience shows that a major problem hindering the effectiveness of Science Teaching is the teachers' attitude towards Science; in general they should change their approach from factual knowledge on specific data, techniques and themes or from the "successful performance" of an experiment, towards a "scientific inquiry" approach [3], in which, in accordance with a Piagetian context, Science knowledge is not acquired by the student but it is discovered or, at least, negotiated anew. This teaching approach is heavily dependent on systematic Science observations and experiments and this makes experimentation a basic required skill of the Science teacher. In this work we discuss one parameter (the use of self-made apparatus) of experiments in Science teaching. We also present examples from different areas of Physics.

Assumptions

In experiments, the use of sophisticated complex equipment may give accurate measurements. However, it removes the authentic creative activity and converts the experiment to a demonstration process in which the student observes the results of an apparatus he-she does not understand. This, combined with the general attitude to get the results of the experiments instead of inquiring a situation of a Natural phenomenon, hinders, at least in general Science, the understanding of the phenomenon under study. Even teachers with a sound scientific knowledge lack, in general, the skill to transform their scientific knowledge into teaching practice [4]. As

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a consequence, Science and Technology are considered as difficult subjects [5] although they are rather simpler (as may be inferred from the fact that, in human history, they appear and advance earlier than other sciences) and possess inherent advantages. For example their subjects of study are easily perceptible through the senses, an irrefutable advantage for most of the compulsory education students who, in a Piagetian context, have not as yet reached the formal logic stage. This constitutes a significant problem in most of the advanced countries. The construction, totally or partially, of the apparatus to be used in classroom Science experiments is a very creative process associated with the development of cognitive and psycho motive skills and facilitates the logical process of induction. In a group work construction, the development of social skills is also facilitated while the “pleasure of creation” covers the sentimental sector. The use of self- made apparatus exhibits also other inherent advantages; it facilitates query situations and the process of planning an experiment; it demonstrates an immediate application of some of the relevant Science issues; it removes the black box” feeling often associated with the use of modern hi-tech devices; it develops the ingenuity of the teacher, especially the primary school Science teacher for alternatives to the usually expensive equipment on sale; it also makes clear the discrimination between observations’ data and their interpretation [9]. Incorporated into the education of the Science Teacher, the construction of self-made apparatus to be used in Science experiments is another example of polymorphic practice [10] and facilitates the transformation of scientific knowledge to school practice.

Principles and Examples

In order to be useful to Science Teaching, the construction of self-made apparatus must follow some principles, in accordance to the context exposed previously, i.e.:

Simplicity and Safety

The construction must be simple. The materials used must be easily available from the everyday environment of the school and the students. The assembly should be within the abilities of a “do it yourself layman”. During the construction process, dexterities and knowledge on the properties of the materials used and on how to handle them become a clear task. Simple constructions facilitate the understanding on the apparatus functioning and minimize safety problems. Safety is always an important issue that must be stressed, even over emphasized. When students, especially children are involved this statement is obvious; it helps also to the development of good safety awareness attitudes. The situation is also similar for teachers, especially teachers in primary schools who, in general, lack a professional training in Science.

Problem Solving

The whole process must provoke the ingenuity and creativeness of the students. On this basis, the guidance offered must remain within the general goal, leaving the initiative to the student. Detailed guidance should be limited to specific queries related to technical or specialized issues.

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Accuracy, Sensitivity and Calibration

As the prime goal is to understand the principles ("natural law") involved, high levels of accuracy are not required. The apparatus constructed, however, if used as a measuring instrument, must be accurate with an appropriate sensitivity. Calibration is a necessary step for apparatus used as measuring instruments. Usually it is done by comparison with a professional instrument but a discussion on the principles used to make the standards is very enlightening. Estimation of the accuracy and errors is very helpful on the conceptual meaning of measuring errors and their treatment.

Assessment

When the construction is finished, a retrospective evaluation on the whole process, on the choices made and on the other possible alternatives and, also, a comparison with apparatus made by others is advised. It recapitulates on the subject under study and facilitates meta-cognitive effects. Although highly subjective, aesthetics of the final construction is an important issue mainly from the viewpoint of practicality and as an indication of deliberation and diligence.

Some Examples

In the following we present some examples of self-made apparatus. All have been realized in the Department of Primary Education of the University of Crete within the normal teaching activities in Science. For a couple of them notes on their usage within teaching are also given.

Gas Thermometer

The task is to construct a thermometer. Additional aims include basics on glass treatment, a useful skill for chemistry experiments, the notions of calibration, accuracy and sensitivity of measuring instruments and of the measurement error. The construction is shown schematically in Figure 1. A glass test tube (similar to the ones used in chemistry) is heated (a). When the glass is soft enough we elongate the tube with a quick steady straight outward motion (b). We cut (break) the glass near the open end of the test tube (c), the result being a bulb chamber with a thin elongated pipe. This is a device with many uses (see also later on). When the chamber is warm to the highest temperature range we plan to use the thermometer (e.g. by holding the chamber in our warm palm), we touch the open end of the pipe to a drop of coloured water (d) leaving the chamber to cool so that the coloured drop enters the pipe. We fix the device on a piece of cardboard (e) and proceed to calibration.
Calibration is achieved by immersing the chamber into water of different temperatures so that the coloured drop inside the pipe traverses the whole length of the pipe. Although the two extreme temperatures would be sufficient, because the pipe's cross section is not constant one or two intermediate points are necessary. Intermediate temperatures may then be noted to construct the scale. During the

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construction the (unsuccessful) trials are a good starting point for a glass handling dexterity. Observing the coloured drop dropping into the chamber or going out of the open end of the pipe when the temperature is too low or too high for the specific construction, a discussion on the range and the parameters it depends may be initiated. Observing differences between different constructions may arise in a discussion on the measuring errors. Checking repeatedly the accuracy of this thermometer against a standard one may unveil the dependence on the atmospheric pressure which may lead to an improvement, for example, another bulb chamber on the open end.

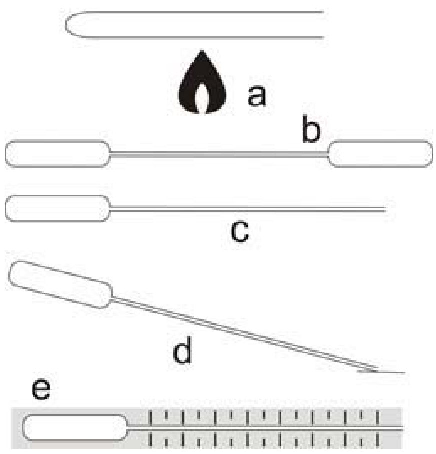

Figure 1. Gas Thermometer

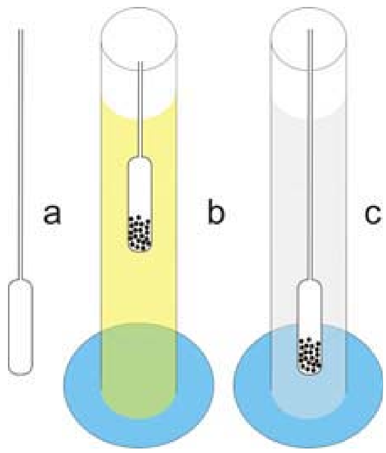

Figure 2. A Hydrometer

Hydrometer

The construction is similar (Figure 1 point c) as in the Gas Thermometer discussed previously. For calibration purposes however, the pipe should not be too thin. Having the device shown in (a) of Figure 2 put into it small lead balls (e.g. thin shot) or even sand and immerse it into liquids of different densities so that the chamber of the device is totally immersed into the liquid while the pipe is either outside (as in b in Figure 2 – a relatively dense liquid) or inside the liquid (as in c in Figure 2 - a relatively thin liquid). By fixing the device into a cardboard the scale may be drawn and then the open end of the pipe is sealed with a gas flame. Liquids more dense than water may be prepared by dissolving salt into water while liquids less dense than water may be prepared by mixing alcohol spirit with water. In both cases the density may be determined by weighting a known volume (e.g. through a volumetric cylinder) of the resulting solution. The device may be used to measure the density of different liquids, for example wines and spirits or must and “infer” the alcoholic content. This construction, especially the calibration process, is advantageous to the understanding of density, of the different ways of titration of solutions, etc.

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A Weighing-Machine

This device (see Figure 3) may be used for the teaching of mechanical moments. The construction is made with materials used to hang slide curtains in house windows. The weight, W, hangs from a hook used to hold the curtain within the slide rod. Similar hooks are used for the joints in p and s. The educational value of this device is in the process of calibration where different aspects on the mechanical moments may be clarified. The construction, if done with diligence, may be very accurate. It is also used in other apparatus (see for example “An amperometer” later on).

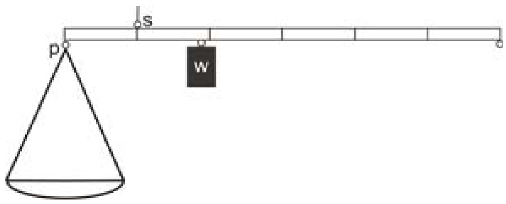

Figure 3. A weighing/machine

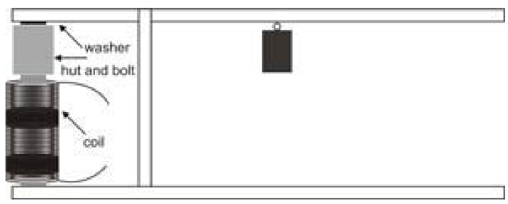

Figure 4. An amperometer

An Amperometer

The construction (see Figure 4) is based on the weighing machine discussed previously. The plate has been replaced by an iron washer fixed on the balance rod and a coil around an iron bolt. Connecting the coil serially to an electric circuit, the current induces an electromagnetic force which holds the washer to the bolt. Moving the weight along the rod the electromagnetic force may be measured by comparing the corresponding mechanical moments. The main objective of the variation presented here is to help understanding the electromagnetic forces. An adaptation could be the following: replace the weight by a (coil) spring. Fix the bolt in the place of the washer. Increase the height of the rod supporting the balance rod. When the electromagnet is activated the bolt is attracted into the (hollow) coil and the corresponding force may be measured by the elongation of the spring. By fixing the spring in different distances from the supporting the balance joint, different current ranges may be measured.

Geographical Coordinates

The device needed is a simple vertical rod OA on a flat horizontal surface (see Figure 5). During the day we mark the end of the shadow of the rod (the s points in Figure 5) together with the time and draw the corresponding line. For demonstration purposes the **s**-point line is shown curved. In practice it is almost a straight line. The point B of the line which is the smallest distance from the rod determines the local meridian (the direction O to B is the North direction for locations in the northern hemisphere). The time the shadow of the rod is along this OB direction is the local noon time and determines the Longitude of the place. For example for Rethymno-Crete, Greece where political time is GMT+2hours, if local noon occurs at 12:22 local political time, the Longitude is 2 (because of the 2 hours difference from

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Greenwich mean time) times 15 arc degrees minus 22 (the 22min in 12:22 local time noon) times 15 arc minutes, that is 24.5 arc degrees. The corresponding angle is related to the local Latitude. It is equal to the Latitude on the equinoxes (21st of March and 23rd of September). On the solstices, the angle takes its extreme values, L±e, where L the local latitude and e ~23.5 arc degrees is the obliquity of the ecliptic. A plot of the angle versus the day of the year is periodic with extremes at the solstices and may be used also to determine the beginning of every season i.e. the days of the solstices (23rd of December and 21st of June) and of the equinoxes (21st of March and 23rd of September). This simple construction and the corresponding measurements may help in clarifying the generally difficult subject of the relation between Earth's movements and the seasons, etc. It also offers a good example on the manipulation of the original measurements, to get results with an estimation of the measurement error. Using advanced mathematical processes very accurate results may be obtained for the estimation of local time (and thus of the Longitude of the place) and of the angle (and thus of the latitude of the place). However, the results may also be obtained with adequate precision of the order of 0.5-1 arc degree and the beginning of each season with a precision of 1 day with the sole use of graphs.

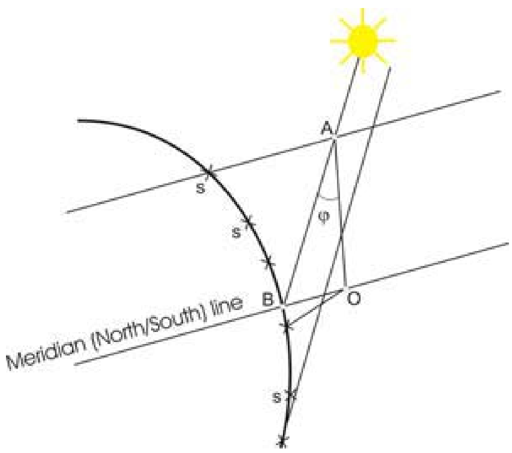

Figure 5. Geographical Coordinates

More Examples

The main objective of the self made devices exposed previously is to make a working construction that will help the understanding of the concepts involved. Making measurements with an adequate precision is also feasible. In the web site http://www.clab.edc.uoc.gr/hsci other examples are given [13].

Epilogue

The self-made constructions, examples of which have been presented in this work, have all been used during the teaching of Science and/or Science Teaching courses in the Department for Primary Education of The University of Crete. All of

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them have been realized as assigned projects by students subscribing to the relevant courses. These constructions have the characteristics of "Polymorphic Practice" and many of them have also been realized partially or totally by school students. Some indicative responses from the University students are:

- ‹ I imagined that for Science experiments a special laboratory was necessary but I realized that doing experiments is not so complicated a matter.
- ‹ I learned to work on my own (a comment made more often by female students).
- ‹ I realized that what we had learned in school may have direct applications.
- ‹ What I learned can be used directly to schools.
- ‹ The construction helped me to understand what I had only memorized.
- ‹ I realized that there is a difference between the graphs in the Science books and the actual data obtained (referring to the scattering of measurements due to measurement errors, a fact usually absent in the graphs of textbooks).

However, there are a significant percentage of students that drop out of the courses. The reasons may be pursued in the direction of the following comments:

- ‹ It was difficult but I learned to work on my own.
- ‹ A good course, but the effort I made was worth of two or more other courses.

In conclusion, the experience is very positive. Students' comments, in schools and in the University, show an acquired positive attitude towards Science, an increase of their self-esteem and confidence on their abilities and an increased interest in Science [14].

References

[1] Michaelides PG, Everyday observations in relation to Natural Sciences, in Learning in Mathematics and Science and Educational Technology, University of Cyprus, pp.: 281- 300, 2001.

[2] Michaelides PG, Polymorphic Practice in Science, Proceedings of the 1st Pan-Hellenic Conference on the Didactics of Science and the introduction of New Technologies in Education, University of Thessaloniki, Thessaloniki May 29-31, pp.: 399-405, 1998.

[3] McDermott LC, Shaffer PS and Constantinou CP, Preparing teachers to teach physics and physical science by inquiry, Phys. Educ., 35: 411-420, 2000.

[4] Halkia K, Difficulties in Transforming the Knowledge of Science into School Knowledge', Proceedings of the University of Cyprus, '1st IOSTE Symposium in Southern Europe – Science and Technology Education: Preparing Future Citizens', Paralimni-Cyprus 29/4-2/5, pp.: 76-82, 2001.

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[5] Piaget, The future of Education, assigns this difficulty in relation to Science while students are performing well in the rest of the subjects to the type of instruction offered with a more probable cause the fast passage from the qualitative management of natural problems to the quantitative mathematization through the use of Physical Laws that enter the instruction in the student's absentia.

[6] Michaelides PG, Understanding difficulties in Science observations, oral presentation, 2nd Pan-Hellenic Conference on the Didactics of Science and the introduction of New Technologies in Education, University of Cyprus, Nicosia, May 3-5, 2000.

[7] See [2]. Polymorphic practice (measurements, experiments...) in Science includes a common psycho motive activity (doing measurements, experimentation...) which consequently is morphed into different levels depending on the (previous) cognitive attainment and/or the mentality of the students. They resemble multilevel teaching i.e. teaching pursuing more than one sector and levels of learning. The need for polymorphic practice teaching arises usually in the training of Science Teachers where there is a requirement of teaching in an advanced level for the teachers themselves, and the requirement of teaching in a level more accessible for the pupils. The difference in the teaching levels is not only on the didactics but also on the subject matter and the attainment levels.

[8] This site is also used by students and is under continuous restructuring. Please report, by e- mail, any difficulties to access the site to michail@edc.uoc.gr. Note that the majority of the Students in schools consider Science as difficult subject (see [4]). Note also that when relevant data were collected, more than 80% of the students in the Department for Primary Education had only the minimum required Science courses in school.

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A Science Fair on Solar Energy with 6th Grade Primary School Children in Greece

Tsagliotis N

Athematic Approach to Science Fair

A science fair appears to be an informal teaching and learning process, which can possibly interweave within teaching sequences or teaching interventions, in a sense of broadening the horizons of formal teaching and learning processes. A science fair mainly aims at developing positive practices and attitudes of children, within a framework of "hands on" science investigations and activities. Of course, this does not mean that the conceptual framework of children's ideas is neither ignored nor neglected. On the contrary, it appears to be strongly considered and elaborated in depth.

Children approach a particular topic, having their questions and interests as a starting point, in an attempt to deal with specific problems and/or every day instances, through a scientific investigation for deeper knowledge and understanding. They develop projects collaborating with each other in pairs or small groups, whereas teachers facilitate investigations and activities and usually facilitate the availability of a variety of materials for children to work with. The end product of a science fair is an open exhibition of children's work, where their projects and/or constructions are presented in public and usually judged, awarded prizes and distinctions (cf. Fredericks & Asimov, 1990; Van Cleave, 2000).

The science fair is considered within a thematic or a cross curricular theme framework and it is seen from the point of view of a specific teaching and learning subject. According to Beane (1997) a safe criterion to discern a thematic or a cross curricular theme approach, within the treatment of a particular topic or theme, is its actual way of design. In such a context, the central theme is taken as the starting point, followed by the treatment of ideas and conceptions related to the theme, alongside with actions undertaken or employed in order to investigate these ideas and conceptions. This kind of design is put into practice without considering the boundary lines amongst different school subjects (i.e. physics, mathematic, crafts, social studies etc.), since the focus is on the investigation of the particular theme and not the linking of the theme with various aspects of school subjects. In this sense, a thematic approach to a science fair is differentiated from a multidisciplinary or interdisciplinary approach, where the recognition of different identities of school subjects is strongly considered. The main focus appears to be on the contribution

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each school subject can have to the treatment of a topic or even the mastery of ideas, skills and processes included within the involving school subjects.
In these terms, the actual treatment of a theme becomes a secondary issue moving back stage, whereas multidisciplinary or interdisciplinary issues come to forth, within the interplay of different school subjects.
A thematic approach to a science fair, which is strongly supported in this study, is based on a design where the investigation of a particular theme, for instance applications and uses of solar energy in everyday life, comes into focus. The framework of study and the investigation of ideas and conceptions are being determined by the theme, but simultaneously shape or constitute its boundaries and limitations. The teaching and learning activities and the design of projects initiate from the investigation of the particular theme and are strongly related to questions and issues which are put forward during the course of the study. A holistic or spherical approach of the theme appears to be taken into account, whereas specific choices in the treatment of its aspects need to be considered in an attempt to achieve an internal congruity and point out interrelations amongst the chosen aspects. Nevertheless, the priority of choices, the educational setting, the situated characteristics of the thematic approach as well as time arrangements and limitations, constitute significant components that shape the framework under study.

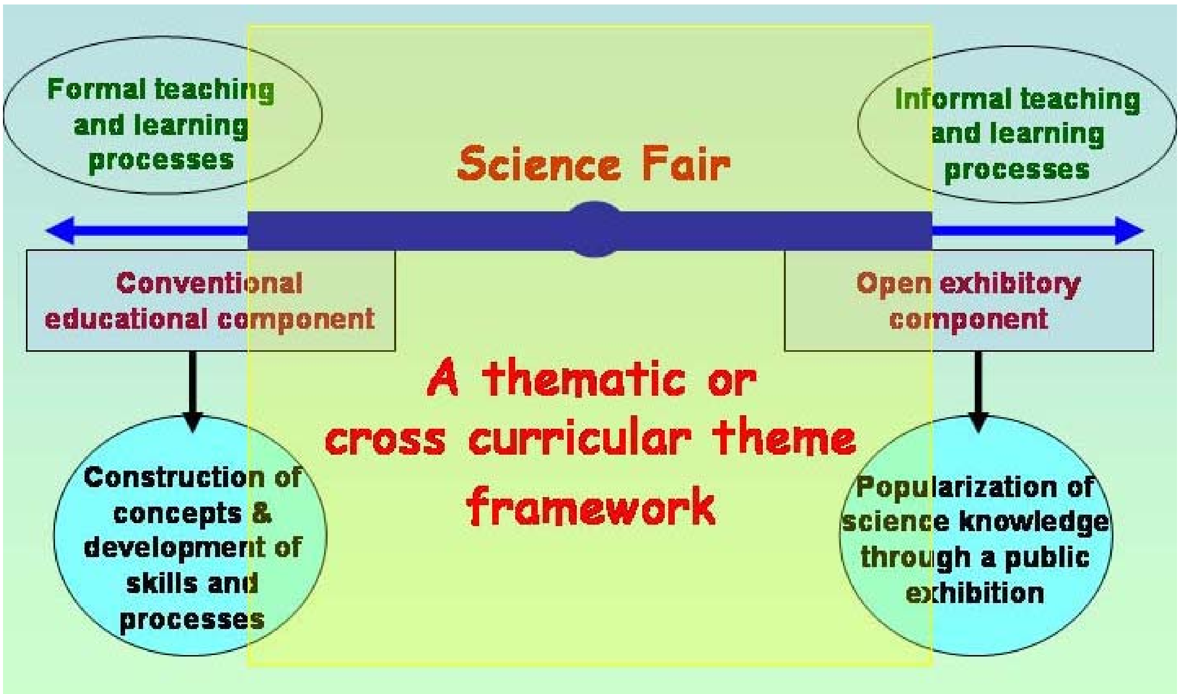

Figure 1. A science fair within an inter-thematic or cross curricular framework

Furthermore, a "balanced" science fair appears to be occupying a considerable amount of middle space along a bipolar continuum with formal teaching and learning processes on the one end and informal teaching and learning processes

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on the other (see Figure 1). That is, informal processes interweave within formal and the other way round, in an attempt to bring together a conventional educational component with an open exhibitory component and consider how one can contribute to the other. In this sense, for a "balanced" science fair to occur, the construction of concepts and the development of skills and processes, seen as characteristics of a conventional education component, have to come closer to an idea of popularisation of science knowledge through an examination of every day instances and a public understanding of science and vice versa (cf. Figure 1). This is not an easy balance to keep, neither for educators nor for learners. It appears to be insecure to slip closer to the conventional end of the continuum and miss all the joy and excitement of an investigative, discursive and inventive approach of the other end. Alternatively, if too much emphasis is put in the exhibitory end of the continuum, conceptualisation of phenomena and deeper understanding of processes is more likely to be underestimated or at least not equally treated, resulting a rather problematic approach about popularisation of science knowledge, based on unstable grounds.

A Science Fair on Solar Energy

Photo 1. The coordinator of the science fair introduces a group of visiting children and teachers to certain aspects of solar energy and their uses in everyday life.

Photo 2. Children had the opportunity to participate in same happenings and activities within the science fair, as in this case where they take part in solar car races.

The science fair on solar energy was organised by the 9th Primary school of Rethymno, Crete, Greece with 35 6th grade primary school children. The class was split in 3 big groups of 12 children with 6 pairs of children in each big group. Each of the three big groups had their own set of projects, which was solar heaters for the first group, solar cookers for the second and solar toys for the third (see Table 1). The children worked in pairs and developed projects and constructions which had to be functional and tested; therefore they had to develop certain techniques and deal with particular problems throughout the development of their projects.

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Apart from the coordinator's supervision and assistance, children also received some help from two more teachers from the school staff, mainly during the morning sessions. Most of the supervision in the afternoon sessions for each pair of children was conducted with the aid of four 3rd year student-teachers from the local University Department. The children worked with the coordinator and the student teachers for their project, mainly in the afternoon sessions and it took about 3-5 meetings with each pair of children to complete their project.
The preparation of the science fair started in February 2003 and the final event was conducted in June 2003, in the school yard with more than 800 visitors, children and teachers from other local schools [see for example, http://9dim-rethymn.reth.sch.gr/contents_gr/scilab/3rd_sci.fair.htm > for a presentation of the science fair, available only in Greek for the moment, but with a lot of photographs].
The science fair received some funding from an EU project on environmental science education, which helped us purchasing some of the materials needed in the science investigations and projects.
The science fair visitors, children and teachers, were briefly introduced in some aspects of solar energy (see Photo 1), which included:

- its origins in the Sun
- how it reaches the earth and what percentage can be of use
- a global solar energy map identifying parts of the earth were solar energy could be used more or less
- solar water heaters, their household uses and the thermosiphon effect
- solar cookers and their worldwide use in cooking food and pasteurizing water
- photovoltaic cells as solar energy converters to electrical energy and their use in households and industry
- solar and renewable energy policies and sustainable solutions for present and future

After that, the visitors moved on to a guided tour accompanied by a student teacher or a school teacher, whereas the science fair children explained to them how they had constructed their devices and the way they worked under the sun shine. Moreover, the visiting children had opportunities to participate in happenings and activities within the science fair, such as: solar boats and car races (see Photo 2, for example), feel the solar heated water from the solar heaters, taste solar cooked cakes and biscuits etc.

Aspects of the Interweaved Teaching Intervention

A 10-hour **teaching intervention** supported the science fair aiming to enhance children's conceptual understanding about the uses of solar energy in everyday situations, mainly within three groups of applications: solar heaters, solar ovens and solar toys (toy cars and small boats moving with photovoltaic cells and motors). It dealt with issues like "energy from the sun", "heat and light from the sun", "the greenhouse effect", "electricity from the sun" (photovoltaic cells) energy change and

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energy degradation (cf. Global Solar Partners, 2000a & 2000b, Gurley & Larson, 1992; NEF, 1991). Moreover, social, environmental and ecological issues had been discussed in class, mainly concerning the energy crisis within a sustainable development framework, policies in the use and application of solar energy, cultural factors that encourage or resist the spread of solar energy applications and so on (cf. Narayanaswamy, 2001; Hayden, 2001).

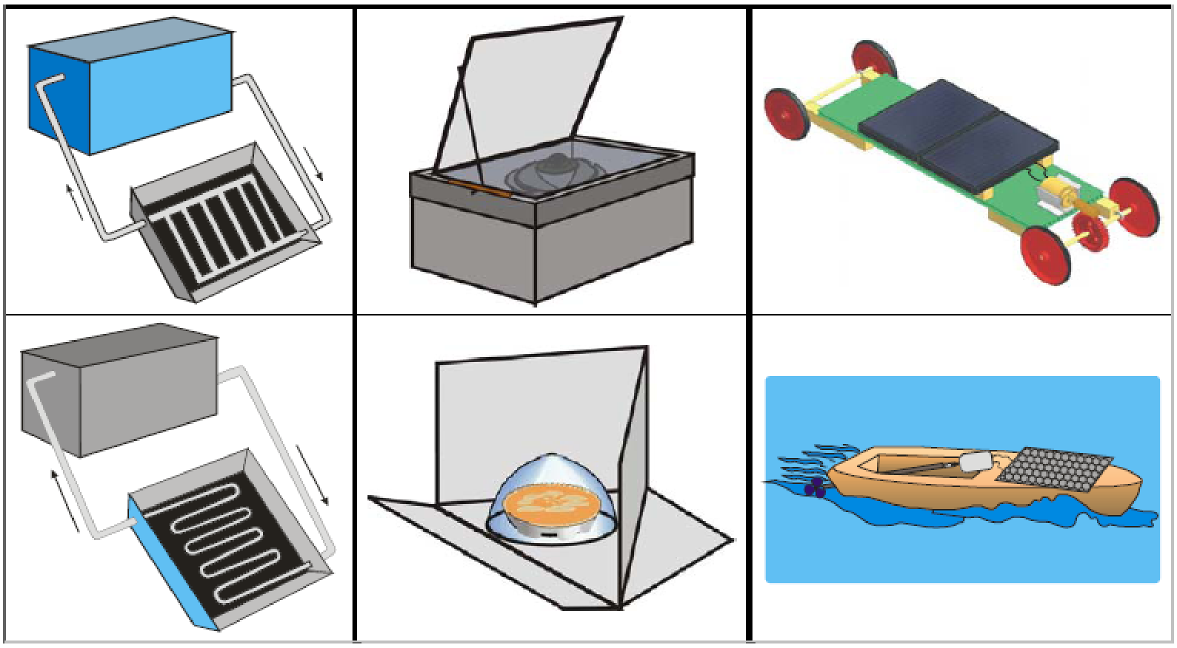

Table 1. Example drawings out of children's projects on solar energy (Solar water heaters, Solar cookers and Solar toys)

The science experiments and investigations were mainly conducted in three phases, in reference to the three groups of constructions for the science fair, as has been reported above:

1. Experiments and investigations regarding **"solar water heating"**, where children initially studied water heating various sizes of aluminium containers left in the sun for some time. More precisely, they compared pairs of equally sized aluminium containers with the same amount of water in them, left in the sun for the same time, whereas one of them was painted black inside. A second experiment that they did was the "ice cube melting", where they placed ice cubes on the surface of black and white pieces of A4 cartons and they left them in the sun to melt, investigating which one would melt faster. Afterwards, they tried other colours of cartons and recorded their observations. Children had an idea that black things absorb more solar radiation, but with these investigations they found out how they can use this principle in solar water heating (cf. Tsagliotis, 2004). As the solar water heaters from children's projects were developing in the afternoon meetings,

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they were brought to be tested in the morning sessions, out in the school yard, whereas proposals for their improvement were put forward after discussion with the children.

2. Experiments were conducted with **"green house models"** made out of equally sized boxes with top lids. Frames of carton around the sides of the boxes had been removed and replaced with transparent plastic film, Plexiglas, or usual glass. The children studied the performance of these "models of solar green houses" measuring the temperature increase inside them, when they were left in the sun for a period of time. The "greenhouse effect" was discussed in class and its main influences in global warming and climate change have been pointed out. Moreover, bridging analogies have been considered regarding the green house effect between the micro-level of our model devices and the macro-level of the planet. Thus, the green house gasses were analogically bridged with the film or glass planes of the green house models and the effect they have with the "trapping" of solar radiation and temperature increase was considered in each case. Similarly, aspects of the artificial creation of the green house effect inside a solar box cooker were discussed, in an attempt to obtain deeper understanding on how some the solar cookers work (cf. Tsagliotis 2004). Another group of experiments dealt with "hot boxes", which were actually cardboard boxes, covered with plastic film, Plexiglas, or glass on the top, with various colours of carton placed inside at the bottom and aluminium foil at the inner sides. They were left in the sun and their behaviour was studied. Nevertheless, the solar cookers developed within children's projects were also tested in whole class morning sessions.
3. Children also experimented with **"photovoltaic cells"** made out of amorphous and polycrystalline silicon. They began by measuring the rounds of a dot drawn on a circular piece of carton within a minute, when this piece of carton was attached to the shaft a motor operating with electrical energy coming from a solar cell. They experimented with the angles towards the sun in which they could turn the solar cell, in order to improve the performance of their motor. Many children thought that the solar cell worked much like the solar heater. This means that their idea, originating from more familiar experience with solar heaters, was that the solar cells produced electrical energy just because they were heated up in the sun (cf. Tsagliotis 2004). Thus, the idea was challenged by putting solar cells inside non transparent vessels and pots with lids, leaving them in the sun for some time. The temperature inside the containers with the solar cells increased, but electrical energy was never produced and the circular piece of carton attached to the shaft of the connected motor never moved. In this sense, they came to the conclusion that the solar cells were affected by the "sun's light" and they observed that they could stop their toys from moving, just by shading them. They further experimented with various colours of transparent films, but also with non transparent materials, which were put on top of the solar cells affecting their performance. Moreover, they used cartons with aluminium foil glued on them as reflectors around the solar cells and they

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observed that reflected light on the surface of the solar cells increased their performance for a little. They claimed that it was an idea taken from the reflectors of the solar cookers, which could have further applications (cf. Tsagliotis 2004). As their solar toy cars and boats were being constructed throughout the afternoon meetings, they were also tested in morning whole class sessions.

A nice thing about solar energy experiments and projects is that, for most cases, you just have to set them up and leave them in the sun shine (cf. DOE 1995; Daley, 1998). This provides time to proceed with a lesson or any other activity and then go and check on the devices over a school break or at the end of a teaching period and afterwards go back to some further discussion in class and so forth (cf. Centre for Alternative Technology, 1997; 1999; 2000a; 2001). Children appeared to be fascinated with the idea of checking their experiments and projects every now and then, recording their measurements and/or observations.

Solar Water Heaters

Solar water heaters appear to be a widespread technology in Greece, where roughly 30% of the solar collectors amongst E.U. countries are set up on the roofs of houses, hotels factories, etc. (cf. IDAE, 2000). Nearly half of those are established in Crete, which makes children very familiar with solar water heaters, increasing their interest to learn more about them.

There is a variety of solar water heaters designs to choose from (cf. CAT 2000b, Trimby 1999 for example), but we chose to construct the following:

- a “classic solar water heater” with flexible black tubes in horizontal and vertical arrays
- two “serpentine solar water heaters” with the flexible black tube arranged in an “S” shape
- a “spiral solar water heater” with the flexible black tube arranged in a circular form
- a “plastic bottles solar water heater” with the flexible black tube arranged in an “S” shape, passing through transparent, 1,5 litter soda bottles
- a “model solar water heater” with a spiral arrangement of a small plastic tube, where the water was gathered in a small container and circulated with a small water pump powered by 3 solar cells connected in a series.

Thus, six solar water heaters were constructed by a respective number of six pairs of children. For the frames of the solar collectors thick expanded polystyrene (DOW) was used, but also wood and cardboard. Flat, non toxic, black paint was used to cover the bottom parts of the collectors, whereas aluminium foil was used to cover the interior sides. Cardboard lids with glass were constructed to cover the top of the solar collectors. Flexible, black water tubes were mainly used inside the solar collectors and plastic cans were used as water containers or water tanks. In most cases theses water tanks were put inside polystyrene boxes, which were constructed according to their dimensions, in order to have better insulation.

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Photo 3. The testing of a "serpentine solar heater" constructed with flexible black tube, inside a collector box and a plastic can used as a water tank.

Photo 4. Final presentation of the "serpentine solar heater" in the science fair, with an improved incline for the serpentine loops, an improved water tank and some colouring

Nearly in all cases children had to resolve construction problems, which could even make their devices inefficient, as in the case of the "serpentine solar water heater". When we had initially constructed that solar water heater we were very pleased and left it in the sun for an hour or so in a morning session. Surprisingly enough, the water got hot inside the tubes and we could feel that, but we did not have the "thermosiphon effect". That is, the water did not circulate from the plastic tank inside the collector and back to the tank again, due to the density difference the cold water has compared to the hot (see Photo 3). It took us quite a while to find out that we had our water tank, the plastic can, tapped with its lid and that had some air trapped inside, the pressure of which created difficulties in water circulation. The problem was resolved as soon as we drilled a small hole in the lid of the can to equalise the pressures. One more thing we did to improve our model was to make the serpentine incline more steep avoiding the initial "curvy loops", which "created problems in the circulation of water" because it appeared to stay within these curved parts of the tube longer, trapped in a way (cf. Tsagliotis 2004). The improved model presented in the science fair was constructed accordingly in order to "ease the way of the hot water climbing up the tube" towards the water tank (see Photo 4, compared with Photo 3).

Solar Cookers

There was a variety of designs for solar cookers to choose from (cf. Tsagliotis, in print), that is from box solar cookers (Kerr, 1991; Halacy & Halacy, 1992; Kofalk 1995, Radabaugh, 1998, Technology for Life, 1998), open solar cookers with reflector panels (Bernard, 1999, Tsagliotis, in print) or even parabolic solar cookers (Halacy & Halacy, 1997). We chose to construct three box solar cookers and three open solar cookers with reflector panels, whereas we avoided the construction of parabolic solar cookers, which are generally considered more technical and difficult (cf. Radabaugh, 1998; Tsagliotis, in print).

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Photo 5. Box solar cookers, as presented in the science fair, cooking biscuits and cakes for children and visitors to taste in temperatures ranging from 110 to 120 °C.

Photo 6. An open panel solar cooker, as presented in the science fair by this pair of children, cooking small round cake-rings for children and visitors to taste.

The box solar cookers were constructed out of two boxes, one internal and one external, with insulation in between them, basically out of folded cardboard pieces (cf. Table 1). One of the solar box cookers had a top lid with a glass frame adjusted to its base, whereas the other two only had a plain glass frame laid atop their bases (see Photo 5). They all had a top reflector adjusted at the base of the cookers, which was set up against the sun accordingly to improve their performance (cf. Funk, 1997; Todd & Miller, 2001). The open solar cookers with reflector panels were constructed out of thick pieces of cardboard, which were set in place according to their design (cf. Table 1 and Photo 6). One was the classic Bernard (1999) design, whereas the other two had a more loose arrangement, with portable features (cf. Table 1, lower drawing in the solar cookers column).

The "green house effect" which is technically created inside the box solar cookers was discussed with children to a great extent as their projects were put to test in the morning sessions, before the science fair. Similarly, in the case of open panel solar cookers the green house effect is technically created inside a glass salad ball turned upside down in order to cover the cooking utensil with the food (pot, pan etc.) and "trap the heat inside".

Nevertheless, quite a few environmental, social, ecological and economical issues regarding the use of solar cookers arose and they were discussed with children, but also put forward during the science fair. Such issues included the following:

- Solar cookers are mainly seen as "hot boxes" or "heat traps", which can cook food for us, but also do other things which are important to people of the third world, and not only, such as pasteurization of physically contaminated water (Andreatta et al. 1994; Metcalf, 1994; 2002). Unsafe drinking water is one of the leading health challenges in the world today. Nearly 80% of all infectious diseases in the developing countries are transmitted through water (WHO). As a result, each year more than four million children die. It is not well known that water, when physically

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contaminated, can be pasteurized if heated in a temperature of 65 °C for a period of about 20 minutes, although the temperature-time relation may vary according to conditions (Ciochetti & Metcalf, 1984; Turdy, 1998).) This process can kill germs and disease-carrying organisms commonly transmitted in contaminated water. Such temperatures can easily be achieved in solar cookers, solving the problem of drinking water for many people. Unfortunately, though, pasteurization cannot remove chemical contamination, such as pesticides or industrial waste.

- Acute respiratory infections are the cause of death of millions of children in the world every year. The large majority of these casualties occur in the developing countries as a result of polluted indoor air due to cooking over open fires in houses without chimneys or ventilation. This problem could be greatly reduced by using solar cookers, which are smokeless over the process of heating and cooking the food. Furthermore, slow solar cooking at temperatures 100-150 ºC preserves several micronutrients better than conventional cookers do. Generally, solar cookers are very safe because we can avoid burning accidents.
- In the developing countries many people, mostly women and children, have to spend hours daily collecting firewood. This is a hard work and causes many injuries to people. Moreover, it contributes to the deforestation and desertification problems, the consequences of which affect human lives all over the world in present time (cf. Chidumayo, 1997). Solar cooking can reduce this time and effort significantly. Thus, women and children could use the time saved for education, leisure, social and communal activities. Of course, money can be saved to cover basic needs, since solar cookers need no fuel.

The most frequent question asked from visitors in the science fair was about the length of time that food needs in order to be cooked inside a solar cooker. Well, it depends on the food, the type of solar cooker and the weather conditions. If a solar box cooker is used, as a thumb rule it can be estimated that it will take twice as much time to cook food than the time it would take in a conventional oven. Perhaps we could see things in a different way and not worry that much about how fast the food can be cooked. Just get it in the solar box cooker early and go back at lunchtime to find a delicious meal ready, without any danger of being overcooked or burned.

Solar Toys

The preparation and the experimental construction of solar toy cars and boats took some time and effort, since quite a few detailed problems had to be resolved and an appropriate combination of materials needed to be arranged and purchased (cf. CAT, 2001; NREL, 2001). Furthermore, the suitable kind of solar cells should be used for each construction to be functional (Komp, 2001). Thus, for example light and powerful photovoltaic cells were needed for the toy cars, whereas they were

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not necessary for the solar boats, which could move with smaller and heavier photovoltaic cells made out of amorphous silicon.

Another significant issue that arose was the “energy degradation”, basically due to friction in axels, wheels, propellers, gears, pulleys and rubber bands. We had to “fight” frictional force in order to have more efficient solar toys on the one hand, but on the other we needed to have friction for the “O” ring rubber bands we used as tyres on the wheels of the toy cars (see Photo 7 and drawing in Table 1). In these terms, we had an interesting interplay with “energy change” from the photovoltaic cells to electrical energy, to kinetic energy and finally “energy degradation” to heat due to frictional forces in various parts of the toys. Children appeared to discern such characteristics of energy and they took a considerable effort to confront them and find solutions to a variety of construction problems (cf. Tsagliotis, 2004).

Photo 7: Visitor children introduced to “solar toy cars” by one of the science fair children, explaining them how the photovoltaic cells can be considered as energy converters.

Photo 8: Children are watching and playing with the “solar boats” floating and moving around in a small swimming pool, which was constructed for the occasion.

The solar motors, which were used for the toy cars, had to be of low friction and function with a voltage of 0,45-4 V with 2000-6000 rpm, suitable for photovoltaic cells, which could produce a potential up to 2 V. The chassis of the toy cars was made out of wood (balsa and pine), corrugated cardboard and Plexiglas. Their wheels were plastic pulleys with “O” rings around them, affixed on iron axels, which moved inside small pieces of plastic rigid tubes, glued at certain places on the chassis.

Another major problem in the construction of the solar toy cars was the transmission, which is actually the part that connects the motor shaft to the wheels or the axle. We experimented with gears, worm-screws and gears and with pulleys and rubber bands and found out that the latter was the most efficient of all for our toy cars. Thus, we fixed small iron pulleys at the shafts of the motors and 4-6 times bigger plastic pulleys to the axles of the wheels (see Photos 9 & 10). With this we achieved higher performance in terms or torque and speed for our solar toy cars, which made them more attractive, even for car races during the science fair. We

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constructed 7 or 8 different designs out of different materials and shapes, since more and more pairs of children wanted to construct their own solar toy as well. Thus, some children constructed solar toy cars and the rest constructed solar boats. We ended up with several solar toys at the science fair, which amused our visiting children and teachers since they could participate in happenings, play with them or even take a closer look to many of our solar toys.

Photo 9. A solar toy car … on the move during the science fair, on the asphalt surface of the school yard.

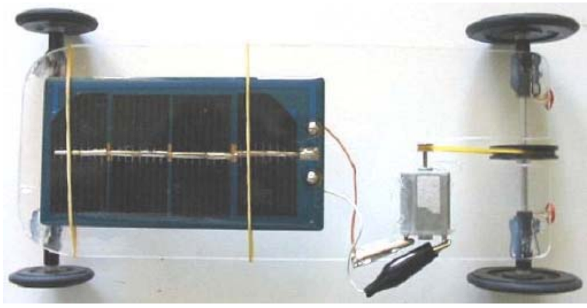

Photo 10. A solar toy car made out of a Plexiglas chassis with a rubber band used for transmission, connecting the two pulleys between the shaft and the axle of the wheels.

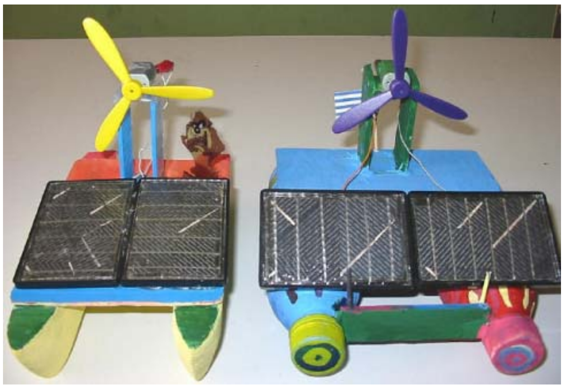

Photo 11. Two solar catamaran boats. Their floaters are made out of expanded polystyrene (left) or used plastic bottles (right) and they both moved with a helix.

Photo 12. Two solar “river boats” with paddle-wheels made out of gears with attached plastic fins cut out of plastic bottles.

Similarly, children constructed solar boats out of expanded polystyrene, balsa wood, but also from scrap materials like used plastic bottles (see Photo 11). They also constructed fishing boats moving with propellers or even a couple of “river boats”, which were moving with paddle-wheels made out of gears with attached plastic fins (see Photo 12).

For our solar boats to be effective we had to give them hydrodynamic shapes in order to have less energy degradation or “not to have a lot of energy put out of use”, that is turned into heat due to frictional forces between the surfaces of the boats and the water (cf. Tsagliotis, 2004). Thus, children had to sandpaper the floaters of

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their boats to the shapes seen above or find materials of relative shape (see Photos 8, 11 & 12). This became a fascinating task, which ended up in contests for faster boats, according to their category of course.

Overview and Discussion

The thematic approach to the science fair, as it has been briefly described above, appears to have captured children's interest and engaged them in an effort to create their own functional models of solar energy applications. Perhaps the essence and educational merit of the whole endeavour is this particular intentional task, where children are actively involved in a project, which they consider to be their own, and they purposefully feel highly committed to complete it as their personal creation and contribution. This commitment lies at the hard core of a thematic science fair project, which appears to be triggering all the other conceptual, discursive and inventive features to be constituted into a broader framework of "science knowledge in action" with "hands on" activities based on everyday situations.

In other words, children actually built up their solar heaters, cookers and toys and they practiced "science in action", as they got involved in the construction processes and dealt with their functionality and refinement problems, as they were put into test during the development of their projects. This process has always been a purposeful goal in the way of "doing science for something", which appears to increase interest and the emotional factors of "having fun with science" and with "hands on" activities, within a framework of particular applications of everyday life.

Despite the critique and predictions of sceptics, that solar energy will never run the world, at least not within a rosy solar future (cf. Hayden, 2001), the children of the science fair, and perhaps some of the visitors, became highly sensitized about available solar energy applications, saw them work in practice and realized some of their limitations and their questionable or disputable potential.

References

[1] Andreatta D, Yegian DT, Connelly L and Metcalf RH, Recent advances in devices for the heat pasteurization of drinking water in the developing world, Paper presented at the 29^{th} Intersociety Energy Conversion Engineering Conference, American Institute of Aeronautics and Astrophysics, 1994.

[2] Beane J, Curriculum integration: Designing the core of democratic education, Teacher College Press: New York, 1997.

[3] Bernard R, La Cuisson Solaire Facile, Editions Jouvence, 1999.

[4] Centre for Alternative Technology (CAT), Teacher's Guide to Renewable Energy Projects: Solar Heating, Southgate Publishers Ltd: Devon, 1997.

[5] Centre for Alternative Technology (CAT), Teaching about Energy: Practical Activities for 7-11 year olds, Southgate Publishers Ltd: Devon, 1999.

[6] Centre for Alternative Technology (CAT), A pupil's Guide to Solar Power, Southgate Publishers Ltd.: Devon, 2000.

ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

[7] Centre for Alternative Technology (CAT), Tapping the sun: A guide to water solar heating, Southgate Publishers Ltd.: Devon, 2000.
[8] Centre for Alternative Technology (CAT), Teacher's Guide to Solar Electricity Projects, Southgate Publishers Ltd.: Devon, 2001.
[9] http://www.sei.se/red/red9707c.html
[10] Ciochetti DA and Metcalf RH, Pasteurization of naturally contaminated water with solar energy, Applied and Environmental Microbiology, 47: 223-228, 1984.
[11] Daley M, Amazing sun fun activities, McGraw-Hill: New York, 1998.
[12] http://www.eia.doe.gov/energy
[13] Fredericks AD and Asimov I, The complete science fair handbook, Good Year Books: Illinois, 1990.
[14] http://web.nmsu.edu/~pfunk/std.pdf
[15] http://www.solarpartners.org/plans.html
[16] http://www.solarpartners.org/plans.html
[17] Gurley H and Larson B, Sunlight Works: Solar Science Educational Activities for Children, SunLight Works, 1992.
[18] Halacy B and Halacy D, Cooking with the sun: How to build and use solar cookers, Morning Sun Press: Lafayette, 1992.
[19] Halacy B and Halacy D, Solar StoveTop Cooker, Morning Sun Press Lafayette, 1997.
[20] Hayden HC, The Solar Fraud: Why solar energy won't run the world, Vales Lake Publishing, LCC, 2001
[21] http: www.idae.es
[22] Kerr BP, The expanding world of solar box cookers. http://www.accessone.com/~sbcn/kerr.htm
[23] Kofalk, H. Solar Cooking, Book Publishing Company: Summertown, 1995.
[24] Komp R, Practical Photovoltaics: Electricity from Solar Cells, AATEC: Michingan, 2001.
[25] http://solarcooking.org/metcalf.htm
[26] Metcalf RH, The science of safe water, Solar Cooker Review, 8, 2002. http://solarcooking.org/newsletters/scrnov02.htm#water
[27] Narayanaswamy S, Making the Most of Sunshine: A Handbook of Solar Energy for the Common Man, Vikas: New Delhi, 2001.
[28] National Energy Foundation (NEF), Science projects in renewable energy and energy efficiency, Salt Lake City, USA, 1991.
[29] National Renewable Energy Laboratory (NREL), So ... You Want to Build a Model Solar Car, 2001.
http://www.nrel.gov/education/student/natjss.html
[30] Radabaugh J, Heaven's Flame: A Guide to Solar Cookers, Home Power Publishing: Ashland, 1998.
[31] http://www.kaapeli.fi/~tep/man/manual.html
[32] Todd JJ and Miller S, Performance Testing of Cardboard Solar Box Cookers. Paper presented at the Women Leaders on Uptake of Renewable Energy Technology Seminar", Murdoch University, Perth, Western Australia, 27 June-4 July, 2001
http://acre.murdoch.edu.au/unep/frameset.htm

ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

[33] Trimby P, Solar Water Heating: A DIY Guide, Southgate Publishers Ltd, Devon, 1999.
[34] Trudy R, Sun and water: an overview of solar water treatment devices, Journal of Environmental Health, 60: 30-33, 1998. http://solarcooking.org/sunandwater.htm
[35] Tsagliotis N, Conceptual change in the teaching and learning of solar energy with 6th grade primary school children in Greece, Paper presented in the 4th EARLI European Symposium on Conceptual Change: Philosophical, Historical, Psychological and Educational Approaches, Delphi, Greece, May 19-22, 2004.
[36] Tsagliotis N, Delightful Solar Cooking: A tour in the world of solar cookers, Typospoudi Publications: Rethymno (in print).
[37] Van Cleave J, Guide to more of the Best Science Fair Projects, John Wiley & Sons: New York, 2000.

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Teaching Physics Modelling with Graphic Simulations Tools

Zamarro JM, Molina GJ and Núñez MJ

Introduction

Computers are used in different ways to teach Physics [1] [2] [3] [4], it can affect drastically the way of teaching Physics, a very good example is the Advancing Physics course [5], a contemporary course developed by the Institute of Physics, it is a huge effort developed by more than thirty teachers to use the technologies of information and communication to introduce Physics in a new, modern and attractive way. Our interest is concentrated in the use of authoring tools to develop interactive simulations that allow the learners to concentrate their effort in the model of the problem. In this paper we shall focus in the use of simulation authoring tools by science students to create simulations by themselves.

Not all the science phenomena are interesting to be attacked with simulations, those that need animation, interactivity, three dimension representation have especial interest for us. We also try to develop simulations following the spirit of the CoLoS (Conceptual Learning of Science) project [6], to proceed from basic principles.

Visual environments to develop interactive simulations allow concentrating the learner effort in building the model of the problem; they facilitate the creation of interactive graphic interfaces for people with little knowledge in software development. These simulations can face issues that are difficult to be treated by other ways because their abstract character or because their needs for animation. Many examples can be found in fields like the introduction of dynamics, waves, thermodynamics, quantum mechanics, electromagnetic fields etc.

Physics problems are mainly described in terms of differential equations. To manipulate these equations a big theoretical effort must be done. One option to facilitate handling these equations, is to introduce the students into the basic principles of numerical computation using simple algorithms to discretize the differential equations. This procedure has shown not to be difficult, and it is well accepted by students without previous knowledge of the numerical methods to treat differential equations [7].

There are many tools to produce simulations, but not so many that gather all the following features: to be easy to use, inexpensive, with good graphic capabilities and oriented to build interactive simulations for learning science.

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The Graphic Simulation Tool Ejs

Easy Java Simulations (Ejs) [8] [9] is an interactive tool developed for the conceptual learning of science. Ejs is not designed for professional programmers, but for teachers and students who want to create (or modify) scientific simulations. With Ejs, they can concentrate their effort on writing and refining the relations in the underlying scientific model, and dedicate the minimum possible amount of time to the programming techniques.

Ejs, is an authoring tool that creates automatically html files with the applet embedded; students are introduced to these html files so that they can modify the default one created by Ejs to personalize it.

Ejs allows the creation of sophisticated interactive animated interfaces, even in three dimensions, with the mouse. To make interactive the interface is an easy task, we do it clicking on icons and relating the properties of the graphic interface with the variables of the model.

Developments

Not all the issues treated in lectures of a course of General Physics are of interest to be treated with simulations. Those that have one of the following features: needs of animation, interactivity, three dimensional representation, abstract concepts sensitive of graphic representation are good to be the object of a simulation. In a first year course of General Physics the topics that fit better this features are: relative motion, dynamics of a particle, waves. quantum mechanics, dynamics of charged particles and field representation.

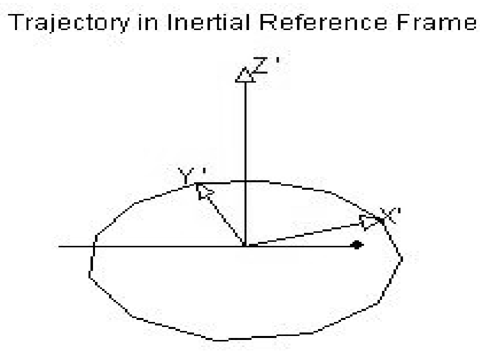

Figure 1. Trajectory of a particle that has constant velocity in an inertial reference frame.

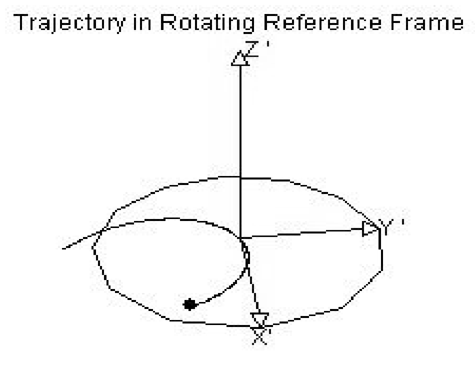

Figure 2. Trajectory of a particle that has constant velocity in an inertial reference frame observed from a frame that is rotating.

Relative Motion.

There are topics that are easy to implement as simulations and are difficult to see without animation, for instance relative motion. In Figure 1 we can see the trajectory of a particle that has constant velocity in an inertial reference frame, the trajectory is a straight line.

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The same movement observed from a reference frame that is rotating, is a curve as we can verify in Figure 2 that has been taken from the simulation. This example is a good one to introduce in a qualitative way the non inertial forces that are usually bad treated in previous courses.
Other nice example of relative motion is the outer planets seen from the earth. All this examples are simple to be simulated by students and serves as an introduction to the authoring tool, they have animation as the main feature.

Dynamic of Particles: Differential Equations.

This is a topic especially interesting to be treated by students to create their own simulations. First of all, animation is a main characteristic of this subject and the mathematics that describe the model are second order differential equations, to approximate this equations by algebraic expressions is well accepted by students, for instance, from the definition of velocity:

$$v = \frac{dx}{dt} = \lim_{\Delta t \to 0} \frac{x(t+\Delta t) - x(t)}{\Delta t}$$

We obtain an algebraic expression accepting the approximation:

$$v \cdot \Delta t = x(t + \Delta t) - x(t)$$

This algebraic equation is easily translated to computer code as the recursive expression:

$$x = x + v \cdot dt$$

it gives the chance to explain students that for the computer this expression is not a mathematical one but an assignment for the value of the variable x, each iteration the value of x is incremented xdt. In an identical way we can transform the differential equation that defines the acceleration. If the student develops the simulation by himself, he is forced to define some initial conditions to run the simulation, this is an important fact of differential equations.

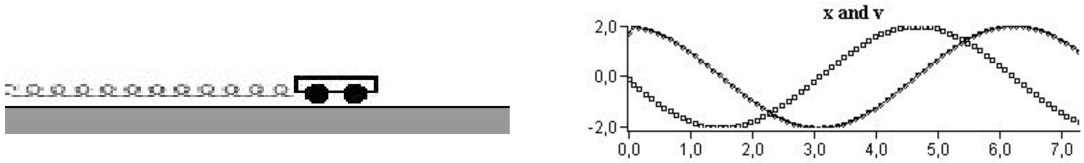

Figure 3. A car linked to a spring. Graph of the displacement and speed versus time.

A wide variety of problems can be faced using this simple numerical integration of velocity and acceleration just changing the value of acceleration. With a constant acceleration students can solve all the dynamic of particles at the earth surface. If

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he defines the acceleration proportional and opposite to the displacement he arrives to the harmonic motion where he can introduce friction forces and forced oscillations to investigate resonance.

Waves

All teachers know how much we miss animation interactivity when we explain this topic to our students using only the blackboard. The main feature of a wave is that a “perturbation” is transmitted, this means that the perturbation at a time at a place is the perturbation that had a previous instant at the previous point. The model for this condition is basically a line: $y[i] = y[i\text{-}1]$, we create a page that is running continuously:

```
y[0] = perturbation;
for(int i =N-1; i >0; i --)
{ y[i] = y[i -1];}
```

To get a way propagating to the left, just invert the last equation. If we link the value of $y[0]$ to the position of a slider this position will be transmitted to the points of the line as it is shown at Figure 4.
If you link the first value, $y[0]$, to a harmonic function you will get the typical pattern than you can see in most simulations.

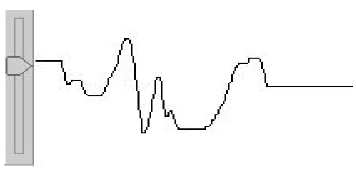

Figure 4. Propagation of the displacement of a slider

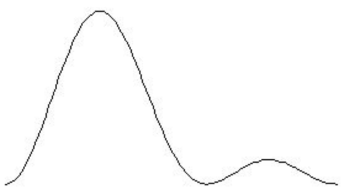

Figure 5. Time evolution of the superposition of two stationary states

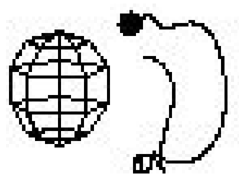

Figure 6. Simulation of the Van Allen Belts

Quantum Mechanics

In the first year University, students of Physics do not have a deep knowledge of Mathematics, Quantum Mechanics is an abstract topic that uses mathematics not easy for students of first year university, simulations can help them. We can find very good simulations introducing basic concepts of quantum mechanics with Physlets as the Interactive Quantum Mechanics Exercises for Just-in-Time Teaching at Davidson College [10].
Our students solve numerically the Schrödinger equation in simple situations like the stationary states in a box, in a potential step and the temporal evolution of a state formed by a superposition of states as it is shown at Figure 5.

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Electric and Magnetic Fields: Dynamic of Charged Particles

Once students have solved problems of dynamic with mechanical forces, dynamics of charged particles due to electrical and magnetic forces are solved straightforward. Students like to build cyclotron, mass spectrum, and perhaps the most spectacular one the Earth's Van Allen Belts approximating the Earth's geomagnetic fields by the field of a magnetic dipole. Particle stays trapped by this field as we can see in Figure 6.

To represent electric fields created by particles is a good exercise for students, this is not a trivial thing to simulate but there is a case easy for them, to create particles at their interest and represent the field by an arrow clicking with the mouse on a point of the simulation window.

References

[1] Iskander MF, Technology-Based Electromagnetic Education, IEEE Transactions on Microwave Theory and Techniques, 50: 1015-1020, 2002.

[2] Esquembre F, Computers in Physics Education, Computer Physics Communications, 147: 13-18, 2002.

[3] de Jong T, Learning and Instruction with Computer Simulations, Education & Computing, 6: 217-229, 1991.

[4] Almeida Barretto SF, Piazzalunga R, Guimarães Ribeiro V, Casemiro Dalla MV and Leon Filho RM, Combining interactivity and improved layout while creating educational software for the Web, Computers & Education, 40: 271-284, 2003.

[5] Advanced Subsidiary (AS) Course & Advanced Level (A2) Course, Ogborn J and Whitehouse M, Institute of Physics Publishing, 2000.

[6] Härtel H, COLOS: Conceptual Learning Of Science, in Jong T and Sarti L, (Eds.), Design and Production of Multimedia and Simulation-based Learning Material, Kluwer Academic Publishers, pp.: 189-217, 1994.

[7] Dias de Deus J, Pimenta M, Noroña A, Peña T and Brogueira P, Introducción a la Física, Mc Graw Hill, pp.: 475, 2001.

[8] Esquembre F and Zamarro JM, EJS: Authoring Tool to Develop Java Applications. Computers and Education. Towards an Interconnected Society, Ortega M and Bravo J (Eds.), Kluwer Academic Publishers, pp.: 143-148, 2001.

[9] Hwang FK and Esquembre F, Easy Java Simulations: An Interactive Science Learning Tool, Interactive Multimedia Electronic Journal of Computer-Enhanced, 1998.

[10] http://webphysics.davidson.edu/qmbook/

Paper presented at the 1st International Conference on “Hands on Science.
Teaching and Learning Science in the XXI Century",
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Understanding Real Experiments in Electricity by Computer Based Simulation of Electrical Forces between Charged Particles

Križaj D and Simeonov D

Introduction

With the advent of technology new approaches to teaching natural sciences have appeared. They are particularly related to possibilities offered by modern computers with increasing sizes of displays and resolution and of course day-to-day increasing computing power [1]. Especially young people are more easily becoming interested in learning technical sciences if the learning process includes the use of modern technology. Those teaching natural/technical sciences should be particularly aware of the strengths of modern approaches and should continually develop new methods to engage students in the learning process.

In this paper we discuss the teaching of electrical phenomena through a combination of demonstrations of virtual and real experiments. In our opinion there is no adequate replacement to real experiments. They should remain the strongest teaching/demonstration tool as no simulation can mimic a real experiment in full detail. Every simulation is to a certain extent only a simplified model of the real experiment. Moreover, students should learn that – especially in the learning of physical sciences – we are in fact applying mathematical models to real life phenomena in order to better understand and control them and to profit by using these principles to develop new devices. To achieve this goal all methods that facilitate the teaching process are justifiable.

Virtual experiments are based on computer simulations that have already found widespread (worldwide) use as a supplementary material in the teaching process. The major advantage of computer simulations is an excellent visualization effect that is of special interest in the description of electrical phenomena since the effects of electrical forces are described through action of abstract fields that are hard to imagine.

Various kinds of computer simulations can be used. Most frequently these simulations are based on numerical solving of differential equations. The equations describing basic physical laws can be solved in a certain discretized domain, as for instance solving discretized Maxwell equations for analysing electrical phenomena. Several programs are available for such purpose (EMAS; FEMLAB; MAXWELL).

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Some offer even student versions of the program free of charge. Advantages of this approach are several possible visualizations of (abstract) electric and magnetic fields and potentials, two-dimensional contours, vector plots, colour graphs, 3D colour graphs, etc. The disadvantage of this approach is a rather time consuming procedure for calculation, especially when dynamic phenomena are observed. In such cases the simulations can be performed in advance and the solutions merged into a movie type demonstration. With the advancement of this type of programs, a hands-on approach is possible and even recommended, however, students of electrical engineering at our institution get fully acquainted with a discretized form of Maxwell equations in the third year of study. As a consequence, it seems more appropriate to use such programs in the first year only for demonstration purposes and eventually for freely chosen student seminars. In this article, we will demonstrate a program for the construction of virtual experiments in electricity that is based on solving fundamental equations describing forces between charged particles/elements. As such, the program is suitable for use even for novice students, since it is based on fundamental law for electric and magnetic forces between the charged particles (Lorentz force). In electrostatics only a Coulomb force is considered that describes attractive and repelling force between charges. By obeying a superposition principle it is possible to calculate forces between large numbers of charges in "real" time. This means that for a reasonable number of charges the calculation can be performed in a short time allowing visualizing the movements of charges in response to electrical forces on a computer screen.

Real Experiment

Electrical ping-pong is chosen as a demonstration experiment for two reasons. Firstly, it is an experiment that is sufficiently dynamic to stir the interest of the students and secondly, it is probably one of the most popular experiments in physics performed around the world [3]. The concept of an experiment is shown in Figure 1. A small conductive ball is hanging on an insulating string that is attached to a casing or to a separate stand. The ball is usually a ping- pong ball covered with a thin conductive foil, a ping-pong ball painted with a conductive paint or galvanized (nickeled). The ball is placed between two parallel conductive plates that are connected to a generator of high voltage. Most frequently we use a DC voltage source of aprox. 20 kV, however, an electrostatic generator such as Whimshurst or Van de Graaf can be used for this purpose as well. When a generator is started and the ball is forced to come into contact with one of the charged plates, it starts to bounce between the two plates. The frequency of bouncing can be increased by reducing the distance between the plates or reduced by increasing the distance.

The reason for bouncing is of course due to the action of electrostatic forces: the ball charges to the same charge as the contacted plate. As such the force on these charges is directed toward the opposite plate. This force plus the force from a non-elastic bounce from the plate and the force due to the gravity are sufficient to bring the charged ball to touch the opposite plate where the process is inverted. The ball first discharges and then charges with the charge from that plate. The process repeats itself until the plates are connected to the high voltage source. As a matter

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of fact, even if the source is disconnected, the voltage between the plates is slowly decreasing due to a discharging process.

From examining the experiments an observer can make some fundamental conclusions: a) since it is obvious that a swinging ball stops after some time, the reason for continued movement of the ball must come from contacting the plates to the electric supply; b) a very high voltage source is required (we are more used to a range of voltages from a few volts to a few tens of volts) to move a small, light, charged ball -> electrostatic forces are week forces; c) the force on a ball is increasing with reduced distance between the plates that electric. With some additional experiments with the same equipment one can see that the charged ball is either attracted to or repelled from the charged plates. From this one can assume that equal charges attract and opposite charges repel. Furthermore, by replacing the conductive ball with a non-conductive (isolative), the experiments show no bounding effect. Non-conductive objects cannot be charged as conductive objects and as a consequence there are no electric forces on such balls. There is an interesting exception worth noting, namely, if a non-conductive ball is placed near the conducive bouncing ball, a small movement, mostly rotation, of a non-conductive ball can be observed. This interesting phenomenon can be nicely explained through an electric polarization of a non-conductive ball by the charged plates and an electric force on a dipole.

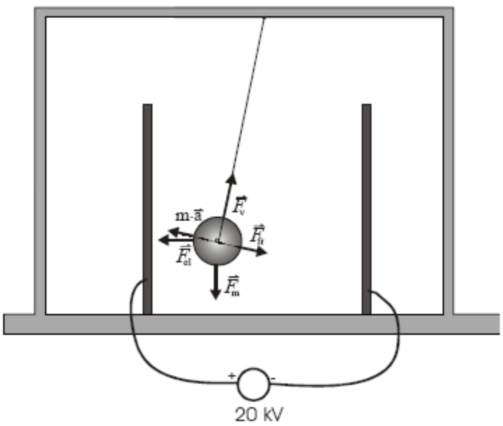

Figure 1: Schematic representation of electrical ping-pong experiment with forces acting on a charged ball

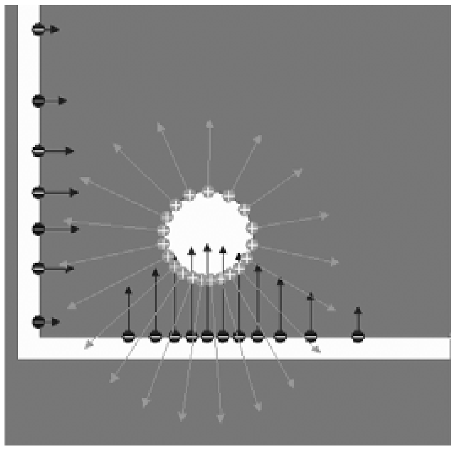

Figure 2: A simple example of two objects with charged particles and electrical forces between them. The particles move until they rest at the position when the force is directed

Virtual experiment

Virtual experiment is performed with a program utilizing particle-particle method (PPM). With this method, basic phenomena in electricity can be modelled by calculating the forces between the charged particles and consequently elements in which they reside. The program used has been named JaCoB, which stands for "Java constructive objects" [4, 5]. The program is dynamically solving electric (and magnetic) forces between particles and in each time step moves the particles for a

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small distance according to the magnitude and direction of a force on each separate particle. The magnitude and direction of force on each charged particle is visualized by arrows as shown in Figure 2 for a simple simulation of a negatively charged corner and a positively charged cylinder (circle).
The particles reside inside primitive objects that can have the form of a circle, ring or an arbitrary polygon. More complex structures can be created by merging the primitive objects.

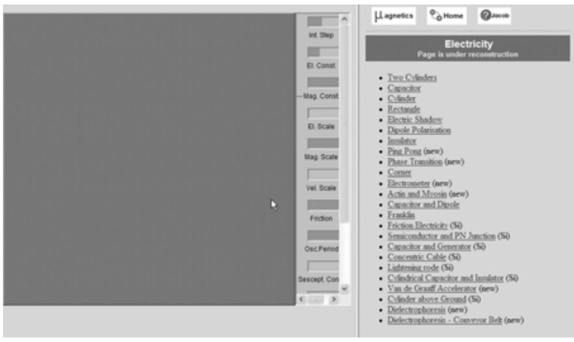

Figure 3. Web page with predetermined virtual experiments and a demonstration table for creation and running of own experiments

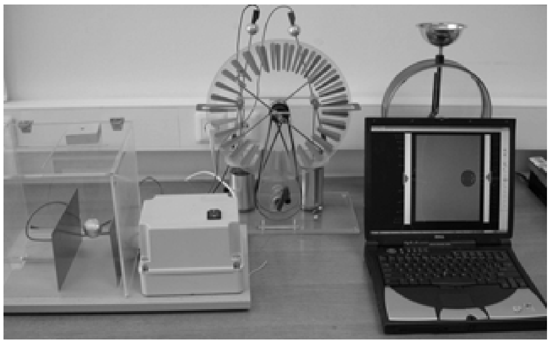

Figure 4. Real and virtual experiment side-by-side. Real experiment can be powered with a 20 kV DC source or with a Wimshurst electrostatic generator

By observing the development of forces between the particles and consequently between the objects containing charged particles, the students can visualize several important concepts of electricity that are otherwise difficult to understand such as electrostatic induction, formation of high electric fields around sharp corners, zero electric field inside conductors (electrostatics), etc.
Figure 3 shows a Web page of the program with a blank demonstration table for creation and running of the experiments on the left and predefined virtual experiments on the right. These experiments utilize special scripting language similar to JavaScript that enables experienced users of the program rapid development of new virtual experiments.
Virtual electrical ping-pong is created by using two sources, one for positive and one for negative charges. If in contact with other objects, the objects are “open”, meaning that the charges are allowed to escape the boundaries of the object. Furthermore, a cylinder (circle in 2D) is created that is allowed to move laterally from the left to the right electrode. At the beginning of the experiment the cylinder needs to be charged or in contact with one of the electrodes. When the program is run, the charges residing in a cylinder discharge when in contact with the electrode of opposite charge and charge to a charge of that electrode. Since equal charges repel, he ball is pushed by electric forces to the other side (electrode) and the process is repeated.
“Real time” observation of particle movements enables clear insight into charging and discharging mechanisms and consequently in the complete operation of a device (experiment).

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In the observation of a virtual experiment we can add some tools that give additional visual feedback on certain physical quantities that are otherwise not observable, such as: potential detector, electric energy gauge, capacitance gauge, electric field detector, current gauge, etc. Figures 5 and 6 present two typical gadgets – a voltage gauge and a current gauge. By use of these gadgets we basically created virtual instruments – a voltage and current meter.

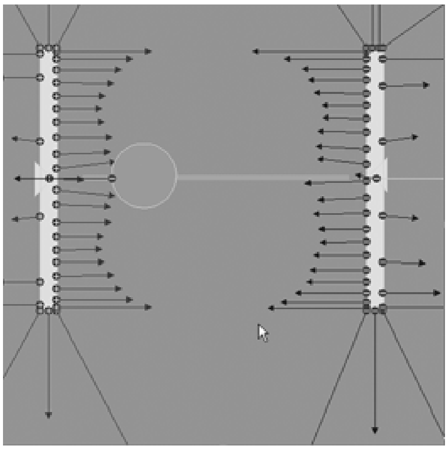

Figure 5: Virtual experiment: electrical ping-pong

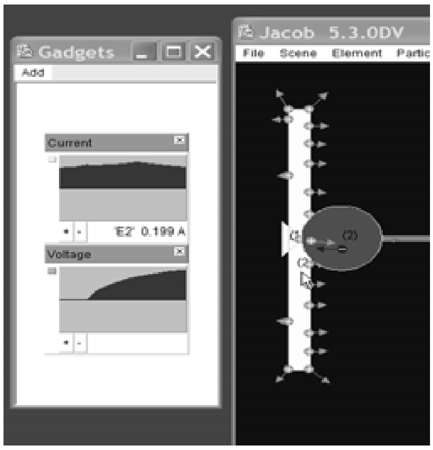

Figure 6: Potential and current gauge acting as virtual voltage and current meters

Discussion

There are many approaches to teaching of natural sciences. In this article we presented one of the possible approaches to utilizing modern technologies in combination with observation of real experiments for learning fundamental electric phenomena. We would like to emphasize the strength and importance of simultaneous use of both approaches – a real and a virtual experiment. In fact, it would be advisable to use several possible approaches offered by modern technology, such as multimedia videos, schematic dynamic models (in Java programming language), simulations on a discretized domain, construction of differential equation(s) describing the fundamental principles of movement of a charged ping-pong ball (that can be solved by such programs as Matematica or Matlab), etc.
We have recognized several important advantages offered by the JaCoB program utilizing particle-particle simulation:

- The program enables “hands-on” approach directly through internet connection (without necessity to load and install the program).
- Fast solution of forces between the particles enables “real-time” observation of fundamental processes (movement of charges).
- Simulation of forces between the charged particles directly and not through the abstract fields gives better insight into interactions
- between charged objects.

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- Additional gadgets (tools) for displaying some additional quantities of interest as for instance potential/field detector, current and voltage meters, etc.
- Special scripting language can be used to facilitate creation of new models and construction of web pages utilizing them.

Conclusion

An approach for learning fundamental principles of electricity through a combination of real and virtual experiments has been discussed. A well-known electric ping-pong experiment has been used for this purpose. Virtual experiment was performed with JaCoB program utilizing particle-particle simulation principle. With this method, electric (and magnetic) forces between the charged particles residing in primitive objects are calculated simultaneously and the particles are moved in each time step according to the last calculated force on a particle.

Several advantages of the utilized approach have been identified as well as some shortcomings that will be investigated in the future.

Acknowledgment

We wish to acknowledge great work of professor Vojko Valenčič†, whose vision and determination has lead to several generations of JaCoB.

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References

[1] COLOS – Conceptual Learning of Science, http://www.colos.org
[2] Fazarinc Z, Computer Simulation in Physics. IEEE Potentials, 30-33, 1990.
[3] Electrostatic Ping-Pong, North Carolina University: http://demoroom.physics.ncsu.edu/html/demos/184.html
[4] Švajger J and Valenčič V, Discovering electricity by computer-based experiments, IEEE Trans. on education, 46: 502-507, 2003.
[5] Valenčič V and Zlobec S, JaCoB: electricity and magnetism by virtual experiments, http://jacob.fe.uni-lj.si

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Hands-on Physics Bibliography

Dorrío BV, Rua A, Soto R and Arias J

Introduction

Physics, as a basic and fundamental science, is a predominant part of the general educational curricula. It is likewise a reference for understanding many parts of current science and technology as well as the many social phenomena affected by both science and technology. However, this potential importance is not recognised socially and therefore confers a simple and poor image of this science. Amongst the many activities that can be used for making knowledge of Physics and its learning, more attractive is that of Hands-on Physics Experiments (HPhysE) where an understanding of natural processes is carried out via direct observations and experience [1,2,3]. Usually, HPhysE can be found at "interactive" science and technology centres, but an important effort has been made in order to import them into schools [4,5].

One of the difficulties in bringing the world of science and technology closer is that the methodology used for presenting their concepts, principles and laws is inadequate. Apparently, the use of the so called "scientific method" at the very minimum would mean a predisposition to science and research. On the other hand, the real participation in a task and therefore achievement, are determined to a greater extent by the amount of interest that the task can generate. Therefore, rather than stick to a mere introduction of established knowledge, a real possibility to approach and experience scientific tasks and the use of "scientific methods" in an applied manner is envisaged [6,7]. In this case, it appears that conceptual comprehension is best stimulated by way of participation in "scientific research" and by providing enough opportunities and support for reflection. All of the above leads to a closer understanding of the nature of science and technology [8].

The growing interest in design, development and evaluation of these types of HPhysE can be appreciated by the increasing number of publications on such topics in journals related to Teaching Physics [9,10]. This type of information can be seen in American journals such as "The Physics Teacher" [11] (which covers a wide educational spectrum) and the "American Journal of Physics" [12] (centred more on the university area), not forgetting the European journals such as "Physics Education" [13] and "European Journal of Physics" [14]. At first sight, the field continues to expand as newer HPhysE come into being when a) new applications are established, b) there is a redesign due to imitation, change or transformation,

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c) modifications are made, or d) contents are changed. Many a time, some HPhysE have been replaced by new HPhysE. Although many such HPhysE can be found in books [15,16,17,18] or even on web pages [19,20,21,22], they however do not have a systematic distribution and therefore there arises the need for a study of their present state and evolution over time.

Figure 1. Hands-on Physics Experiments

This work is a first attempt to study the present state of literature published in journals from 1980 onwards. Each identified article was classified according to the different categories, which enabled the establishment of a time analysis, a relative weighting and/or the identification of relevant topics. Likewise, the data were subject to an association or contingency analyses with a view to obtaining a cause-effect relationship between the different categories.

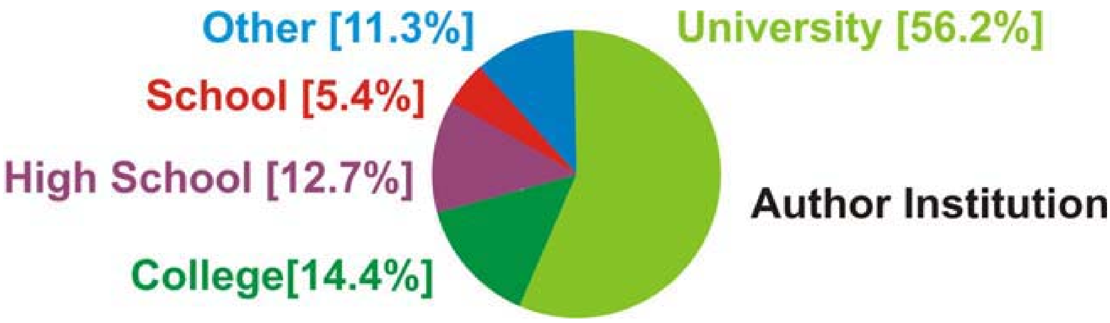

Figure 2. Distribution by author institution for the analyzed HPhysE

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Classification and description

A detailed search was carried out for articles in journals such as "The Physics Teacher" (PT) and "Physics Education" (PE).
About 700 articles (70.1% in PT and 29.9% in PE) were identified and classified into the following types:

a) topic: Electromagnetism (10.5%), Fluids (8.2%), Kinematics (4.9%), Vibrations and Waves (19.0%), Static Electricity (5.2%), Modern Physics (4.9%), Optics (12.9%), Other (1.0%), Multitopic (4.6%), Magnetism (4.6%), Dynamic and Static (21.1%) and Thermodynamics (3.1%);
b) author institution: university (56.2%), college (14.5%), high school (12.7%), school (5.4%), and others (11.3%) (museums, individuals, laboratories, companies,…);
c) author country;
d) number of pages; or
e) use of overhead projector.

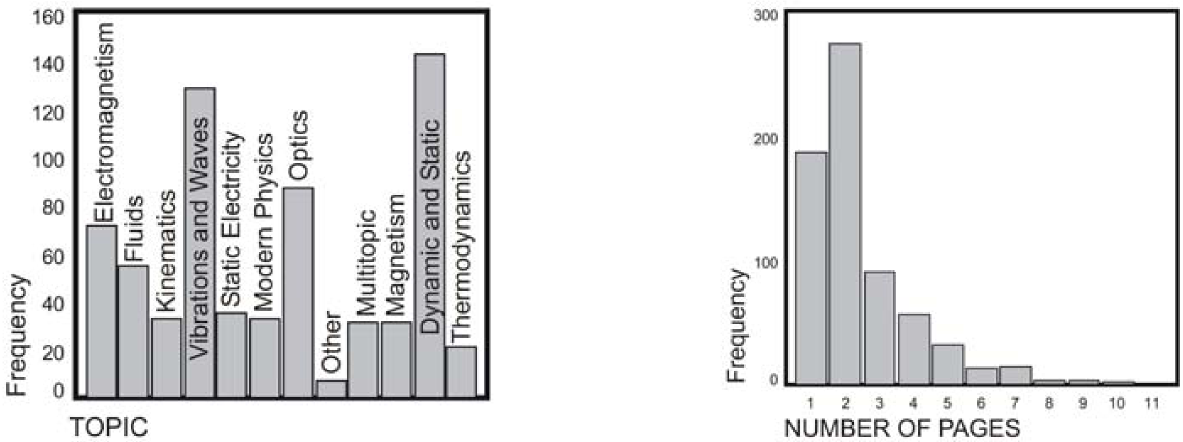

Figure 3. Distribution by Topic and Number of Pages for the analyzed HPhysE

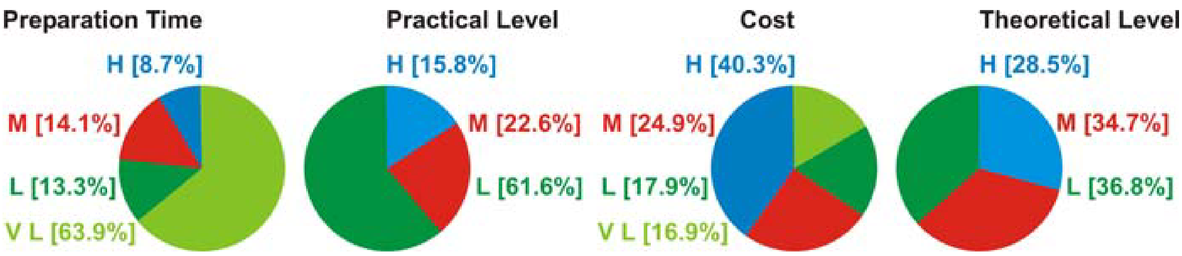

Figure 4. Percentages for preparation time, practical level, cost and theoretical level for the analyzed HPhysE (High, Medium, Low or Very Low)

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A relative characteristics analysis related to the nature of HPhysE was likewise undertaken for each article, where each was subject to cost, preparation time, theoretical and practical level (on a scale from very low, low, medium and high). The results of such a classification can be seen on the obtained graphs.
From an analytical point of view, since these are qualitative variables, we can highlight on the mode results and on the extreme values. Thus we can emphasize that: a) 95.6% of the articles deal with just one exclusive topic, b) most of the authors are from the USA (60.6%) and the UK (17.1%), c) the institution which publishes most is the university (56.2%), d) the number of pages is either one (27.6%) or two pages (40.6%), e) although the level of preparation needed is usually low (63,9%) there is a sizeable percentage of high cost HPhysE (40.3%), f) just 12.6% use, or can easily adapt, a overhead projector for a greater public viewing, g) although the theoretical level is pretty similar, the practical level is quite low, h) only 6.1% of the HPhysE are models, and finally i) just 6.2% of the HPhysE use toys.

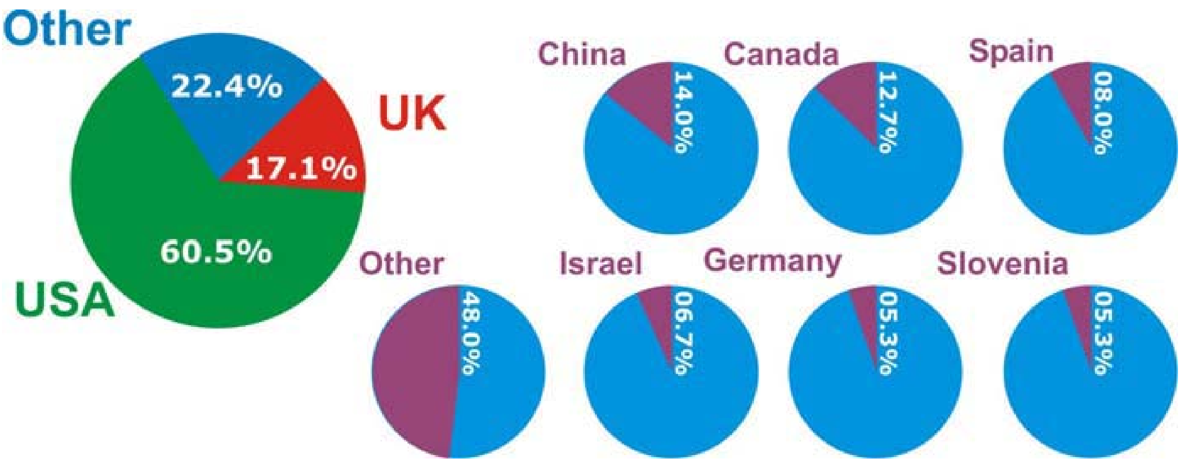

Figure 5. Distribution by author country

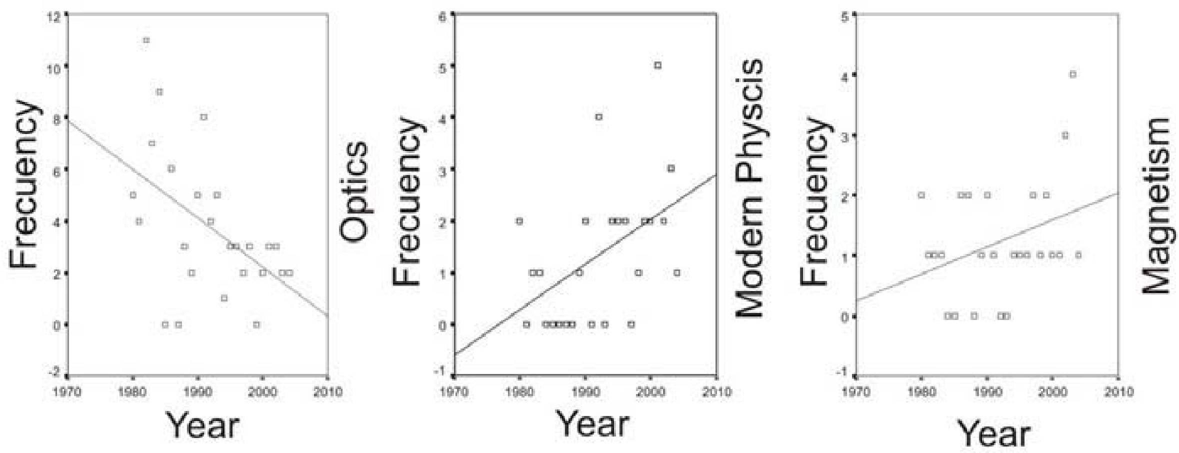

Figure 6. Temporal evolution from 1980 onwards for selected topics

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It is also worth noting that within each topic, there are certain themes that repeat more frequently: Kinematics/Circular Movement (14.7%), Dynamic & Static/Centre of Mass (15.5%), Oscillations & Waves/ Interference (16.2%), Fluids/Cartesian Diver (16.7%), Static Electricity/ Electroscope (14.3%), Magnetism/ Field (38.7%), Electromagnetism/Induction (37.1%), Optics/Refraction (29.9%), Thermodynamics/ Ideal Gases (14.3%) or Modern Physics/Chaos (14.28%). Finally, a time evolution analysis shows an increasing trend towards topics such as Magnetism and Modern Physics and a decreasing trend towards topics such as Optics.

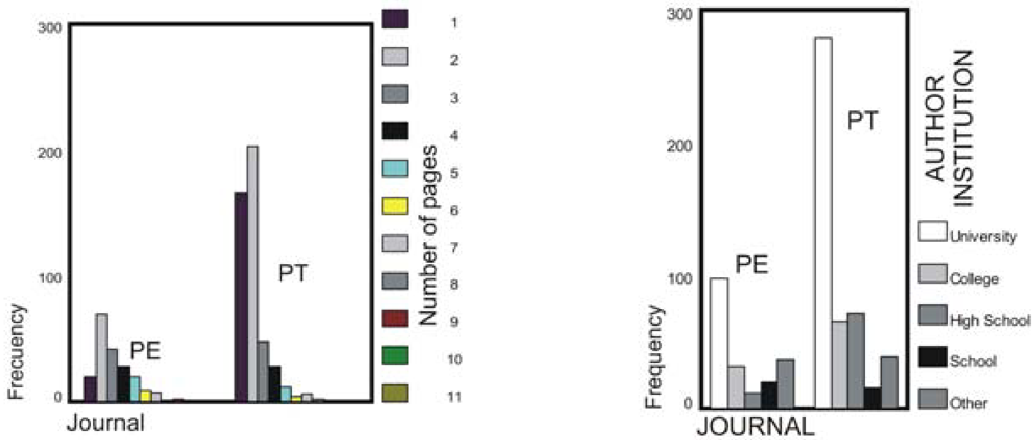

Figure 7. Significant association between the pairs of variables journal/number of pages and journal/author institution

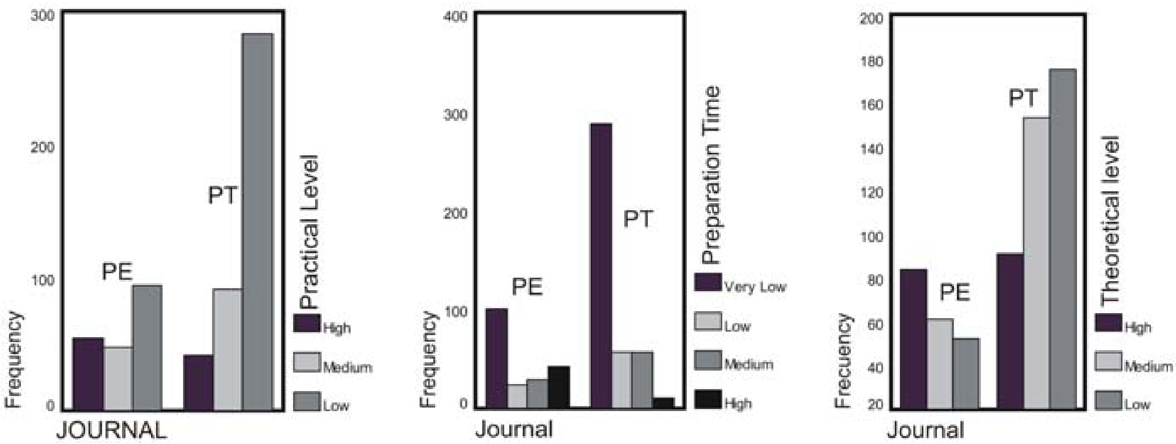

Figure 8. Same as Figure 7 but for the pairs of variables journal/practical level, journal/preparation time and journal/theoretical level

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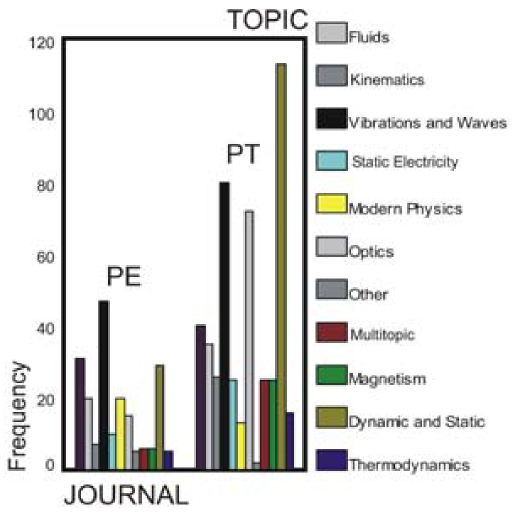


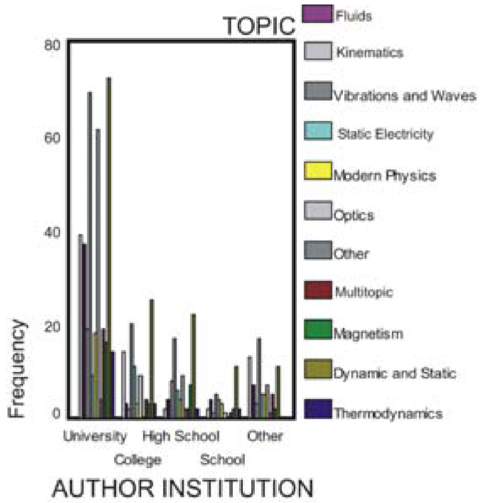
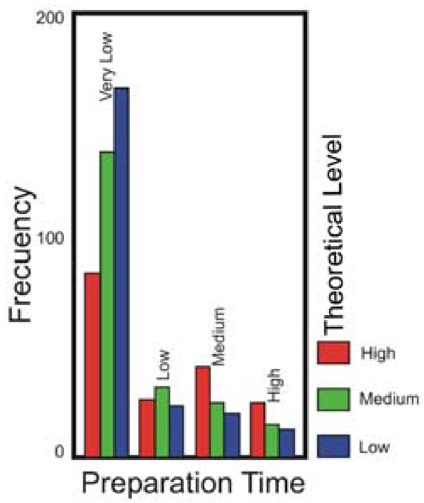


Figure 9. Same as Figure 7 but for the pairs of variables journal/topic and author institution/topic



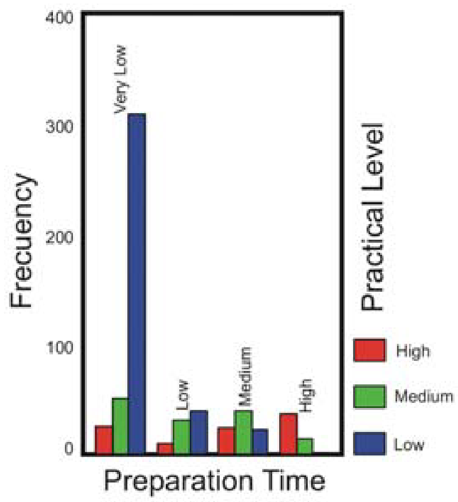


Figure 10. Same as Figure 7 but for the pairs of variables preparation time/ theoretical level and preparation time/practical level

Statistical Analysis

A contingency analysis was carried out using SPSS11.5 for Windows [23] with a view to analysing the causality relationship between the different categories of the qualitative variables. This analysis is used to study the possible relationship, association or dependence between a pair of qualitative variables and the strength or intensity of such an association. We are talking about developing a hypothesis where a null hypothesis means the existence of independence as against the existence of association or dependence. The differences between the characteristics of the null hypothesis and that of the two variables observed are

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studied using a statistical Chi-Square test (χ^2 with (r-1)×(s-1) degree of freedom (where r and s respectively represent the rows and columns of the contingency table). If the p-value is less than 0.05, the null hypothesis is refused with a 95% confidence limit, which will mean the acceptance of the alternative hypothesis and therefore the existence of association or dependence. Cramer's V coefficient is usually used to get an idea of the intensity of such an association, which depends on χ^2 but which reduces its value to an interval between 0 and 1, such that the nearer the value to 1, the more intense is the relationship and the nearer the value to 0, the least is the relationship.

	Journal				Institution			
	χ^2	*d.f.*	*V Cr*	*p-val.*	χ^2	*d.f.*	*V Cr*	*p-val.*
Institution	37,185	4	0,236	0,000				
Country	420,995	31	0,792	0,000	218,62	124	0,285	0,000
N-pages	90,136	10	0,366	0,000	48,284	40	0,134	0,000
Cost	1,513	3	0,05	0,679	11,987	12	0,081	0,447
Preparation time	65,003	3	0,327	0,000	14,276	14	0,088	0,283
Theoretical level	30,424	2	0,222	0,000	6,331	8	0,072	0,610
Practical level	36,172	2	0,243	0,000	12,099	8	0,099	0,147
Topic	48,824	11	0,269	0,000	67,840	44	0,159	0,012
	Theoretical level				**Practical level**			
Preparation time	χ^2	*d.f.*	*V Cr*	*p-val*	χ^2	*d.f.*	*V Cr*	*p-val.*
	38,349	6	0,178	0,000	241,374	6	0,446	0,000

Table 1. Summary of contingency analysis. Statistical Chi-Square test coefficient χ^2, the corresponding degrees of freedom, Cramer's V coefficient and the p-value

The most significant associations are shown in the graphs and the main results are shown in summary Table 1 where one can see the value of statistical contrast χ^2, the corresponding degrees of freedom, Cramer's V coefficient and the significance of the association (a p-value <0.05 indicates the existence of a significant relationship with a 95% confidence limit).

Therefore, we can highlight that there does not exist (see Appendix 1) any significant relationship between the pairs of variables:

a) cost/journal,
b) institution/cost,
c) institution/number of pages,
d) institution/preparation time or
e) institution/theoretical level

At the same time, there exists a weak significant relationship between the pairs of variables journal/number of pages (PE publishes bigger articles), journal/preparation time (PT offers HPhysE with the least time), journal/theoretical level (PT<PE), journal/practical level (PT<PE), journal/topic (PT) publishes more of

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Optics/Dynamic & Static, while PE tends to publish more of Electromagnetism/Vibrations and Waves/Modern Physics), country/institution (the American authors are normally from University/College, while those from UK are mostly from College/High School), institution/category (according to the institution, the weighting for the topics is different), theoretical level/time (greater the theoretical complexity, the greater is the preparation time), and lastly practical level/time (HPhysE that need a higher preparation time are the most complex).

Figure 11. Hands-on Physics Experiments

Conclusions

A detailed analysis of the articles published in PT and PE from 1980 onwards has enabled the identification and classification of Hands-on Physics Experiments (HphysE). The categories in which the articles are classified clearly show the trend for each topic. Such behavioural trends could be further analysed with data provided by other popular journals related with the subject as “American Journal of Physics” and “European Journal of Physics”. A statistical contingency analysis of the data has enabled the identification of important relationships and deficiencies. There seems to be an observed tradition for design HPhysE in countries such as the USA/UK and a weak incidence in the remaining countries. Such an incidence is also very weak at educational levels such as in High Schools/Schools where the priority ought to be higher. Equally noteworthy is the low percentage of HPhysE that use an overhead projector and there should perhaps be a greater effort to adapt/create HPhysE so that these can be used more often in the classroom as a demonstration tool.

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References

[1] McAlenxander A, Physics to go, The Physics Teacher, 41: 214-218, 2003.
[2] UNESCO, 700 Science experiments for everyone, Doubleday: New York, 1962.
[3] Vázquez Dorrío JB, García Parada E and González Fernández P, Introducción de demostraciones prácticas para la enseñanza de la Física en las aulas universitarias, Enseñanza de las ciencias, 12: 62-64, 1994.
[4] Quin M, What is hands-on science, and where can I find it?, Physics Education, 25: 243-246, 1990.
[5] Wellington J, Formal and informal learning in science: the role of the interactive science centers, Physics Education, 25: 247-252, 1990.
[6] Arons AB, A guide to introductory Physics teaching, Wiley: New York, 1990.
[7] Gil D, La metodología científica y la enseñanza de las ciencias: una relación controvertida, Enseñanza de las Ciencias, 4: 111-21, 1995.
[8] Hodson D, In search for a meaningful relationship: an exploration of some issues relating to integration in science education, International Journal of Science Education, 14: 541-566, 1990.
[9] Freier G, The use of demonstrations in Physics teaching, The Physics Teacher, 19: 384-386, 1981.
[10] Hilton WA, Demonstrations as an aid in the teaching of Physics, The Physics Teacher, 19: 389-90, 1981.
[11] http://scitation.aip.org/tpt/
[12] http://scitation.aip.org/ajp/
[13] http://www.iop.org/EJ/journal/PhysEd
[14] http://www.iop.org/EJ/journal/EJP
[15] Walker J, The flying circus of Physics with answers, Wiley: New York, 1977.
[16] Ehrlich R, Turning the world inside out, Princeton University Press: New Jersey, 1990.
[17] Cunningham J and Herr N, Hands-on Physics activities with real life applications: Wiley, 1994.
[18] Pizzo J, Interactive Physics demonstrations, AAPT, 2001.
[19] http://demoroom.physics.ncsu.edu/
[20] http://www.exploratorium.edu/snacks/
[21] http://www.wfu.edu/Academic-departments/Physics/demolabs/demos/
[22] http://physicsdemos.phys.cwru.edu/
[23] http://www.spss.com/

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Interactive Virtual Chemical Laboratory

Fir M, Dolnićar D, Vahćić A, Vrtaćnik M and Divjak S

Introduction

MacFarlen (1998) in his analysis of correlation between information, knowledge and learning stresses the importance of the role of lifelong learning in the information- based society. Lifelong learning takes place at the workplace and at home and its quality depends to a great extent on the use of information communication technology. Therefore, according to Wilson (2001), the basic precondition for a qualitative life-long learning is well-developed information literacy, which is a skill common to all disciplines and educational environments. Education institutions must adopt new trends in designing their educational programmes.

As a joint project between Faculty of Science and Engineering, Faculty of Computer and Information Science, Faculty of Chemistry and Chemical Technology and University College of Health Care a novel Interactive Virtual Chemical Laboratory (IVCL) has been developed. It can be regarded as a new multimedia educational tool for teachers and students. It enables the introduction of new teaching strategies and supports the development of higher skill levels: communication and information literacy, independent knowledge management, problem solving, individual and collaborative learning, etc.

Scenarios

In the initial project phase, multiple activities were designed and were then interlinked with the interactive chemistry laboratory. The main activity is learning chemical concepts and processes on the macroscopic, sub- microscopic and symbolic levels. Other activities are: discovering the properties of reagents and product of chemical reactions, using the database, learning chemical software for drawing 2D and 3D chemical structures, and knowledge testing.

IVCL was developed in multiple steps. First, the content, corresponding the chemistry curriculum for primary and secondary schools was selected on the criteria of suitability for multimedia presentation, and applicability to everyday situations. The topic selected was "Particles and Reactivity", in which the main concepts presented were: diffusion in comparison with solvatation and

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precipitation, differences between the reactions occurring among ions in a water solution and among molecules in gaseous or dissolved state.

Production and Technologies

The next step was designing experiments for visualisation of selected chemical concepts and processes on the macroscopic level. Different versions of video with experiments were made with a digital camera. Several considerations had to be taken into account: angle, lighting, contrast, hand movement, effectiveness of the experiment (quantity of reagents used to achieve maximal visual change). Best videos were selected and then processed with Adobe Premiere 6.0. Sound (narration), subtitles, pointers, symbols and pictures were added to support the understanding of experiments. Visual information on the hazards of the reagents was also incorporated in the clip.

In parallel, scenarios for the animation of the experiments on the particle level were prepared. For each scenario we had to define the properties of particles (i.e. shape, relative and absolute size, relative and absolute speed at the reaction temperature). The main part of the scenario was divided into a series of scenes. For each scene we had to define the number of particles, their movement in the virtual space, types of collisions, change in size and shape of particles after collision. The organization of particles in a crystal lattice, when the reagents or products of the reaction were in solid state, had to be described. The connection between the macroscopic and sub-microscopic world was achieved by including short clips of the experiment, using the zoom effect. In the following step molecular models (molecules, ions and crystal structures) were prepared with the 3D modelling software (Spartan, ChemSketch, MoluCad).

The next step was animation and choosing between modern technologies that offer many options how to make a 3D animation. We wished our animation to be interactive. We also wanted to avoid problems with hardware, software compatibility and portability between different operating systems. At the end we decided on Maya software, which can be used for modelling and animation. The limitation of the selected software is that it does not allow interactivity, but the film we created can be used in different systems. With Maya we made short animated films, which we later combined with sound, subtitles, pictures and other elements to create the final version of film. The database on substances with the information on physical and chemical properties, environmental and medical impact and visual and structural representations of substances was created.

Following video production, the animations and the database had to be prepared, various types of interactive exercises, aimed at testing the understanding of the macro and sub-microscopic change, were developed. The user needs to associate the results of the experiment with the particle nature of matter, thus developing skills for information retrieval (database). Explanations and correct solutions are provided for every exercise.

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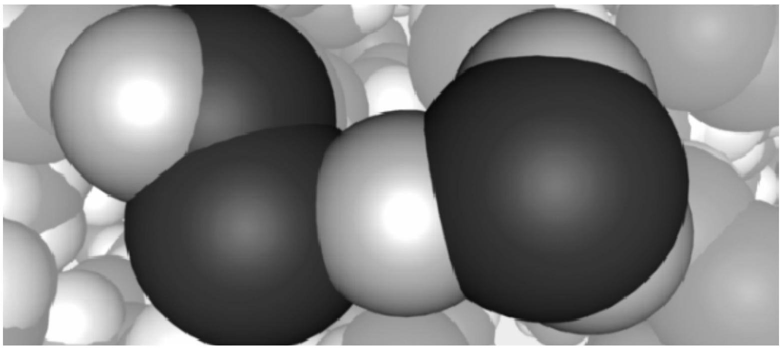

Figure 1. Snapshot from animated chemical reaction

Virtual Laboratory on Web

In the final phase the online portal of the Virtual interactive chemistry laboratory was set up. Interactive representations of chemical structures and videos require specific freely available plug-in software. To reach the broadest spectrum of users, both the English and Slovenian version were created. The web address of the laboratory is http://www.ntfkii.uni-lj.si/crp2-eng/frame.htm and http://www.ntfkii.uni-lj.si/crp2-slo/frame.htm

The content of the virtual laboratory can be accessed from different entry points: experiments (micro/sub-micro level), media elements (videos, animations, 3D molecular models, and images), interactive exercises, reagent/product database.

The laboratory is intended to teach students about chemical reactions and processes on three different levels of explanation: macroscopic, sub-microscopic and the symbolic level. For the teachers, the laboratory represents an additional teaching tool, supplementing their explanations and at the same time developing students' information literacy. The use of the laboratory encourages logical thinking, by correlating the conclusions made from observation with the theoretical background.

References

[1] MacFarlane A, Information, Knowledge and Learning, Higher Education Quarterly, 52: 77-92, 1998.

[2] Wilson AW, Information literacy: fluency across and beyond the university, In: Library user education: powerful learning, powerful partnership, The Scarecrow Press: London, pp.: 1-17, 2001.

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Growing up with Robots

Costa MFM and Fernandes JF

Introduction

Piaget's theory of cognitive development [1] is considered a fundamental pedagogical tool that in different approaches, educators at different levels and situation widely use.

The vast majority of students have tendency to learn in a concrete manner by experiencing or feeling, and process the information actively by experimenting doing or acting upon [2].

Hands-on experimental activities have long time proved to be one of the most effective ways to drive the students to a successful learning of science and technology [3].

Constructivism is a pedagogical approach where in a structured way the learning process is centred in the process of building or constructing something [4].

The development of computers and computer science gave the educator of science and technology new invaluable tools [5] that soon lead to new approaches to constructivism [6] and to the use of the concept of artificial life as a reality every day closer to our lives. The idea of using the construction of robots or automated systems as a pedagogical tool [7] emerged naturally and is proving to be very effective in science and technology education in different age or development levels.

The process of conceptualisation design and construction of a robot leads the students to positive cognitive development. The students as to, both, on one hand understand a real dynamic object, mechanism or living being in their complexity, and, on the other hand to reproduce and integrate those concepts and behaviours in a simplified, as needed or required, but effective artificial mechanism. More than a mere mechanism it may be considered to be an artificial organism.

The students have to realize accept and cope with the difference between the real situation they are dealing with and the artificial "organism" they built and that behave according to the "will" and control and conception capability of the students themselves.

School' Robotics. An Experiment

In July 2004 the world championship of the Robocup Junior League will take place in Lisbon [8]. The Robocup Junior League is an initiative that supports local, regional and international robotic events for young students. Essentially robots or teams of

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robots idealised constructed and programmed by groups of school students have to compete in a number of competitions from robotic dance to football. The pedagogical approach lays on the autonomous voluntary and committed learning by practice and hands on experimental activities. Students with different interests and strengths will work together as a team to achieve a common goal.
“RoboCupJunior aims at bringing together many of these ideas, promoting project-oriented, team-based education, giving children with a variety of interests and abilities an opportunity to pick their own challenges while contributing to the progress of the whole” [8].
Responding to a call from the Portuguese Unidade Ciência Viva [9] of the former Ministry of Science and Technology, the first author induced and presented, three pedagogical projects aiming the development of teams of robots to participate in the Robocup2004 world championship. The projects were located in three different schools on the Minho northwest region of Portugal.
The Basic and Secondary School of Celorico de Basto lays in a rural area that in spite of the improvements in the last years has a limited access to science and culture.
The College Teresiano of Braga is a traditional and prestigious basic school in the town of Braga. The school as a strong catholic focus as the city of Braga itself.
The third one is a vocational school (CENATEX) in the industrial town of Guimarães with older students that will in most cases leave the school directly to a technical employment in the industries of the region.

Growing up with Robots

The students develop their activities working in teams, in a methodical, autonomous and responsible way.
They learn by working and integrating knowledge and competences in a wide range of subjects: mathematics, physics and mechanics, electricity and electro-mechanics, construction and design, electronics and computers, programming and artificial intelligence… Not only had they chosen the types and characteristics of the robots and teams to be established as they choose their own ways of solving the problems that might appear along the way. They project, develop and improve their own robots. Aiming to participate in festivals workshops and competitions, working and learning how to understand and use technologies and activities already of great importance and that in a few years will become fundamental in our everyday life: robots and automation, programming and artificial intelligence.
All three projects [10] were structured in four main phases:

1. presentation and popularization and motivation of teachers and students for the theme.
2. establishment of the conditions that may allow the students involved of each team to form, the autonomous development of their activities.
3. development of the robots teams, the knowledge and expected competences.
4. participation in tournaments, competitions and activities of demonstration/ popularization of robotics, automation and artificial intelligence.

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Figure 1. The Robocup 2004 logo

The projects involved the establishment of 18 robotic teams built by almost 100 students. Many more students from 10 years old up to 18 years old were involved in support groups or fan clubs. Indirectly nearly one thousand students from these and other schools of the region take contact with robotics in lectures, demonstrations or festival organised by or with the participation of our students.

Types and Main Rules of the Competitions

There are 3 types of ROBOCUP JUNIOR [8] competitions: soccer, dance and rescue. The two first ones will be described in more detail below. In the football competition on or two robots play against others in a small soccer field colour-coded in shades of grey and using a special IR light emitting ball, with rules that "approaches" those of regular soccer.
In the rescue competition the robots have to race to rescue "victims" from artificial disaster scenarios including uneven terrain and different obstacles.
In dance one or more robots perform choreography according to music chosen by the team, eventually in an appropriate scenario.
In all competitions there are two age levels: primary (up to 14 years old) and secondary (from15 to 18 years old).

Robotic Soccer Junior

Teams of autonomous mobile robots play games in a rectangular field with ground colour- coded in shades of grey. In the robotic soccer are used contact, light and infrared light sensors that allow the robots to identify the field, the opponents, and the ball. Other sensors may also be used. Thus the robot is a structure somewhat complex requiring important programming skills. Teams must be prepared to calibrate their robots based on the lighting conditions at the venue.

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Figure 2. Rules must be obeyed!

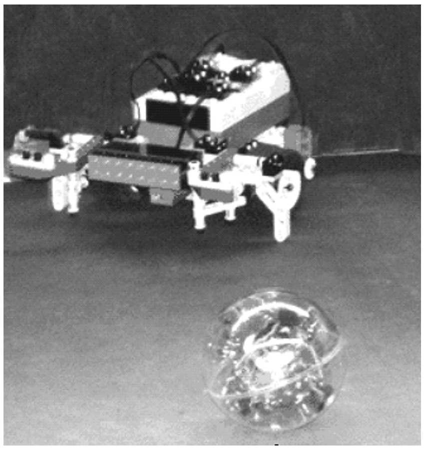

Figure 2. To find the IR ball… the first major difficulty

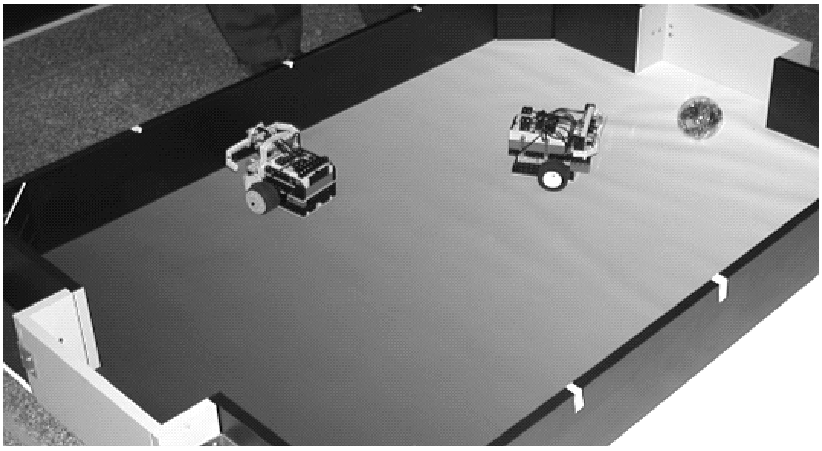

Figure 3. Ball found?… lets kick it towards the goal! The opponent's one… of course!

The need of controlling in a well balanced way the movement of the robots according to the readings of the sensors that the robot should have, renders the building and programming of this type o robots a complex task. Upon the age level different kinds of robots were assembled and programmed [10].

Soccer Rules

Team.

For the 1-on-1 League, a team shall consist of one and only one (1) robot.

For the 2-on-2 League, a team shall consist of no more than two (2) robots.

Playing Field.

Size.

The playing field for the 1-on-1 League is 87 cm by 119 cm

The playing field for the 2-on-2 League is 122 cm by 183 cm

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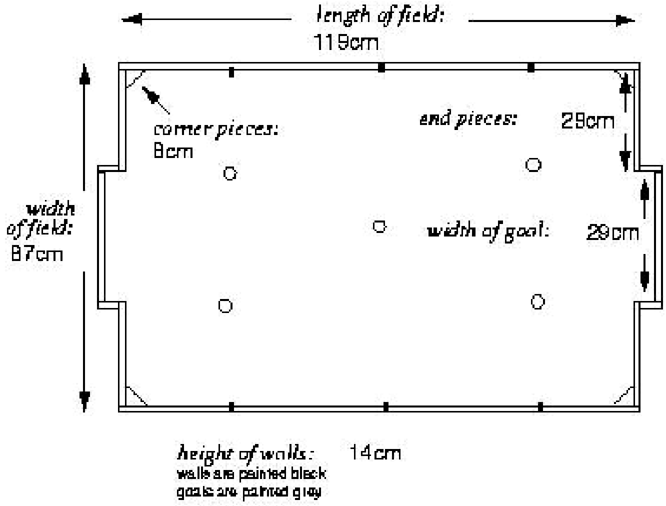

Figure 4. Diagram of a robotic' football playing field for the 1-on-1 league

The **floor** of the playing field is covered with a printed, matte greyscale. The playing field should be placed so that it is flat and level. The field may be placed on a table or on the floor.
Walls are placed all around the field, including behind the goals. The walls are 14 cm high and are painted matte black.
The **width of each goal** for the 1-on-1 League is 29 cm, centred on the shorter end of the field.
The width of each goal for the 2-on-2 League is 45 cm, centred on the shorter end of the field.
The **back and sides and floor of the goal** (inside the field) are painted matte grey: 75% matte white and 25% matte black.
Teams must come prepared to calibrate their robots based on the **lighting** conditions at the venue.

Robot

Diameter

For the 1-on-1 League, the upright robot must fit inside an upright 18cm diameter cylinder.
For the 2-on-2 League, the upright robot must fit inside an upright 22cm diameter cylinder.
Robots will be measured with all parts fully extended.

Height

The robot height must be 22cm or less.

Control

Robots must be controlled autonomously but must be started manually by humans.
The **game** will consist of two 10-minute halves. There will be a 5-minute break in between the halves. The game clock will run for the duration of the game (two 10-minutes halves), without stopping (except when robots are damaged).
A well-balanced **electronic ball** shall be used. The ball will transmit infra-red (IR) light.

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Ball Movement. A robot cannot hold a ball. The ball must be visible at all times. Other players must be able to access the ball.
Ball Capturing Zones. Ball capturing zones are defined as any internal space created when a straight edge is placed on the protruding points of a robot. The ball cannot penetrate the Ball Capturing Zone by more than 2cm.

Robotic Dance Junior

One or more robots perform to music, in a display that emphasizes creativity of costume and movement.
As there is no mandatory use of sensors, and thus a somewhat simplified approach to robotics, the focus of the activities dealing to the setting up of the kind of teams will be both the dynamical control of the machine and design and creativity.
Dance' rules:
Stage:
The dance stage will be a flat area of 10m x 5m.
There will not be any direct spotlight on the stage.
Teams are permitted to provide their own scenery.
Robots:
Size: Robots may be of any size.
Team: There may be any number of robots on a team. Each team may perform one and only one routine.
Control: Robots must be controlled autonomously. Humans may start robots, either manually or with remote control.
Costumes: Costumes are encouraged.
Routine:
Duration: The duration of a routine is no more than two (2) minutes.
Music: Teams must provide their own audio source.
Humans: Human team members may perform along with their robots. However, human team members must not touch the robots (except to start them). Start of Routine. An official will start the music for the routine. One human team member will start each robot, either by hand or remote control. Teams are allowed to repeat their routine, at the discretion of the officials.
Judging.
Routines will be judged by a panel of five officials. The five officials will be designated prior to the tournament. The officials shall not have any relationship with any of the teams entered in the tournament.
Routines will be judged according in the following categories:

1. Programming.
2. Construction.
3. Costume.
4. Choreography.
5. Creativity.
6. Originality.
7. Entertainment Value.

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Scores from 1 to 10 (best) will be assigned to each team for each category.
Winners.
A winner will be chosen for each category, as the team with highest total score for that category.
More information concerning these projects can be found in the websites created by the project students: http://robos.no.sapo.pt

Conclusion

In-class hands-on experimental activities have a very positive impact in the large majority of the students involved. The construction of robots and robots' teams is a challenging activity that students regardless of their age level, take in a very responsible and committed way.
The fact that the large majority of our teams were chosen in the Portuguese selection' competition for participation in the world robotics championship Robocup'2004, (representing over 40% of the Portuguese teams in the competitions they will participate), is important.
However, by far, the most important outcome of the project is the self-confidence and responsibility our students developed and that it is in a very positive way replicating among their colleagues.

Figure 5. Some of the dance robots that participated at the Robotica'2003 National Robotics Festival in Lisbon

Figure 6. The sweet flavour of victory

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References

[1] Piaget J and Inhelder B, La psychologie de L'enfant, P.U.F.: Paris, 1966.
[2] Kolb DA, Experimental learning: Experience as source of learning and development, Prentice Hall: Upper Saddle River, 1984.
[3] Costa MFM, The importance of experimentation on teaching the basics of optics at elementary and high schools, Proc. Soc. Photo-Opt. Instrum. Eng., 3190: 228-232, 1997.
[4] Harel I and Papert S, Constructionism, N J Ablex Publishing Corp, 1995.
[5] Papert S, Mindstorms: Children, Computers, and Powerful Ideas, Basic Books: New York, 1980.
[6] Kafai Y and Resnick M, Constructionism in Practice: Designing, Thinking, and Learning in a Digital World, Lawrence Erlbaum: Mahwah, 1996.
[7] Pagliarini L, Lund HH, Miglino O and Parisi D, Artificial Life: A New Way to Build Educational and Therapeutic Games, In Proceedings of Artificial Life V, MIT Press/Bradford Books: Cambridge, 1996.
[8] www.robocup2004.pt
[9] www.cienciaviva.pt
[10] robos.no.sapo.pt

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Promoting the Construction of Knowledge during Practical Work

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Introduction

Practical work is an essential component of doing science. It is present as part of science across many countries, reflection national and international commitment to promoting scientific literacy for all and public understanding of science (Jenkins, 1999). Even from an early age, teachers get children to experience phenomena, try things out, to tinker with apparatus. Many times this process involves students in asking questions and making observations in order to find answers to their questions. This approach can be summarised to be that of hands on science. The assumption, in many cases is that if children are carrying out experiments, then they are learning scientific concepts too. This premise, in fact was that used by the Nuffield series developed during the 1960s and who based their approach on the belief that children learn by doing. Research in science education has since recognised that carrying out experiments does not necessarily equate to the understanding of concepts. Many times traditional practical work results in the mere following of instructions, the gathering and processing of data without really stopping to think about the how and why of such activities. This is why they have been aptly termed recipe-type experiments, where students simply follow instructions, as in the case of a recipe when cooking, without the need to know why or reflect on what they are doing. Experiments can also be reduced into a simple guessing game where students would be more interested in figuring out what they should notice rather than really be actively involved in the experiment itself (Driver, 1975).

This paper is not about abolishing practical work in science. It is about how practical work is to be organised such that it is used effectively to help students understand scientific concepts. This can be achieved through the constructivist approach whereby students are presented with situations, in this case, experiments, which provoke reflection and consequently the construction and understanding of concepts. It provides examples of such circumstances from research findings of a teaching scheme carried out with secondary level students in the area of Newton's Laws of Motion where cognitive conflict was used as the main vehicle to promote the construction of knowledge.

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Theoretical Background

The constructivist approach to learning has been written about by many educators and given a number of different interpretations. It has also been applied widely in many teaching schemes. Basic to the theory of constructivism advocated by these numerous educators and researchers is the belief of the necessity for every human being to put together thoughts, interpretations and explanations that are personal to themselves in making sense of his/her experiences and situations. Windscith & Andre (1989) consider constructivism to take place when students construct their knowledge from individual and/or interpersonal experience and from reasoning about these experiences' (p.147)

On the same lines Watts (1994) states that 'constructivist learning is always an interpretative process involving individual's constructions of meaning relating to specific occurrences and phenomena. New constructions are built through their relation to prior knowledge." (p.32). Constructivism considers that all individuals construct for themselves a unique picture of the world. In other terms, constructivism refers to learning in the form of 'making sense of'. The person needs to go through a mental process in order to be able to interpret and make sense of his/her surroundings. When one applies this to learning and teaching, it is important for the individual to be capable of understanding, or construing, the concepts that the academic community accepts as being true. Construction does not give learners the licence to claim that their meaning is as good as that of accepted knowledge. It is important to keep in mind that some meanings are better than others, especially those constructed and agreed on by the community of academics of any subject area or knowledge.

The debate regarding the constructivist approach to teaching concerns the extent to which it is possible for any teacher to intervene in the thinking of a learner. This highlights the purpose and value of an intervention and how this can be achieved, and how effective it may be (Watts & Jofili, 1998). Learners organise and manage experiences so that their actions maximise desirable results and minimise undesirable ones. A constructivist teacher works at the interface between learner and the curriculum, making understanding knowledge and concepts meaningful for the learner without in any way diminishing the importance of having a specified curriculum. Had it not been possible for teachers to be able to play a role in determining and promoting the construction of knowledge, then teacher capability would not have any influence on the amount and quality of learning (Gatt, 2003).

There are two aspects of constructivism: the personal and the social aspect of learning and constructing knowledge. Many of the leading theories such as that of Piaget and Kelly are personal in nature, referring to the individual's cognitive activity and the brain interacting with the material to be learnt. Learning, however, also occurs within a social context, as is the case with the classroom the social aspect of constructivism focuses on how knowledge is constructed within a group or community. Knowledge is considered to be created and legitimised, now not through personal conviction but by means of social interchange in its many forms. The objective of language is that of delineating the relations among members of a community, being social, geographical or academic, and to achieve coherence in

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the community of knowledge (Staver, 1998). Knowledge is thus built both within the individual and by the community.
Constructivism is not a theory of teaching but a way of looking at knowing and learning. Therefore it does not imply a single specific teaching method. The individual may construct and learn under a variety of circumstances (Welford, 1996). In developing teaching approaches, one must keep in mind that knowledge is actively constructed by learners rather than transmitted by teachers.
Constructivism has been widely adopted when developing teaching schemes aiming at improving students' learning. The main approaches included conceptual change (Posner et al, 1982; Strike & Posner, 1985) and Driver and Oldham's (1986) constructivist approach. Many other schemes like concept mapping (Hammer et al., 1998) and mental models, (Gilbert, 1998), have also been developed by many researchers. Common features that emerge are the use of cognitive conflict, metacognition and the application of scaffolding in promoting students' active participation in learning.
These approaches emphasise the need for learning to be stimulating. This can be achieved through the use of challenge or cognitive conflict, reflection or what is known as metacognition, and the ability to build patterns (Adey, 1997). It is important to provide children with opportunities where they can work out their ideas in their own language.
Stofflet and Stoddart (1994) assert that conceptual change is a necessary prerequisite for the formation of any valid theory. Learning involves the development of a new conceptual perspective through which content can be personally mediated and understood. Conceptual change allows challenging prior knowledge, a conflict that leads to accommodation of the pre-existing knowledge structure. Strike and Posner (1985) are the main advocates of conceptual change. They list four main steps necessary. These include the following: the student must first experience dissatisfaction with an existing conception; the new conception must be intelligible; the new conception must be plausible; and the new conception must be fruitful in that it has the power to make predictions and to predict phenomena.
Rosalind Driver is one of the pioneers of constructivism and research on children's ideas in the area of science. She has in turn also developed a constructivist teaching approach that formed part of the Children Learning in Science Project (CLISP). The strategy involved first eliciting children's ideas about the topic concerned, then helping them discuss the different views held, testing them for viability, and eventually, hopefully, changing the incorrect ideas into scientifically correct reasoning. The scheme was divided into the steps: Orientation, where students are given the opportunity to develop a sense of purpose and motivation for learning; Elicitation, where students spell out their ideas about the scientific topic tackled; Restructuring of Ideas involving the clarification and exchange of ideas where ideas held are conflicted and followed by the construction of ideas in a variety of ways in considering different phenomena; Application of Ideas, involving the application of the learnt ideas to a variety of situations; and Review, the final stage where students reflect on their learning (Driver & Oldham, 1986).

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Cognitive conflict is also a vehicle used to promote the construction of knowledge and has been described as being central to the achievement of conceptual change (Park & Pak, 1997). Shayer and Adey (1994) define cognitive conflict as 'the term used to describe an event or observation which the student finds puzzling and discordant with previous experience or understanding' (p.62) Stavy and Berkovitz (1980) argue that cognitive conflict occurs in two different ways: either between a child's cognitive structure related to a certain physical reality and the actual reality, or between two cognitive structures related to the same reality. It is not easy to produce cognitive conflict if students do not perceive causal relationships between the variables. This implies that the skill of attending to evidence may have to be explicitly taught on its own at some point in the school curriculum.

Cognitive conflict is not, however, without problems. One problem is that students may not even be aware of any of the anomalies present (Stavy & Berkovitz, 1980). As Fensham & Kass (1988) point out, not all surprising events fulfil the potential of cognitive conflict, and can be simply shrugged off as just being inexplicable. This may occur either because students do not possess the cognitive ability to realise that a contradiction is present, or do not manage to observe that different behaviour is taking place. If students do not realise that the predictions are in contrast with their observations, or that the other students' ideas differ from their own, then it is not possible to promote the desirable conceptual change. Problems may also arise even though students are aware of the discrepancies between observations and predictions. This may occur if students opt to disregard findings on the ground that they are irrelevant to the current conception being considered by them. They may also choose to reject the observed results by voluntarily or involuntarily manipulating evidence (Gauld, 1989). In addition, students may be able to accept two conflicting conceptions at the same time where they do not distinguish between everyday and scientific reasoning (Solomon, 1983). Another problem with cognitive conflict is that it may make the situation intimidating to students (Watts & Bentley, 1987). It is discouraging for a student to realise that his/her ideas do not agree with what is actually believed by scientists to happen or to the conceptions held by peers, especially if the situation repeats itself a number of times. The teacher must be careful to provide conflict that is of the appropriate level to promote learning without demoralising students.

Every learning situation should have an element of self-regulation and awareness of one's own learning process – what is known as metacognition. Wittrock (1994) describes metacognitive learning as the 'awareness and control over one's thought processes during learning' (p.30) and argues that it should be included as part of teaching. The advantage of metacognition is that it increases transfer among students of different abilities and across different subject matters and facilitates conceptual change.

Aim of the Study

The research reported here involves a teaching scheme developed within a constructivist framework. The topic area chosen is Newton's Laws of Motion. This topic was chosen since it is a particularly problematic topic and it happens to be

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taught at the beginning of the fourth year of secondary education. This ensures that students have a minimum of one year background knowledge of Physics but are as yet far from their national school leaving examination. The research aims to promote the construction of knowledge and consequently better understanding of Newton's Laws of Motion. It aims to achieve this through the use of cognitive conflict, scaffolding and metacognition. This paper focuses on how cognitive conflict can be used to promote construction of knowledge during practical work.

Methodology

The scheme adopts particular methods in providing the environment and situations to promote construction of knowledge. The main tool used includes cognitive conflict, between the prediction of and actual outcomes of experiments, and that promoted through the social construction of knowledge through discussion and exchange of opinions.

The scheme incorporates two types of cognitive conflict. The first one involves comparing and contrasting of ideas expressed by different students, while the second one compares a prediction with the actual outcome of experiments carried out. The conflict situations have been chosen such that they are: within a context familiar to the students; and while making a cognitive demand on the students, are neither too easy nor too difficult that they are incomprehensible.

One way of promoting the type of conflict described above is the use of social interaction between students. Different individuals have different ways of looking at things. They will, therefore, often have discordant ideas. Such ideas provide the necessary conflict, leading students to insight and understanding. This type of conflict can be identified in a number of occasions. The main pattern is that students, when working in groups, are given opportunities to discuss and debate the outcomes and results of their observations. Discordant observations will promote the desired conflict whereby students would then be interested and motivated to understand the concepts being discussed in order to know whether their assertions are good or not and why.

Cognitive conflict can also be brought about directly through practical experiments. The students are introduced to the experiment to be carried out. They are asked to predict what outcome they expect to obtain and why. When the experiment is actually done, and a different result is obtained, students would want to know and understand why. Constructive learning thus takes place.

One situation of cognitive conflict was used in introducing the properties of Newton's third law pairs. Students were organised in groups of four and given a pair of spring balances. They were asked to predict what each spring balance would read in two situations:

- when both students are pulling at the same time; and
- when one student is pulling and the other is holding his/her hand stiff.

Many of the students are expected to predict that the readings will be the same in the first case but different in the second. It is envisaged that students will expect the

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person pulling to exert a greater force than the one who is holding the spring balance. A common misconception is to believe that the more active one would exert the greater force. When the situations are eventually tried out and the same reading is obtained in both situations, conflict will arise. This will motivate students to try and make sense of the situation, providing fertile ground for active learning.

Another example of cognitive conflict was used when introducing Newton's First Law. The students were presented with a trolley on a friction-compensated runway. They were then asked to identify the forces acting on the trolley and to predict the resulting motion when released. Many are expected to predict acceleration. This would provide the first instance of cognitive conflict when constant velocity is obtained. Students are expected to realise more easily that a resultant force of zero gives constant velocity. The argument is further developed by considering two other situations. In the first case an additional forward force is added whereas in the second instance a resistive force is introduced. In these cases, a resultant force is present which produces acceleration and deceleration respectively.

The scheme consists of ten lessons, each three quarters of an hour long. The first five lessons focus on the properties of forces and Newton's third law. Lessons 6-8 focus on the effect of a net resultant force, while the last two lessons introduce the concept of momentum and Newton's second law. A teacher, teaching fourth form students in one of the Junior Lyceum schools (local state grammar type schools) was willing to try out the scheme. The teacher was a female education graduate and had five years teaching experience.

A total of 42 students in two fourth form classes in a girls' Junior Lyceum School were taught according to the scheme developed by the researcher. One class consisted of 25 students, and were considered to be of average ability. The other class had 17 students and were the weakest students in the whole form. Although there were disruptions in lessons due to class outings and other extra curricular activities, the scheme was eventually done within four weeks of work.

Data was collected in different ways and from different sources to ensure a degree of triangulation (Hammersley,1983). Quantitative and qualitative methods were used together in order to obtain as clear a picture as possible. The data collected included: Field notes through non-participant observation of the researcher; audio-taping all the lessons; and personal diary filled by students at the end of each lesson.

Results

The activities aimed at provoking cognitive conflict mainly included situations requiring students to make predictions about outcomes of experiments. This occurred basically in two situations: during the activity requiring students to arrive at the properties of the Newton's third law pairs of forces and when learning that a resultant force causes an object to accelerate.

The students' dialogues provide insight into the students' reasoning in any one of the situations identified. The transcript below shows the dialogue between the students and the teacher before trying out the experiment where they had to pull two spring balances connected to each other. The students predicted that the

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balances would give different readings depending on how much the person at each end was pulling. The role of the teacher here was crucial. The students had only considered the possible size of the force exerted and did not really think much about their logic. The teacher's questions not only helped the students to become aware of their own hypothesis, but also to reflect on how they arrived at their conclusion.

S_1	**The first experiment… one pulls from one side and another from the other.**
T	**Yes, and what is going to happen?**
S_2	**They are going to extend**
T	**Yes, what do you think… what did you write that will happen?**
S_1	**I wrote that the one pulling more will have a greater force.**
T	**What do you think, will the forces be the same or different?**
S_1	**No, different**
T	**Why different?**
S_1	**Because they are going to pull with a different force.**
S_2	**It depends on his force**
T	**What do you mean by 'depends on his force'?**
S_2	**The force of gravity and the force he exerts.**
T	**Who is making the force?**
S_1& S_2	**We are**
T	**Do you want to try it? You are saying that they are different**

The following excerpt, which occurred just afterwards, sheds light on the students' reaction on trying out the experiment in practice and noticing that the two balances gave the same reading. On reading the result together, the students experienced surprise on noting how much their predictions differed from what actually happened.

T	**Do you want to try it out?**
S_1	**It moves on its own.**
Chorus	**They have the same reading!**
T	**Read the values**
S_2	**The force is being distributed.**
T	**What do you mean by the force is distributed?**
S_2	**Because they are connected to each other**
T	**What do you mean?**
S_2	**Because they are connected by the hooks in the middle.**
T	**By the way, do you know what the spring balance does?**
S_1	**It depends on how much you pull.**
S_2	**It gives the force present……**
T	**How much force you are making. What can you say about the force you are making?**
S_2	**That they are equal.**
T	**So is it the same as what you thought before?**
S_1	**No**

Cognitive conflict alone, however, does not ensure that correct understanding will follow.

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The teacher's role in guiding the students thinking is again observed to be crucial in promoting the desired learning. As the transcript shows, the reason put forward by the students just after the observation does provide a logical and plausible explanation for the observation made. The reasoning manifested, however, is wrong, in that it is not the case that the force is distributed equally between the two, but rather that the two students were pulling with the same force.
The effectiveness of cognitive conflict arising from obtaining a different result to that expected transpires also from the students' diaries. The students realised the educational benefit of thinking about an experiment before actually trying it out. The 'unexpected outcome', as one student described the discrepancy, helped the students to gain greater insight of the situation and to consider it in more detail than just at face value. Some comments made by students include;

'I enjoyed the lesson as it gave us time to think about the experiment before we made it.'
'I liked the lesson because things that are obvious to me, when doing them in an *experiment, you find out that they are completely different than you imagined.'*
'I liked the lesson because we did experiments in the lab to determine what was right and wrong about what we said and thought.'

Cognitive conflict was also designed to take place when introducing the effect of a net resultant force. The situation involved studying the motion of a trolley going down a runway. Having shown students that a trolley moves down the friction-compensated runway at constant velocity, an additional forward force was introduced through a falling weight attached to a string. At this point, the teacher, asked the students to predict the motion they expected to see. As had been expected, some of the students predicted a larger constant velocity whereas others mentioned acceleration. Cognitive conflict thus also occurred in this situation. It also motivated the students to want to know what actually results.

T	**What type of motion do you expect?**
S_1	**It will go faster.**
T	**It is going faster, but is it going to be constant velocity?**
S_1	**No**
T	**Will I have constant velocity?**
S_2	**I think that the space between the dots will be larger, but the same**
S_1	**No, not equal, the space will increase with time.**
T	**So what do you think? Will I have constant velocity but greater, or will the trolley increase its velocity with time?**
S_1	**As time passes, the trolley will go faster, gain velocity.**
T	**We have different opinions. Let's then try it out.**
S_2	**I think that the space between the dots will be larger, but the same**

The teacher has a crucial role and must help students in trying to make sense of the situations encountered when doing experiments. The excerpt below shows students realising the effect of a net resultant force and making generalisations from the situation considered. The teacher's contribution not only can be seen to direct the

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students' thinking but also to the language that is typically used in Physics when expressing their reasoning.

S_1 **In the first situation the forces were equal, in the second case…**
S_2 **We had acceleration.**
T **Yes in the first case …**
S_1 **We did not have any weight (referring to the weight which provided the extra force forward)**
T **We did not have the weight, and we had constant velocity, and the forces…**
S_3 **Were equal**
T **Equal, with equal forces we had constant velocity, then what did we have?**
S_1 **Acceleration**
T **Acceleration, and the forces?**
S_2 **Not equal**
S_3 **They are not the same.**
S_1 **Equal forces, constant velocity, not equal forces make acceleration**
T **Yes you can say that, but instead of equal what can you say?**
S_2 **Different**
T **Or unbalanced forces because we do not have balance…**

Evidence that some form of knowledge construction did actually occur during these experiments can be gleaned from a number of the students' entries in their diaries. There are instances where the students are capable of stating the new knowledge constructed.

'I enjoyed the lesson because we learned about interesting forces that we didn't notice'
'I liked the lesson because we looked at knowledge about things we see everyday and which we find difficult to understand. So we can maybe learn the scientific reason'

Metacognition forms an essential step in learning and should follow cognitive conflict. It is not enough for students to discuss and resolve conflict when doing experiments, they also need to become aware of their own reasoning. Such examples can be identified in the teaching scheme. In one particular circumstance, in promoting metacognition, the students were not only asked to reflect on their own thinking, but also to learn how to label the situation, the thinking process.

T **When you had a weight similar to this, what type of motion did you get?**
S_1 **The weight was greater than the frictional force**
T **So, when you have one force greater than the other, what do we say that we have? If you look up your notes, you will know? Look it up.**
S_2 **Net resultant force**
T **Yes, I will have a net resultant force. Now, what type of motion do you expect to get in the situation you are considering?**
Ss **Acceleration (Chorus)**
T **Why are we going to get acceleration?**
S_1 **Because the force due to the weight is greater than the friction**
T **But what can you say overall?**
S_2 **The frictional force is smaller.**

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T **So, I have one force greater than the other. What can I say?**
S_1 **A net resultant force**
T **And when I have a net resultant force, what type of motion will we have?**
S **Acceleration (chorus)**

The teacher's questions and probing is essential. Rather than giving the answer, the teacher directed the students to previous work and asked them to go through their notes to identify the language they had used to talk about that specific situation. Not only did the students realise that there was a net resultant force forward, but also that one usually discusses the situation in terms of the presence of a net resultant force.
Some of the student diary entries show their realisation of their own previous thoughts and ideas, and how they changed as a result of the activities done in the class.

'*We learned the different properties of forces working in pairs. The most important thing was that we concluded what the properties are ourselves and how we can understand'*
' was interesting because I learnt things which are easy but not so easy at first sight'
'I liked the lesson as it was very interesting. I did sometimes ask the same question to myself when I came across them, for example of magnets or that of having two forces'

It can be seen that although the activities involved mainly practical work, the students' focus is on their learning process – the construction of knowledge.

Discussion

If there is anything that comes out from this research it is that organizing practical work for effective learning takes much more thought than the preparation of equipment. Teachers need to think and plan about how to get their students to think and reflect on the activities and experiments that they are carrying out. What has been shown is that cognitive conflict is one approach that can promote such reflection. When presented with observations that conflict with predictions made, students are motivated into finding the reason to why such a discrepancy is present. The learning process has been activated.
It is important to consider a number of factors when evaluating the effectiveness of practical work. Miller et al. (1999), in drawing up a model for measuring effectiveness of practical work, include the teacher's objectives, the design features, what the students do and what the students actually learn as the four key factors. These are in turn influenced by the teacher's view of science, learning and the institutional context in which the practical is to take place, as well as the students' view of science, learning and institutional context. Within this framework, in order for constructivist activities to be effective, it is necessary for teachers to endorse fully constructivism and believe in its effectiveness in enhancing learning. If teachers are not convinced of the efficacy of the teaching methodology that they are using, then

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it would be difficult to promote the construction on knowledge. Likewise, students need to learn to appreciate that practical work goes beyond the mere following of instructions but that they need to reflect on both the experiments they are performing as well as their learning processes in grappling with the various scientific concepts they are learning.

Practical work should be the basis for active learning and the context for providing learning environments promoting it. Practical work should also be a vehicle to help students become independent learners. As Bentley and Watts (1989) state, active learners need to initiate their own activities and take responsibility for their own learning. This implies that they have to make decisions and solve problems, know how to transfer skills and learning from one context to other different contexts. Students therefore need to learn how to organize themselves and how to evaluate their own and their peers' work. Experiments form a very good context within which such skills can be developed. Finally they also help to make students feel good about themselves as learners, particularly in science. Practical activity thus goes beyond the scope of covering specific topics. It leads to a greater emphasis on learning how to learn than how to learn specific topics and areas in science or in any other subject.

Active learning can only be achieved within a particular framework. From an affective point of view, it is essential for active learning to take place within a non-threatening learning environment, as students need to work within a supportive environment if they are to discuss and test out their ideas (Bentley & Watts, 1989). Students need also to become involved in the organization of the learning process. Obviously, students need to have opportunities to take decisions about the content of their learning. This does not come alone, they need to learn the skills of learning, of evaluating and assessing their own work and of giving relevance to the work they are doing.

Conclusion

Practical work should be considered more as a vehicle through which students' learning can be enhanced than simply as a means of introducing students to the process of doing science. While one cannot diminish the importance of laboratory work to that of simply introducing students to the skills of observation, hypothesizing, data collection and evaluation etc. on which scientific methodology is based. The understanding of concepts should still keep centre stage in such activities. If one can manage to capture the development of skills concurrently with effective learning then practical work can be considered to be the central driving component in learning science.

References

[1] Adey PS, It all Depends on Context, Doesn't it?, Searching for General Educable Dragons, Studies in Science Education, 29: 45-92, 1991.

[2] Bentley D and Watts M, Learning and Teaching in School Science, Open University Press, Milton Keynes, 1989.

ISBN 978-989-95336-2-2 ©Hands on Science Network 2008

[3] Driver R, The Name of the Game, School Sci. Review, 56: 800-805, 1975.
[4] Fensham P, Gunstone R and White R, The Content of Science: A constructivist Approach to its Teaching and Learning, The Falmer Press: London, 1994.
[5] Gatt S, Constructivism – An effective Theory of Learning, in Gatt S and Vella Y (Eds.), Constructivist teaching in Primary School Social Studies, Mathematics, Science, ICT, Design and Technology, Agenda Publishers, Malta, 2003.
[6] Gauld C, A Study of Pupils' Responses to Empirical Evidence, in Millar (Ed.), Doing Science: Images of Science in Science Education, The Falmer Press: London, 1989.
[7] Gilbert J, Explaining with Models, in Ratcliffe M (Ed.), ASE Guide to Secondary Science Education, Stanley Thornes: Cheltenham, 1998.
[8] Hammer P, Allmark B, Chapman J and Jackson J, Mapping Concepts in Science, in Ratcliffe M (Ed.), ASE Guide to Secondary Science Education, Stanley Thornes: Cheltenham, 1998.
[9] Jenkins EW, Practical work in School Science –some questions to be answered, in Leach J and Paulsen AC, Practical Work in Science Education – Recent Research Studies, Kluwer Academic Publishers, Roskilde University Press, 1999.
[10] Johnson JK and Howe A, The use of Cognitive Conflict to Promote Conservation Acquisition, Journal of Research in Science Education, 15: 239-247, 1978.
[11] Miller RH, Le Marechal JF and Tiberghein A, Mapping the domain – varieties of practical work, in Leach J and & Paulsen AC, Practical Work in Science Education – Recent Research Studies, Kluwer Academic Publishers, Roskilde University Press, 1999.
[12] Park J and Pak S, Students' Responses to Experiential Evidence based on Preconceptions of Causality and Availability of Evidence, Journal of Research in Science teaching, 34: 57-67, 1997.
[13] Posner G, Strike K, Hewson P and Gertog W, Accommodation of a Scientific Conception: Towards a Theory of Conceptual Change, Science Education, 66: 211-227, 1982.
[14] Shayer M and Adey P, Really Raising Standards, Routledge: London, 1994.
[15] Solomon J, Four Frames of Mind, in Black P and Lucas AM (Eds.), Children's Informal Ideas in Science, Routledge: London, 1993.
[16] Staver J, Constructivism : Sound Theory from Explicating the Practice Science and Science Teaching, 35: 501-520, 1998.
[17] Stavy R and Berkovitz B, Cognitive Conflict as a basis for Teaching Quantitative Aspects of the concept of Temperature, Science Education, 10: 99-110, 1980.
[18] Stofflet R and Stoddart T, The Ability to Understand and use Conceptual Change Pedagogies as a Function of Prior Content Learning Experience, Journal of Research in Science Teaching, 31: 31-51, 1994.
[19] Strike K and Posner G, A Conceptual Change View of Learning and Understanding, in West LHT and Pines AL (Eds.), Cognitive Structure and Conceptual Change, Academic Press, London, 1985.

ISBN 978-989-95336-2-2 ©Hands on Science Network 2008

[20] Watts DM and Bentley D, Constructivism in the Classroom, Enabling Conceptual Change by Words and Deeds, British Educational Research Journal, 13: 121-135, 1987.
[21] Watts DM and Jofili J, Towards Critical Constructivist Teaching, International Journal of Science Education, 20: 173-185, 1998.
[22] Watts DM, Constructivism, Re-Constructivism and Task- oriented Problem-Solving, in Fensham P, Gunstone R and White R (Eds.), The Content of Science: A Constructivist Approach to Teaching and Learning, The Falmer Press: London, 1994.
[23] Welford G, Introduction, in Welford G, Osborne J and Scott P(Eds.), Research in Science Education in Europe, The Falmer Press: London, 1996.

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Investigating the Rebounce of Squash Balls: a Computer Simulation - Based Intervention to Foster the Development of Procedural Skills in Grade 5

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Introduction

The discrepancy between what we teach and what scientists and citizens need is greater than most educational systems are willing to admit. Science for citizenship and science in the technical workplace, both involve greater emphasis on procedural understanding than on understanding of concepts. Our efforts to develop either are commonly undermined by student tendency to bypass the learning process through, for instance, rote memorization. Despite extensive research in science education over recent decades, we have yet to witness serious breakthroughs in teaching and learning processes on a wide scale. Furthermore, most research has tended to address issues related to the development of student conceptual understanding in science, with relatively little work done on student mastery and application of procedural skills.

In science teaching and learning, designing experiments is an important procedural skill. In many science programs, children are expected to undertake investigations, formulate questions, design and perform experiments. Designing experiments involves two reasoning skills: identification and control of variables.

Assuming that the control of variables skill is an essential scientific skill and evaluating the results of previous research, which proved that very few children spontaneously apply the control of variables strategy when they design an experiment, it is important to investigate whether there are fruitful teaching methods to help children acquire this fundamental scientific skill (Chen & Klahr, 1999).

This paper relates to an ongoing project to investigate student ability to identify and control variables in multiple contexts, and examines the level of transfer of these skills to the design of controlled experiments.

Background

Children often come up with questions in science lessons that can lead to investigative work. In many science classrooms, activities on designing a fair test or

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organizing a valid experiment in order to answer a given investigable question are commonplace. In order to investigate, for instance, whether the mass of a ball affects the time it needs to roll down a ramp, when released from the top of the ramp, a child must

- recognise that the investigable question is "Does the mass of a ball affect the time it needs to roll down a ramp?",
- identify the two variables involved in the investigable question, the mass of the ball and the time of flight,
- control variables, which means that, in every measurement, the variable that has to be changed is the mass of the ball (independent variable), the variable that has to be measured is the time of flight (dependent variable), and all other variables (e.g. the volume of each ball, the surface of the ramp) that might possibly affect the time of flight need to kept constant.

When the above procedure is followed in a systematic way, we assume that the child has designed a fair test or a controlled experiment, and the conclusion that derives from this experiment is also thought to be valid.

The ability to design controlled experiments and make valid inferences from their outcomes is basic procedural skills that have attracted a lot of attention both in science education and in cognitive psychology. The acquisition of the control of variables strategy is an important step in the development of scientific reasoning skills. In order to fully appreciate the importance of the control of variables strategy, one must take into consideration that, although this strategy is closely linked with the design of experiments in science contexts, it is also applied in different domains of science and everyday life and it underpins more complex abilities such as multiple causality, correlational dependencies, historical causality, and decision making on issues of public and private policy.

The Learning in Physics Group at the University of Cyprus has a co-ordinated program combining research with the development and validation of inquiry based curriculum. In one aspect of this program, we designed a series of lessons that aimed to guide fifth grade children to construct the concept of variable, to formulate investigable questions and relate experimental design to these questions, to design and critically evaluate experiments as to their validity, as well as to transfer the control of variables strategy to previously unfamiliar contexts. The context in which we based our curriculum was kinematics. Specifically, we engaged the children in an investigation of the variables that might affect the time of flight of a ball rolling down a ramp. Specially developed pre-tests and post-tests were administered before, during, and after the instruction. The tests provided valuable data for further refining the children's level of acquisition and transfer of the control of variables skill and evaluating the effectiveness of the curriculum.

Two tests that were used to evaluate children's ability to design controlled experiments after instruction are shown as Post-tests 1 and 2.

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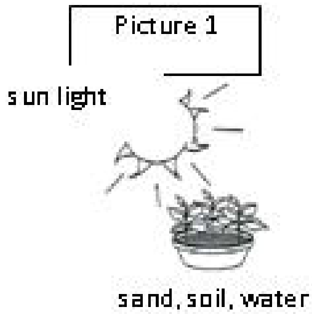
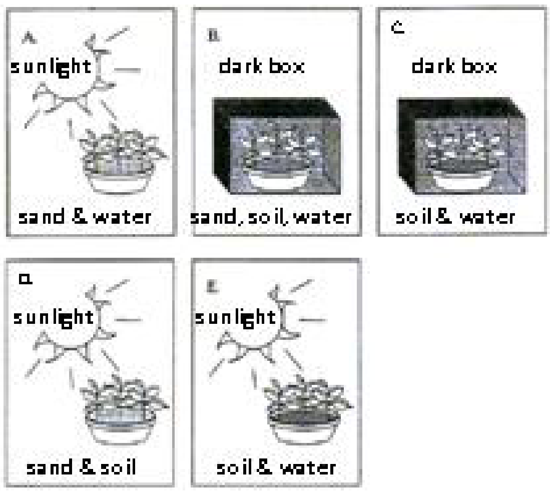
Post-test 1

Tim believes that plants need sand in their pot to grow. He tested his belief performing the following experiment: he took a pot with a grown plant in it, added sand, soil and water, and placed it under direct sunlight (Picture 1).



Which of the following experiments will he also perform in order to decide whether plants need sand for growth? (circle the correct answer)



Answer the following questions:

- What is Tim's investigable question?
- According to Tim's investigable question, What variable has to be changed?
- What variables have to be kept constant?
- What variable has to be measured?

Modified from TIMMS REPEAT

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Post-test 2

George wanted to examine if the colour of the wrapper of specific type of ice cream affects the time the ice cream needs to melt. In order to answer this question, he performed the following test:

He bought several ice creams with different colour wrappers, measured each ice cream's mass as it is shown in the table below and put all ice creams in the freezer. Afterwards, he took out of the freezer all ice creams at the same time, placed them all on his car's front dash board and measured the time each ice cream needed to melt.

	Ice cream flavour	Colour of ice cream wrapper	Ice cream's mass	Melting time
1	Lemon	White	80 gr.	8 minutes
2	Lemon	Brown	80 gr.	8 minutes
3	Chocolate	Green	100 gr.	6 minutes
4	Chocolate	Yellow	120 gr.	9 minutes
5	Vanilla	Blue	120 gr.	11 minutes
6	Strawberry	Black	120 gr.	12 minutes

According to George's test and his measurements, can you say whether the colour of the ice cream's wrapper affects the melting time?

Explain your reasoning, mentioning which of the above measurements you used to reach your conclusion.

Adapted from
©*Physics by Inquiry* by L.C. McDermott and the Physics Education Group
University of Washington, Seattle

Both Post-test 1 and Post-test 2 examine children's mastery and transfer of the control of variables strategy in contexts other than kinematics and provide useful evidence of children understands of the fairness of the experiment. The format of the question in Post-test 1 was familiar to the children, as it was based on a procedure they had worked on during the lessons, albeit in another context. Post-test 2 was a completely new type of task that they had not encountered before. It is reasonable to consider that Post-test 1 required near-transfer and Post-test 2 required far-transfer on the part of the children. Post-test 1 required the application of the control of variables strategy in order to select one out of five choices in experimental design. The questions at the end of the test provided additional help: children could go back to their selection and check whether it was consistent with their subsequent answers to these latter questions. Post-test 2 was more difficult for the children, because it also did not guide them through the reasoning underpinning

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the design of controlled experiments, and, as a result, it required the following mental steps:

a) isolation of the investigable question,
b) identification of the variables involved in the question,
c) identification of the variable that has to be changed, those that have to kept constant, and the one that has to be measured,
d) isolation of the measurements from the table that differ only in the values of the variable that has to be changed and perhaps the one that has to be measured, while all other variables are kept constant,
e) comparison between the values of the variable that is measured,
f) formulation of a conclusion, as to whether the examined variable affects or not the measured variable.

The analysis of children's responses to these tests, as shown in Table 1, provided variable results about their mastery and application of the control of variables strategy.

	Correct response with correct reasoning	Correct response with inadequate reasoning	Incorrect response
Post-test 1	73 %	24 %	3 %
Post-test 2	0%	13 %	87 %

Table 1. Children's rates of success in Post-test 1 and Post-test 2

A typical answer given in Post-test 2 ("The experiment is not fair, because all ice-creams ought to have the same mass") enabled us to identify the following difficulty; when faced with a series of measurements, children refused to select the ones that could validly be used to answer a question with the rationale that the experiment had not been designed correctly. In other words, the presence of additional, irrelevant measurements rendered an experiment invalid in the eyes of the children.
This paper evolved from our effort to respond to the following question: can an interactive database be used to guide students to overcome this difficulty?

Method

Participants

Thirty-three fifth graders participated in the present study. Their socioeconomic status was medium to high and, prior to our intervention, they were all able to use a computer confidently.
The curriculum that guided our intervention and the children's work is part of an ongoing project known as Science by Inquiry, a program that seeks to promote reasoning skills, epistemological awareness, and the development of procedural and conceptual understanding in an integrated manner.

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The Teaching Intervention

The teaching intervention took place at one of the computer laboratories of the University of Cyprus and the curriculum designed aimed at continuing the development of investigative skills. The main objectives of this part of the curriculum are detailed below. Children are expected to:

- develop the ability to identify and formulate investigable questions,
- identify the variables involved in a given situation and appreciate whether some of them are being controlled or not,
- design experiments that can lead to valid conclusions in relation to a given question,
- organize the collection and analysis of data in a systematic manner, purposefully targeted at answering a given question.

Children initially identified variables that might possibly affect the bouncing of squash balls. Children were then guided to design a valid experiment to test whether a particular variable actually influenced the bounce height. Hence, the children at this stage had to apply the control of variables strategy that had been developed in previous lessons, in order to design a fair test. The main shortcoming that appeared in many proposed experimental designs concerned the measurement of the dependent variable. Children failed to find a way that would enable them to measure the exact rebound height of the squash ball. After this difficulty was revealed, the curriculum went on to present an interactive computer-based simulation package that could be used to make fast (virtual) measurements.

The interactive simulation is titled The Science Investigation Workshop. It was designed and developed by Richard Gott, Shawn Roberts and Sandra Duggan at the University of Durham, and consists of “The Eggs of Albatros” and the “Squash Balls” databases. For the purpose of this study, we will concentrate on the “Squash Balls” database, as did our intervention. Figures 1 and 2 present the user interface of the simulation environment.

The simulation package enables users to investigate four variables that might possibly affect the rebound height of a squash ball. In each trial the rebound height is automatically measured (recalled from the database file), and is presented on the screen as if it had been measured by eye or other techniques, such as video recording.

The children had time to familiarize themselves with the simulation environment. Several questions for investigation had been discussed and children were asked to design and implement valid experiments using the simulation, record the “measurements” obtained and use them to formulate a conclusion as to whether the variable of interest really did appear to affect or not the rebound height of the ball.

Throughout the intervention children worked in groups of three and kept laboratory notebooks. Their work was mostly guided by the curriculum materials. The instructor was constrained to leading semi-socratic dialogues at specific points in the curriculum. These conversations relied on instructor led questions that were aimed at eliciting detailed group difficulties and guiding the children to address them. The conversations also provided feedback (through questioning and

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reflection) and gave guidance as to the next steps in the group's work. The actual conversations and the detailed procedure followed varied widely from group to group as the children came up with different issues they wanted to explore. However the curriculum provided the necessary guidance to keep them on target even if the path varied and tangents were seldom avoided.

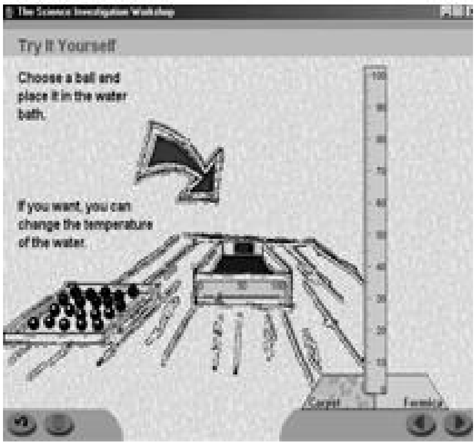

Figure 1. The interactive database simulation "The Squash Balls" provides users with an environment in which to explore the potential influence of many variables on the bouncing of squash balls

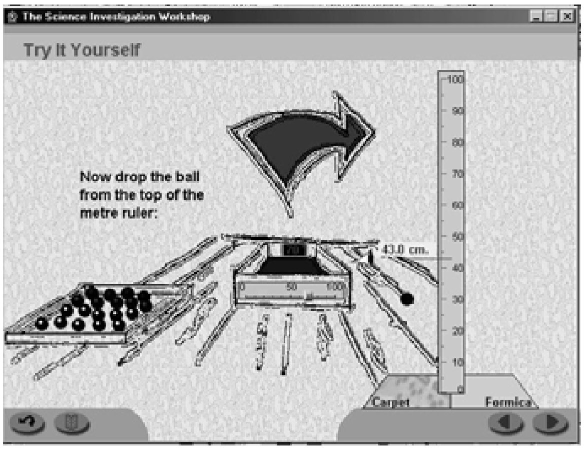

Figure 2. The rebound height of the ball, as measured by eye (the data is retrieved from the database of the simulation)

Evaluation

A week after the computer-based intervention, a post-test (Post-test 3) was administered that was designed to assess the participants' ability to apply the control of variables strategy in designing experiments. Post-test 3 was of the same format as Post-test 2 and was based on the context of balls and ramps. One month after completion of the intervention, Post-test 2 (now renamed Post-test 4) was again administered to the same participants for two purposes:

a) to make a measurement on the degree of retention of the control of variables strategy, and
b) to obtain comparable pretest (Post-test 2) and post-test (Post-test 4) results on the intervention that utilized the interactive database simulation package.

Results

Children's responses to both Post-test 3 and Post-test 4 were analyzed using pnenomenographic analysis.
The results demonstrate significant gains in children's ability to

- identify investigable questions,
- identify the variables involved,

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- decide which variable has to be changed, those that have to be kept constant, and the one that has to be measured (mental application of the control of variables strategy),
- isolate the measurements from a given table that differ only in the independent and possibly the dependent variable, while all others are controlled
- make comparisons between the values of the measured variable, and
- formulate a conclusion as to whether the independent variable influences or not the dependent variable.

The categories of reasoning that emerged from the phenomenographic analysis were then classified into three categories based on whether the overall response was deemed as correct or not and whether it was appropriately explained. The participant success rates in each of the four tests are presented in Table 2. We decided to present the results of Post-tests 3 and 4, as well as the results of the tests prior to simulation use, in order to make the comparison more obvious.

		Correct response with correct reasoning	Correct response with inadequate reasoning	Incorrect response
Prior to simulation use	Post-test 1	73 %	24 %	3 %
	Post-test 2*	0 %	13 %	87 %
After simulation use	Post-test 3	73 %	6 %	21 %
	Post-test 4*	79 %	0 %	21 %

* Post-tests 2 and 4 were identical.

Table 2. Participant success rates in Post-tests 1, 2, 3 and 4

Typical answers in each of the three categories of responses obtained from the analysis of Post-tests 3 and 4 are quoted below. Prior to each set of quotes we re-iterate the main task question.

Post-test 3

Does the distribution of mass influence the time a ball takes to roll down a ramp?

Correct response with correct reasoning:

"The question is: Does the distribution of mass affect the time of flight of a ball running down a ramp? In order to respond to this question, I have to select measurements 3 and 4, because only in those two measurements the distribution of mass changes, while all the other variables are kept constant. Observing the time of flight, I conclude that the distribution of mass affects the time of flight"

Correct response with inadequate reasoning:

"I will select measurements 3 and 4, because the balls in these measurements are made of the same material and they differ in mass distribution (hollowness)"

Wrong response:

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“I will select measurements 2 and 3 because in these measurements the hollow ball ran faster than the other one”

Post-test 4

Does the colour of the ice cream wrapper affect the melting time?

Correct response with correct reasoning:

“The colour of the ice cream cover does not affect the time it needs to melt. I selected measurements 1 and 2 and I said: since the ice cream flavour and the mass are the same in both measurements, and they differ only on the colour of cover, if the cover’s colour affected the melting time, the time would be different in these measurements. As I observed in the table, the time is constant in both measurements, so the cover’s colour does not affect the melting time”.

Wrong response:

“The colour of the ice cream cover does not affect the time needed to melt, since both ice creams are in the same place. If we placed one in a shadow place and the other under the sun, the time of melting would be different”.

Discussion

Our results demonstrate convincingly that it is possible for children aged 11-12 to acquire the control of variables strategy and to apply it in designing experiments and drawing conclusions from experiments in varied contexts. There are three aspects of our curriculum development effort that we believe have made this possible:

- The rigorous research base that underpins and guides all our curriculum development effort, enables us to make refinements in an iterative cycle of design, implement and evaluate. These refinements gradually yield the robust curriculum that can be implemented away from its site of development with comparable large gains in real understanding.
- The integration of thinking skills, epistemological awareness and conceptual understanding as well as the emphasis on inquiry-based collaborative learning make the curriculum challenging and, at the same time, keep children engaged for the extended periods of time necessary to develop some of the fundamental thinking skills.
- The flexibility in adopting technological tools where they are available and useful in order to fulfil learning objectives and to guide students to overcome specific difficulties identified through research.

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References

[1] Chen Z and Klahr D, All Other Things Being Equal: Acquisition and Transfer of the Control of Variables Strategy, Child Development, 70: 1098-1120, 1990.
[2] Edward SN, Computer based simulation of laboratory experiments, British Journal of Educational Technology, 28: 51-63, 1997.
[3] Fisher WB, Computer modelling for thinking about controlling variables, School Science Review, 79: 87-90, 1997.
[4] Linn MC et al, Teaching Children to Control Variables: Investigation of a Free-Choice Environment, Journal of Research in Science Teaching, 14: 249-255, 1977.
[5] Mazur E, Doing Physics with Computers, Academic Computing, 18: 34-40, 1998.
[6] Murphy P, Insights into pupils’ responses to practical investigations from the APU, Physics Education, 23: 330-336, 1998.
[7] Park J and Kim I, Analysis of Student’s Responses to Contradictory Results Obtained by Simple Observation or Controlling Variables, Research in Science Education, 28: 365-376, 1998.
[8] Ross JA, Controlling Variables: A Meta-Analysis of Training Studies, Review of Educational Research, 58: 405- 437, 1988.
[9] Sneider C et al, Learning to Control Variables with Model Rockets: A Neo-Piagetian Study of Learning in Field Settings, Science Education, 68: 463-484, 1984.
[10] Sodian B et al, Young Children’s Differentiation of Hypothetical Beliefs from Evidence, Child Development, 62: 753-766, 1991.
[11] Swatton P, Can We Know Whether Pupils are Passing the “Fair Test”? Research Papers in Education, 10: 51-73, 1995.
[12] Weller H, Diagnosing and altering three Aristotelian alternative conceptions in Dynamics: Microcomputer Simulation of Scientific Models, Journal of Research in Science Teaching, 32: 271-290, 1995.
[13] Wollman W and Lawson AE, Teaching the Procedure of Controlled Experimentation: A Pagetian Approach, Science Education, 61: 57-70, 1977.

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Romanian Strategy on Virtual Instrumentation Training in High Schools

Savu T and Sporea D

Introduction to Graphical Programming

Programming in a graphical environment may be described as defining an algorithm by drawing its related diagram and not by writing text based instructions and commands. In this way the programming act does not require any more command names and complicated syntactic rules to be memorized, so the risk for programming errors is drastically reduced [1], [2].

Two main windows are available for the user: a front panel in which objects are inserted for defining the future user interface and a diagram in which the data flow is described.

The objects to be inserted in the front panel are picked-up by the user from a controls palette (Figure 1) in which several groups for different data types (i.e. numerical, Boolean, strings and tables, lists, arrays, clusters) and various other programming aids (i.e. paths, graphs, dialog boxes) are available. As an example the group for numeric objects is represented in Figure 2. The user simply drag-and-drops an object from the palette to the front panel in order to design the function blocks of his interface.

When an object is inserted into the front panel, a corresponding "terminal" automatically appears in the application's diagram.

In the diagram the user may insert different function symbols for describing the applications' algorithm.

The symbols are picked-up from a function palette (Figure 3) in which different groups are available, each one for a certain scalar data type (numeric, Boolean, string) or for a certain data structure (arrays, clusters etc.). Functions groups are also available for file operations, data acquisition, advanced mathematical functions, application control etc.

For defining the algorithm, the user may also insert different programming structures: *For* and *While* loops, case and sequence structures, event programming structures.

The control functions available to the user on the front panel can be tailored according to custom needs through their defined properties. Input and output data can be displayed in numerical and graphical form, with scalable frames. A complete colour palette helps the functionality design of the user's interface. An example of

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such a front panel is given in Figure 4, where data acquired form a remote instrument is represented in a graphical form. The operator has also the possibility to input some parameters or to select/ define files management path for saving and recalling data. For the case of remote control of instrumentation the user's interface can designed to mimic the real interface front panel.

Figure 1. Controls palette (partial)

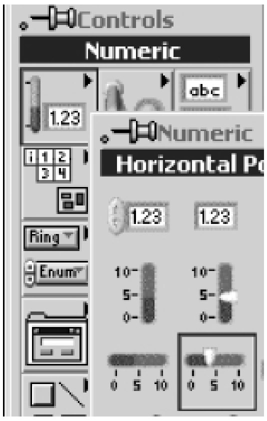

Figure 2. Numeric objects group (partial) opened in the controls palette

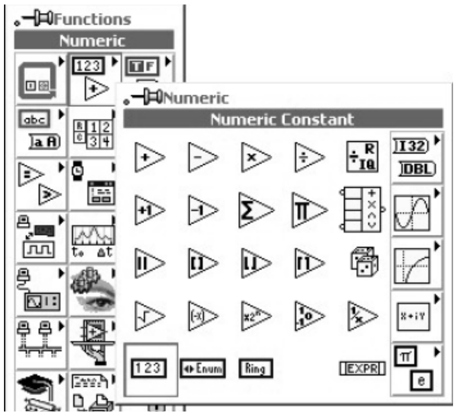

Figure 3. Numeric functions group opened in the functions palette

Each function symbol has one or more input and output terminals. By connecting the terminals representing the objects in the user interface and the functions terminals, the programmer is defining the application's data flow (algorithm). The resulting diagram is more intuitive and it can more easily be understood by other programmers. Sets of functions can be grouped into subroutines called virtual instruments (VI). Virtual instruments can be further organized according to a user defined hierarchy. By working with a virtual instrument layout the developer can build his own "functions" libraries, based on already tested programmes.
LabVIEW programming enables data acquisition from various PC-based or external acquisition boards, image acquisition and processing, instrumentation control through different connecting links (serial, parallel), motion control, distributed processing, etc.
Additionally, the programmer can control different signal conditioning blocks.
The concept of the application diagram is illustrated in Figure 5, where programme sequences and conditioning branches are marked as the frames which include other programming functions having a graphical representation. All symbols associated to functions are very intuitive and easy to remember and understand.
In order easy the programming task, the environment includes some debugging tools such as: break pint, step-by-step execution, skip over, highlighted execution, pause, etc. The programmer can change parameters during the testing process or can monitor data flow.
Being the most advanced and the most widely spread graphical programming environment, LabVIEW, the industry-standard programming environment developed

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by National Instruments, may be described as a new step in computer programming, allowing a non-professional user, with a minimum operating experience, to realize a complex, user-friendly, professional looking interface, while taking full advantage of the big number of specialized functions and procedures.

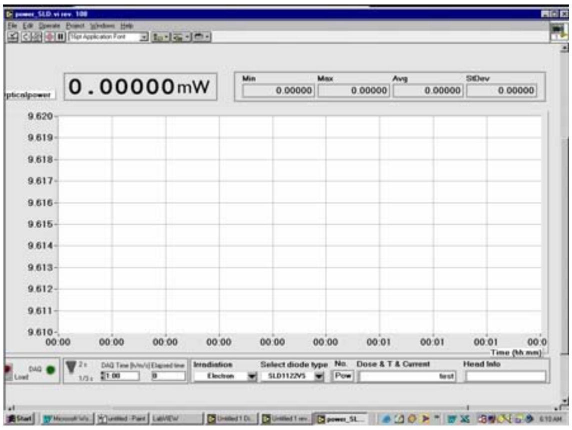

Figure 4. The graphical user's interface built with LabVIEW for the remote control of an instrument

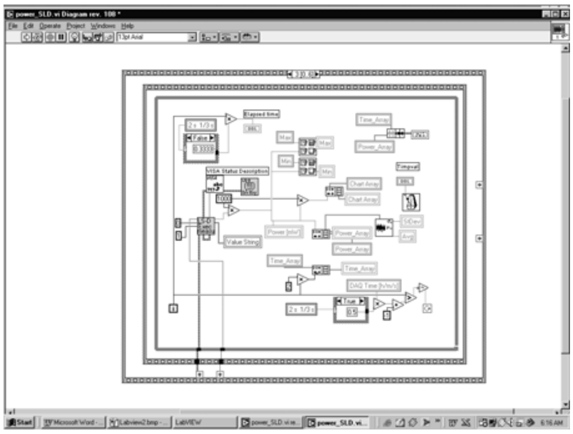

Figure 5. The diagram for the application on the ree control

Training in Graphical Programming

In Romania, considering that graphical programming competencies are, for pupils in technological education, as useful as office software packages, graphical programming topics were introduced in the 10th year syllabus and a dedicated manual was printed (Figure 6).

The Romanian Ministry of Education acquired, in 2002, with a great support from National Instruments Corp. U.S.A., LabVIEW full development licenses for several hundreds high-schools, distributing the first licenses especially in the units were the environment was already known, evaluation versions were previously used or teachers had some LabVIEW training or prerequisites.

After a short period during which teachers' LabVIEW training was organized in independent training centres, two of the main Romanian universities (POLITEHNICA University of Bucharest and the Bucharest University) are now joining into a consortium for organizing the teachers training at new and higher quality standards. LabVIEW training is intended to become compulsory for computer science teachers and to be considered as part of the continuing education programmes for the others.

Training will be recognized only in centres which will be accredited by the university consortium, an accreditation condition being that for the tutors to be trained in one of these universities.

Using LabVIEW as a programming tool is encouraged not only in computer science classes, but also for developing useful applications for physics, chemistry, mechanics and other classes. Applications developed by high-school teachers and

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pupils are advertised through LabVIEW User Club (Figure 7), a set of Web pages listed also in the LabVIEW Web Ring.

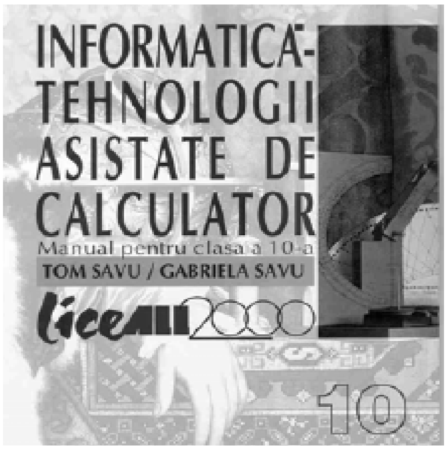

Figure 6. High-school manual for graphical programming, introduced in 2000

Figure 7. LabVIEW Users' Club main Web page

After several years during which an annual seminar was organized, allowing the high-school teachers and pupils to present their developments, this year a National Conference of Virtual Instrumentation will host together presentations from industry, research, academia and high-schools.

A national project is now under preparation [3], for implementing computerized measurements into high-school laboratories. Several high-schools had already received free data acquisition boards from National Instruments Corp. U.S.A., teachers and pupils being encouraged to develop their own set-ups and software applications (Figure 8).

In the frame of the Comenius "Hands-on Science" project, the institutions of the two authors are co-operating to further support the spread of LabVIEW programming in high schools. Within this frame they signed a protocol for strategic collaboration to support among other objectives: the assistance to high school teachers in using LabvIEW, the coordination of funding efforts for the acquisition of needed equipment; the preparation of a special section for high school teachers at the Annual National Conference on Virtual Instrumentation. This year Conference already exposed the notable results obtained by the Romanian programming community form high schools. The section dedicated to teachers included more than 15 papers dedicated to the use of LabVIEW in both simulation and data acquisition. Romanian authors were encouraged to participate with their contribution to the International Conference in Slovenia.

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Figure 8. Data acquisition application developed in a high-school physics laboratory (courtesy of "Grigore Moisil" Theoretical High-School, Bucharest, Romania)

The Comenius project team will consider also the possible integration of its activities with other training institutions in Romania (i.e. the CREDIS Center [4]) in order to exploit in the best conditions the available resources.
Some funds from the project budget will be dedicated to the acquisition of hardware required for the preparation of some experiments in high schools laboratories (physics, chemistry, etc.). The purchasing will be directed towards sensing components and systems and some training kits which can be converted into laboratory autonomous experiments.
Additionally, demo set-ups with complex instruments from the National Institute for Lasers, Plasma and Radiation Physics will be available to high school teachers during dedicated visits at the Institute.
The project will promote also:

- a closer cooperation with network members interested into the subject;
- the financial support to teachers interested into this type of training to participate to international events.

Acknowledgements

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References

[1] National Instruments Corp, LabVIEW User Manual, Austin, USA, 2003.
[2] Savu T and Savu G, Informatics – Computer Aided Technologies (Original title: Informatica – Tehnologii Asistate de Calculator), ALL Publishing House: Bucharest, 2000.

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[3] Savu T, LabVIEW Virtual Laboratories (Original title: Laboratoare Virtuale LabVIEW), Proceedings of the National e- Learning Conference, University of Bucharest, Romania, Bucharest, Jul 3-5, 2003.
[4] Munteanu M, Logofatu B and Lincke R, Instrumentatie virtuala, LabVIEW, Editura CREDIS, Universitatea din Bucuresti, 466, 2001.

Paper presented at the 1st International Conference on “Hands on Science.
Teaching and Learning Science in the XXI Century",
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Constructivism 25 Years on: Its Contribution, Missed Opportunities?

Gatt S

Introduction

Students' performance and level of understanding has been a cause for concern for as long as there has been research in science education. Science teaching has experienced a shift from the traditional 'transmission' approach [14] to focus on process skills and discovery learning (see Nuffield Science) to constructivism. The shift has been in two directions: from teacher-centred to child-centred; and from a passive view of learning to one which considers the learner as actively involved with the learning content.

In the transmission view, the learning process is considered as the simple transfer of knowledge from the teacher (the knowledgeable) to the pupil (the less knowledgeable). The teacher is the active participant whereas the student is the passive receiver of knowledge, hence the teacher-centred approach. Science educators soon recognised the insufficient adequacy of the transmission view [14]. It was recognized that effective learning could not take place without the active participation of learners. One thus finds the famous statement 'children learn by doing' approach as advocated in the Nuffield approach [2]. This was a shift from one extreme to another whereby students within the 'discovery approach' were left to their own devices to understand not only the scientific concepts but also what they were supposed to learn. Hence, one finds the criticism put forward by Rosalind Driver [3] who compared this approach to a simple guessing game where students were more concerned with finding out what they were supposed to learn rather than focusing on understanding the concepts involved in the situation presented to them. Constructivism succeeded the Nuffield Science, following research findings that students already hold ideas (and often wrong ideas) about scientific concepts. This implied that students naturally like to make sense of things and consequently learning involves recognizing these ideas and building on them.

Contribution of Constructivism

Constructivism has provided a number of significant contributions to the teaching of science, these being listed to mainly include: developing teaching approaches based on theories of learning; recognising students' ideas; changing the role of

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scientific knowledge from objective and infallible to being socially constructed; recognising the role of language as a part of the learning process; changing the role of practical work.

Despite the evident little improvement in the learning and understanding of science, constructivism has none the less, provided a contribution to the understanding of the learning process. Not only has it consolidated the shift from teacher-centred to child-centred approach, but it has also provided insight into how learners construct knowledge. Although the main criticism put forward to constructivism is that it does not tend to be much of a theory, on the other hand it has great potential in its possibility for application in the classroom. Many teaching schemes and approaches in fact have been developed under the umbrella of constructivism. This is also reflected in the number of theories developed by key people such as Piaget, Ausubel and Vygotsky. A common theoretical basis for each teaching approach developed is that they all view the learner as a cognitive process where the learner is actively engaged, on a personal level internally and/or within a social context with the learning material in the process of constructing knowledge. So one finds applications such as the use of cognitive conflict [1], scaffolding [12] as well as metacognition [10, 19].

Cognitive conflict can be considered as a means of provoking the construction of knowledge. When there is difference between an experimental outcome, learning material or other students' ideas with those that the learner holds, the learner experiences a state of dissonance. Consequently accommodation (using Piaget's language) takes place during learning. We thus find examples [8] where students were asked to predict actual experiments' outcomes. These activities are usually designed in such a way that they bring out students' alternative frameworks which differ from correct scientific concepts creating cognitive conflict. One also finds examples of group-work which is used to get students to spell out their ideas about specific scientific concepts with the aim of generating different models and ideas. This also creates cognitive conflict. In any case, these are situations where students are given ownership of their own learning as they would want to know whether their ideas are correct and if not for what reason. The successful use of cognitive conflict depends on the types of conflict created. It cannot be too difficult as otherwise it would be beyond the students' capabilities. On the other hand, it shouldn't be too easy as it would not be challenging enough to motivate the students. It should be targeted within Vygotsky's zone of proximal development [17].

Work by Vygotsky [17] based on his theory of zone of proximal development and the use of scaffolding is another example of how teaching schemes have been developed within a constructivist approach. In scaffolding the teacher provides support so that students are able to do activities that they would not otherwise be able to tackle. As students gain experience, the teacher removes the amount of help and support provided gradually until they can perform the task on their own. The role of the teacher is to create learning situations and support structures so that mediation of learning takes place. Such an approach can be considered to be within the constructivist approach as the responsibility for learning shifts from the teacher to the student.

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Metacognition can be described as the ability to 'think about one's own thinking'. Such cognitive process is at a higher level of thinking than cognitive conflict and scaffolding. Whereas the latter two deal directly with the learning context, metacognition goes further as it requires the learner to reflect on his/her process of thinking in dealing with the learning content. Approaches devised include examples where students are asked to describe their learning path at the end of a teaching session [8], or at the end of a teaching scheme. Metacognition is difficult to achieve but it provides the learner with control over his/her developed learning processes.
Another major contribution of constructivism is that it acknowledges the existence of students' ideas and gives value to them. If one goes through literature published during the 80's one finds many studies on children's alternative [6, 7] in practically any area of science. Whole publications, for example Driver et al [6, 7] and Pfundt and Duit [15] are classic examples of such collections. These studies have brought insight of the ideas that students hold, before and often also after formal science teaching, to science education. Consequently, they have shifted the focus from the teacher and content to the students and given value to their existing "knowledge". This was a major shift since up to that point science educators tended to focus mainly on content and its logical structure from an epistemological point of view rather that from the students' learning point of view. It also served to acknowledge students' attempt to understand natural scientific phenomena that they encounter in their everyday life. The commonly used label of alternative frameworks [5] fully endorses the value given to students' ideas.
Going to a completely different type of contribution, constructivism has changed the way that science educators view scientific knowledge. Within a constructivist perspective, science educators hold the view that learners, and likewise scientists, construct models and theories about natural and scientific phenomena. Thus scientists are also involved in the social construction of knowledge. Scientific knowledge has thus lost its positivistic image of being totally objective and infallible. Scientific knowledge is now recognised as being constructed by the community of scientists. This change of view has brought closer the accepted scientific views to the students' alternative frameworks. However, the latter still have much lower status compared to that of the scientific knowledge within the community of scientists.
Another contribution of constructivism is the recognition of the importance that language has as a tool to promote the construction of knowledge. Language is not only the means through which scientific ideas are communicated, it is also the medium through which ideas are constructed [18]. Language can be used for more than transmitting knowledge to learners. It is also the vehicle through which learners become aware of their own thoughts, thus facilitating understanding. This brought about a change in the types of activities organised within science classrooms. Constructivist teaching promotes student participation in discussions, group-work, in interacting with texts etc. This is a move from the passive student or the physically active learner, to the cognitively active learner.
In the same way as the role of language has changed in science education, so has that of practical work. Traditional practical work tends to consist in the illustration of relationships and concepts described in class. Experimental reports usually

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followed (and often still do) the same traditional format of aim, method, results etc. Constructivism has placed practical work at the heart of the learning process. Worksheets developed within a constructivist perspective are designed in such a way as to provoke student thinking and reflection on what happened in the experiment and more importantly to explain why. The why requires students to try and make sense of their observations using their existing frameworks. When these fail to provide plausible explanations, then, hopefully construction of good scientific understanding, takes place. Such an approach falls within, but is not exclusive, of the conceptual change [11] teaching strategy.

Criticisms to constructivism

If one had to make up a list of the most overused and abused words within educational settings, constructivism would feature high on the list. In the literature one finds all sorts of constructivism such as: cognitive constructivism, sociocultural constructivism, piagetian constructivism, sociological constructivism, pragmatic constructivism, radical constructivism to structural constructivism within sociology of education. Too many labels for one construct leads to confusion. One theory cannot have so many aspects. This leads to a situation where different educators mean different things of else that the theory is too wide. A too open a theory tends to become vague and is prone to be interpreted in many different ways. In any case such situation weakens the position of constructivism from being recognised as a serious and well developed theory of learning.

The main criticism that I bring to constructivism comes from another point of view. This is that it does not deal with the learning process holistically but limits itself just to the cognitive aspect of learning. As stated in the beginning of this paper, constructivism refers to learning as the active construction of knowledge, whether this is considered to take place internally at a personal level or in a group within a social context. It, however, fails to include a sociological perspective to learning. If one were to review the many constructivist methodologies developed, the main focus tends to be students' alternative ideas within a psychological perspective. The focus is just on making students construct scientific knowledge where the only difference between the learners tends to be mainly the different alternative frameworks. There is no recognition of other types of conceptions that students hold and bring with them to the learning situation. Let us just consider one extreme situation. What if a student in a classroom comes from a poor background, does not even have basic living conditions at home, has always been told that he is slow, incapable of learning, would get up to no good in life. How can a student with such background possess the desired readiness that leads to learning? Unfortunately, science educators have failed to include this perspective within their schemes. This nearly total disregard of the sociological perspective may be the root as to why constructivism has fallen short of providing the so much desired improvement in student learning. Sociological readiness to learning is the basis on which psychological readiness stands. It is only when both are in place that valid and effective construction of knowledge takes place. This is thus an aspect that

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educators need to keep in mind when developing new methodologies within a constructivist framework.

A word in defence of constructivism

However, the inability to improve significantly student understanding may not only necessarily be the inadequacy and limitation of constructivism, but rather that constructivism has not been given the chance to be fully implemented within the educational system. What does this mean? The constructivist approach, whether involving cognitive conflict, scaffolding or any other approach, has one thing in common. It is time consuming. It thus requires much more time to help students learn content material in a constructivist methodology than the typical transmission approach. This has created great practical limitations to the implementation of constructivism since syllabi have not really changed much in amount of content over the past years. Constructivism is not really as yet, the main approach adopted when teaching in science. One can say that developments in science education research have not really found their way to actual classroom practice. Hence, maybe, it would be unfair to blame constructivism for failing to bring about the much desired improvement in students understanding.

It is not sufficient to expect significant and long-term effect from short 3-6 weeks of constructivist teaching. It is thus a problem that constructivism has never really been fully implemented than its failure as a valid theory of learning. A similar argument can be put forward with respect to assessment procedures. Assessment procedures have more or less remained unchanged within education systems worldwide. Many still prefer a summative approach. If students have an examination at the end of the school year, this tends to promote the accumulation of knowledge. In many cases students are faced with a thick pile of notes which they need to know well. This is a type of assessment that promotes the accumulation of knowledge. It is thus often the case that many students cram their learning, resorting particularly to rote learning. Students thus, may not find constructivist teaching that fruitful within a summative structure of assessment. Rote learning tends to give good results in the short term, as often examinations tend to ask student to regurgitate content covered in class. On the other hand, constructivism has a more long-term effect which could not be in line with the students' goals at the time. Assessment thus sends a strong message to students that learning demands the accumulation of knowledge without the need to really 'understand' it, making constructivism and the learning of knowledge appear futile and a waste of time to learners.

What are the challenges that science education is currently facing?

If one looks at recent publications, there appears to be shift in the interest of science educators. Constructivism has moved away from centre stage. There is now more interest in social aspects of science and citizenship. These are not just the result of researchers' personal interests. They are the consequence of the impact that scientists' work such as that in the field of genetics related to cloning and the use of stem cells for research is having on the role that science is currently

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taking up in society. There is suddenly a great crisis where citizens are being bombarded with information about scientists' work and are expected to have opinions and to express them, and to give consent or to disapprove not only as politicians but also as citizens. One case in point is Italy, where normal citizens were asked to express their opinion about this issue in a referendum. Such circumstances mean that science education does no longer only have the responsibility of preparing young people with a basic level of scientific knowledge. It now needs to equip young people with the ability to realize what the social implications of certain scientific activities are, to consider them from an ethical point of view, and to know how to weigh the pros and cons of such activity in order to be able to participate as active citizens in the debate.

One may wonder in what way constructivism can contribute to this new challenge. Science educators are now faced with the additional problem of understanding how attitudes, values and ethical consideration are taught and in what way do students develop a critical attitude that will help them to weigh up social implications. Constructivism can be that framework within which researchers can work to start understanding this new process of learning attitudes and values, reflection and civic action. In addition, if one were to take a wider view of constructivism and include the sociological perspective, then society and social implications will be integrated within constructivist theory.

So how can this new dimension of constructivism be implemented within the classroom. If one is to include the sociological aspect within the constructivist theory of learning, then it must also be present when it is applied to classroom practice. Part of the science education that students are to experience need to include the discussion of science and its social implications. One, however, would need to go beyond simple role playing. Social players involved can be taken inside the classroom, asked to view their concerns and then students are helped with weighing the implications and deciding what opinion they would like to have and for what reasons. This would help students construct attitudes and values. In this case, rote learning would not provide better assessment. Attitudes and values cannot be accessed through a written examination. Constructivism would then be the better approach for them to adopt.

Conclusion

As always it is much easier to talk about possibilities than implementing them. It is my hope that what I put forward as a possible alternative today can be one possible direction for research in science teaching that would promote further growth of constructivism rather than its eventual extinction.

References

[1] Adey P, Shayer SM and Yates C, Thinking Science: The Curriculum Materials of the CASE Project, London: Thomas Nelson and Sons, 1989.

[2] Alexander D, Nuffield Secondary Science: an evaluation, London: Macmillan Education, 1974.

ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

[3] Driver R, The Name of the Game, School Science Review, 56: 800-805, 1981.
[4] Driver R, Leach J, Scott P and Millar R, Young People's Images of Science, Milton Keynes: Open University Press, 1996.
[5] Driver R and Easley J, Pupils and Paradigms: A Review of Literature related to Concept Development in Adolescent Science Students, Studies in Science Education, 5: 61-84, 1978.
[6] Driver R, Guense E and Tiberghein A, Children's Ideas in Science, Milten Keynes: Open University Press, 1985.
[7] Driver R, Squires A, Rushwork P and Wood-Robinson V, Making Sense of Seconday Science Research into Children's Ideas, London: Routeledge, London, 1994.
[8] Gatt S, Alternative Frameworks about Newton's Laws of Motion: Examination Performance, cognitive development and cognitive styles of Maltese Fourth Form Junior Lyceum Students, Unpublished Ph.D. Dissertation, University of Malta, 2002.
[9] Gatt S and Vella Y, Constructivist Teaching in Primary School Social Studies, Mathematics, Science, ICT, Design and Technology, Malta: Agenda, 2003.
[10] Gunstone R, The Importance of Specific Science Content in the Enhancement of Metacognition in Fensham P, Gunstone R and White R, (Eds.), The Content of Science: A Constructivist Approach to its Teaching and Learning, London: The Falmer Press, 1994.
[11] Hewson PW, A Conceptual Change Approach to Learning Science, European Journal of Science Education, 3: 383-396, 1981.
[12] Hobsbaum A, Peters S and Sylva K, Scaffolding in Reading Recovery, Oxford Review of Education, 22: 17-35, 1996.
[13] Matthews M, Science Teaching: The role of History and Philosophy of Science, New York: Routledge, 1994.
[14] OECD, Learning for Tomorrow's World-First results from PISA 2003, OECD Report, 2004.
[15] Pfundt H and Duit R, Bibliography, Students' Alternative Frameworks and Science Education, (4th EOO.), Institute for Science Education: Kiel, 1994.
[16] Sutton C, Words, Science and Learning, Milton Keynes: Open University Press, 1992.
[17] Vygotsky LS, Mind in Society: The Development of Higher Psychological Processes, Harvard University Press: Cambridge Massachusetts, 1978.
[18] Vygotsky LS, Thought and Language, MIT Press: Cambridge Massachusetts, 1986.
[19] Wittrock M, Generative Science Teaching, in Fensham P, Gunstone R and White R, (Eds.), The Content of Science: A Constructivist Approach to its Teaching and Learning, London: The Falmer Press, 1996.

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Preparing Teachers for Cognitive Coaching: the Case of Physics by Inquiry as an Experiential Basis for Science Learning

Constantinou CP

Introduction

It is generally accepted that science education is in serious difficulty on a global scale. In Cyprus, between the eighth and twelfth grades, the number of students who are able to keep up with curriculum objectives drops by more than 50%. When achievement is compared, Cypriot students perform significantly below the international average at all grade levels [26-28]. Internationally, performance measures repeatedly demonstrate disappointingly low achievement in tasks that require fundamental understanding, systematic reasoning or creative thinking.

There are surely many aspects of our educational systems that contribute to this problem. They include the lack of adequate support for our teachers, the complex expectations from a single profession that translate into unrealistic expectations from individual teachers and the excessive standards that are routinely specified by our societies. All these aspects contribute to a global culture of largely ignoring the essential aims of science education in favour of finding ways to bypass the learning process at all levels of the educational system. Another such aspect that is commonly ignored is the failure of the scientific community that is concerned with education to formulate established terminology and procedures that it can then use as a basis for making progress. The cultural tendency of this community to be more political than technical (falsely justified as being in the interest of political correctness and humanitarian ethos) has tended to make it prone to continual re-invention of past practices and new fads. It has also largely prevented it from gradually weaving scientific expertise with widely recognized and respected applicability. This article focuses on one facet of the current crisis: the failure of our universities to provide the type of preparation that pre-college teachers need to teach science effectively. The discussion is in terms of physics, but the situation in other sciences is similar.

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The problem

The problem of inadequate teacher preparation extends throughout the spectrum from kindergarten to high school [11]. Lacking the proper background, adequate preparation and the support necessary to teach with enthusiasm and confidence, teachers often pass onto students a dislike of science, especially physical science. With a negative attitude often firmly established by ninth grade, most students do not voluntarily take physics in high school. Failure to do so decreases the likelihood that students will go on to complete a University course in the natural sciences or engineering. On the other hand, taking physics in high school does not necessarily ensure adequate preparation for later study. Incompetent teaching may leave students serious deficiencies early on that are bound to make it increasingly difficult and uninteresting in subsequent years. Poor performance in high school physics not only closes the gateway to a career in physics, but to participation in other science related professions as well as the technical decision making procedures that modern knowledge-based societies rely on for their democratic underpinnings.
The chain of events described above has other serious ramifications. One is the early limitation of opportunity for students who cease to respond to science teaching early in their teen years partly caused by under-prepared teachers. A disproportionately large number of these students belong to groups under-represented in the physical sciences and engineering: minorities and women. The result is unequal opportunity for a large segment of our population and a waste of potential talent that might otherwise increase the pool of students pursuing advanced degrees in science and engineering. This also constrains the degree of public appreciation and enjoyment of science as one of the major aspects of human cultural achievement. The low level of scientific literacy produced by our educational system has another serious consequence [20]. In a democracy, the formulation of national and local policy is highly susceptible to public opinion. Therefore, uninformed judgments on important technological issues may have an effect that extends beyond the scientific community to our entire society. This is the most alarming aspect of the current situation. The consistently poor performance of science students to demonstrate conceptual understanding by applying their knowledge successfully in order to make appropriate predictions in unfamiliar situations and to rely on transferable creative thinking, problem solving and reasoning skills in order to analyze decision making situations will continue to hamper the ability of our societies to make best use of available talent both for technological and cultural advancement.

The perspective

The perspective taken in this article reflects the cumulative experience of the Learning in Science Group at the University of Cyprus where holistic teacher preparation has been an integral part of a comprehensive program in research, curriculum development and instruction for some years. Our research focuses on investigations of student understanding of physics and on the design, development and research validation of innovative curriculum to promote that understanding. The research results into student understanding are used to guide the development of

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instructional strategies and activity sequences to develop coherent conceptual understanding by addressing specific conceptual and reasoning difficulties encountered in the study of physics. Curriculum development takes place as an integral part of our instructional program. Our program includes special physics courses for prospective and practicing teachers at all grade levels as well as extended school-based intervention programs for children. Continued international support for years has made it possible to devote a major effort to the production of instructional materials that can be used to teach physics and physical science in pre-college classrooms. Our instructional program takes a holistic approach to teacher preparation and owes its success to committed effort, continuous monitoring and evaluation and above all to careful tuning of four mutually complementary components: science content classes, science method classes, extensive pre-service school experience and support for in-service practice. Our work has benefited immensely from international collaboration, especially with the Physics Education Group at the University of Washington.

Suggestions for solving the problem

To help define our point of view, it may be useful first to examine some popular proposals for improving the quality of science education in schools. The remedy most frequently suggested by teachers themselves involves increased financial investment in school laboratories and equipment. Although experiences with physical world phenomena provide the foundation for constructing conceptual understanding, there is little evidence that hands-on approaches per se are more effective than more traditional techniques. In particular, hands-on without minds-on activities routinely deteriorate into recipe routines devoid of any meaning other than getting “the right answer” at the end. To the contrary, there is a lot of evidence indicating that practical work that is conceived as a support measure for demonstrating the origin and applicability of knowledge explained in lecture format is doomed to failure in terms of promoting real student understanding.

A popular recommendation among physicists for increasing the number of good teachers is to offer financial incentives combined with relaxing the requirements in education for certification. Such a change would allow more individuals with a strong background in physics to take up teaching immediately after graduation. Many physicists assume that students who have studied physics at university are adequately prepared to teach the subject well. The experience of many countries, including Cyprus, with appointing teachers immediately after graduation with a first degree in the discipline, does not bear this out. This assumption will be examined in greater detail later in the article.

Some governments have pushed for increased if not total emphasis on practical school experience. Given the state of the art in student science learning outcomes, apprenticeship is hardly a suitable model. Furthermore, technical training tends to emphasize routine administrative procedures with only an indirect influence on quality education, differentiation, flexibility and fulfilment of student potential.

Many governments have recently placed much emphasis on assessment procedures. It is true that student behaviour in upper secondary and university

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education is almost entirely determined by assessment practice. It is also true that traditional assessment procedures tend to be thoroughly inadequate as measures of real student understanding. However this approach rests on the erroneous premise that if ineffective practice is currently determined by assessment, improving assessment procedures can spontaneously improve learning. Indeed quality in assessment may be a necessary pre-requisite but it is also most likely to be an insufficient pre-condition for quality in learning. Furthermore, it has been repeatedly demonstrated that good assessment practice is thoroughly integrated with instructional approaches and is well tuned both with the range of abilities among examinees and with the content of the course including all pre-requisites, an issue that is commonly underestimated.

A popular recommendation among education professionals for improving the quality of science learning is to increase the requirements for pedagogical training of science teachers. The rationale relies on psychology, sociology and philosophy providing a framework for these teachers to be able to critically analyze the development of individual needs, classroom situations and school environments so that they can then develop appropriate interventions with a high degree of personal ownership. Alas, an operational framework of this kind has never been properly conceptualized by education scientists. Partly as a result, there is little or no evidence that the traditional foundation subjects actually influence classroom practice in any substantial manner. Only exceptionally talented students are able to bridge theory in any of the foundation disciplines to influence practice. The question of identifying what type of transformation is required to synthesize aspects of the foundation disciplines into principles that can influence actual classroom practice still remains largely unresolved by contemporary research.

Another proposal involves entry into the classroom of technically trained professionals as teachers. In some countries, a small but significant number of scientists and engineers are opting for mid career and late career shifts into teaching. It is taken for-granted that the technical competence of these individuals ensures that they have the necessary command of the subject to be effective teachers. However, working in industry does little to develop the requisite depth of understanding, either of the subject matter or of the learning process. Practical experience is usually sufficient for carrying out day-to-day duties. Furthermore, during the years of industrial employment, the scientist or engineer has been away from the school environment and is likely to be less aware than a classroom teacher of the special difficulties physics presents to students.

Volunteer teaching in the classroom by scientists and engineers has been suggested as an alternative way of improving the quality of pre-college science education. Such efforts can be highly motivational to young students in the short term, but occasional or intermittent visits are unlikely to result in sustained long-term learning. Experience has also shown that volunteers seldom succeed in leaving the teacher better equipped to teach science independently. Indeed, very often the result of having a visitor in the classroom is to provide relief for the teacher, who turns attention to other matters.

The measures discussed above are simple in concept and in many places could be implemented relatively quickly, provided financial and administrative complications

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could be resolved. However, such remedies are temporary at best and usually cannot be applied on the scale of an actual educational system. It is essential that teacher preparation be a major focus in any effort at reform.

An effective teacher education program must take into account the needs of two different populations: (1) prospective (or pre-service) teachers who are not yet certified and (2) practicing (or in-service) teachers who are already in the classroom. Pre-service teachers have the flexibility to attend day courses at the university. However, in-service teachers have less flexibility and may be unable or unwilling to participate in a standard instructional program unless special arrangements are made. Important differences also exist in the preparation needs of elementary and secondary teachers.

The emphasis in this article is on the subject matter preparation of both pre-service and in-service teachers. We have concentrated on science as an example even though much of the discussion relates to other disciplines as well. Throughout the discussion, the word “teachers” refers to both prospective and practicing teachers; the modifiers “pre-service” and “in-service” are reserved for cases in which a distinction needs to be made. The only aspects of in-service teacher education that are considered are those that can be addressed through the regular departmental structure of a college or university. No attempt is made to give an overview of the variety of in-service programs.

Traditional approach to teacher preparation

In recent decades it is common for pre-college teachers to be educated in the same universities as the general population.

In Cyprus, prospective secondary teachers must complete a Bachelor’s degree in the discipline and also obtain certification by completing the requirements of a seven month pedagogical training program. In many countries, two independent administrative units are involved in the process of producing science teachers: a department or school of education and a school of sciences (or equivalent). Faculty in education offer courses on methodology and on the psychological, social and cultural aspects of teaching and learning. Faculty in the sciences offer courses on the subject matter. In Cyprus, the situation is even more disparate since two independent institutions are involved: the University of Cyprus offers the Bachelor’s programs and the Pedagogical Institute is responsible for the pedagogical training. In primary education the situation is much simpler. Prospective kindergarten and elementary school teachers must simply complete a four year Bachelor’s degree in Education offered entirely by the Department of Educational Sciences at the University of Cyprus.

Traditional Program Design

Most teacher preparation programs, whether for prospective primary or prospective secondary teachers, consist of varying proportions of subject matter content, educational research methods, psychological, social, philosophical and cultural foundations of teaching and learning and a period of school practice [5]. As

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indicated by the common requirement for a discipline-based first degree, the greater emphasis in secondary education is on subject matter content. Primary education often presents a more equal and far wider representation of the different components. However, even here the content coverage tends to be immensely broad in the hope of producing multi-dimensional professionals that are capable of teaching any discipline at this age level. The underlying premise that *a good teacher can teach anything* continues to plague the programs offered by education departments the world over.

The greatest shortcoming of traditional teacher preparation programs at both levels is fragmentation and lack of coordination. The courses are offered by scientists specializing in the different disciplines, often in the same department but sometimes not. Hence, teacher educators often hold variable cultural values and very different priorities with little or no incentive to collaborate in order to make the overt connections that are necessary for students to build a coherent whole out of the different aspects. Students often simply perceive an immense breadth in coverage with little opportunity for in-depth analysis or critical application. In the eyes of the students, the fragmentary presentation of the disciplines invariably reduces to a series of assessment hurdles that students have to overcome before getting certification. It is extremely rare to witness a situation where a student is able to synthesize the operational understanding necessary to make appropriate decisions on developmental appropriateness, group management and adaptability in motivating and rewarding students. Good teachers develop some of these characteristics after years of experience and only in particular contexts.

Inadequacy of the traditional approach in Physics Departments

Subject matter preparation for teaching science is often distributed among the respective discipline departments. Prospective science teachers generally take standard departmental courses. Usually no special attempt is made to take into account the needs of these future teachers.

Many science faculties seem to believe that the effectiveness of a pre-college teacher will be determined by the number and rigor of courses taken in the discipline. This attitude seems to prevail in most physics departments. Accordingly, the usual practice is to offer the same courses to future teachers as to students who expect to work in industry or to enter graduate school. However, traditional physics courses generally do not provide the type of preparation that teachers need nor do they meet the needs of people who will be guiding the development of student understanding. The breadth of topics covered in the typical introductory physics course allows little time for acquiring a sound grasp of the underlying concepts or of linking them with applications to real life phenomena. Ordinarily, no special effort is made to address the common conceptual and reasoning difficulties that prospective teachers, like other students, encounter. The lecture format encourages passive learning. Students become accustomed to receiving knowledge rather than helping to generate it. The emphasis in these courses tends to be on solving traditional exercises through application of formulae rather than on the conceptual understanding that is a crucial pre-requisite to teacher effectiveness. This routine

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algorithmic problem solving that often characterizes introductory physics courses does not help teachers to develop the reasoning ability necessary for handling the unanticipated questions that are likely to arise in a classroom situation.
The laboratory sequence that often accompanies the introductory physics course also does not address the needs of teachers. Often the equipment used is not available in the teachers' schools and no provision is made for showing them how to plan laboratory experiences that utilize simple apparatus. A more serious shortcoming is that experiments are mostly limited to the verification of known principles. Students have little opportunity to make observations and perform the reasoning involved in formulating these principles. As a result, it is possible to complete the laboratory course without confronting conceptual issues or understanding scientific processes.
The most worrying outcome of science content courses is not that our students emerge without good understanding of many science topics. Often prospective teachers emerge with a misconstrued notion of what it means to understand and how one would go about developing good understanding. By definition, students who have not come to a fundamental appreciation of the nature of conceptual understanding in science through experiencing understanding themselves cannot be helped by science methods courses.
A year of introductory university physics is admittedly insufficient for preparing science teachers. However, it does not follow that advanced physics courses provide useful preparation for teaching, either. The abstract formalism that characterizes upper division courses in physics is not of immediate use in the pre-college classroom; neither are the complicated experiments and sophisticated equipment of advanced laboratory courses. Although work beyond the introductory level may help some teachers deepen their understanding of physics, no guidance is provided about how to make appropriate use of this acquired knowledge in teaching younger students.
Sometimes, in the belief that teachers need to update their knowledge, a university instructor may give a lecture course on contemporary physics. Such courses are of limited utility. The information may be motivational but does not help teachers recognize the distinction between a memorized description and substantive understanding of a topic.

Inadequacy of the traditional approach in Education Departments

Sometimes content courses are offered within education departments, particularly in the case of primary teacher training programs. Often these have similar disadvantages for teachers as undergraduate courses offered by the other departments. To help fill the gaps in background and to match school curriculum coverage, instructors often attempt within a short period of time to present a large portion of the content covered in a traditional physics course. There seems to be a tacit assumption that if the material is well organized and clearly presented, teachers will be able to absorb the information quickly and disseminate it to their own students. However, the amount of material and the rate of presentation may be so overwhelming that learning is impossible at any but the most superficial level.

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Content courses taught by education departments often have an additional disadvantage. In education we use the term theory somewhat more freely than is common practice. For instance, we do not require our learning theories to have predictive capability that can be checked at the classroom or individual level. In addition, science education has suffered from complete domination of the constructivist paradigm as an all encompassing theory of learning that for many years has been beyond dispute. In this context, science educators are often keen to apply their "theory", usually some version of constructivist strategy, to their teaching. The consistency in thinking that transcends the researcher and teacher roles is admirable. However, when theory is reduced to blind strategy, with little or no evidence of effecting real learning, it can have a detrimental effect both on the course and on prospective teacher perceptions of science education as an enterprise aiming to promote science learning. One common example of this detrimental influence is the indiscriminate application of cognitive conflict as a classroom strategy. While usually justified as a constructivist strategy, it often tends to leave the student in despair at the perceived pleasure that their instructors take out of student ignorance. In contrast, the constructivist paradigm could be viewed as a basic principle that characterizes human learning and has important implications for the design of teaching interventions. This principle could then inform strategies for developing curriculum and other resource materials that teachers badly need in order to respond to the challenges and the level of responsibility we expect of them.

The total separation of instruction in methodology from instruction in content decreases the value of both for teachers. Effective use of a particular instructional strategy is often content specific. If teaching methods are not studied in the context in which they are to be implemented, teachers may be unable to identify the elements that are critical. Thus they may not be able to adapt an instructional strategy that has been presented in general terms to specific subject matter or to new situations. The consequences of underestimating the amount of teacher preparation needed for implementation of a new science curriculum has been demonstrated repeatedly with various reform initiatives that have been undertaken from time to time. Even detailed directions cannot prevent the misuse of excellent instructional materials when teachers do not understand either the content or the intended instructional approach.

The traditional approach to teacher preparation has another major shortcoming. Teachers tend to teach in the same way as they have been taught. If they have learned through lecture, they will essentially lecture to their own students, even if this type of instruction may be inappropriate. Many teachers cannot, on their own, separate the physics they have learned from the way in which it was presented to them. It is especially unrealistic to expect large adjustments in instructional approach if teachers must teach material soon after having learned it themselves. Even very able teachers, who eventually might be able to adapt content learned through lecture to activity-based instruction, cannot be expected to do so quickly.

More crucially, both science courses for teachers and curricular specifications for schools are often concept centred and ignore other important aspects of science such as reasoning and procedural skills, epistemological awareness and evidence-

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based decision making. This commonly leads to erroneous understanding of the nature of science and hence a misconstrued conception of its teaching. The model of science that teachers commonly adopt as a result of our courses is incongruous both with the nature of science as a process of inquiry and with effective science learning.

Development of holistic programs for science teachers

A well-prepared teacher of physics or physical science should have, in addition to a strong command of the subject matter, knowledge of the difficulties it presents to students as well as expertise and experience with identifying patterns in student thinking and in formulating appropriate sequences of questions to guide their students in further developing their thinking [9]. To counter the public perception that physics is extremely difficult, the teacher must be able to teach in a way that allows students to achieve adequate mastery of the topics studied and confidence in their ability to understand and apply what they are learning in their daily life. Since neither traditional physics courses nor foundation or professional education courses can provide adequate preparation for pre-college teachers, there is a need for a new conceptualization of our teacher preparation programs including in particular special science content courses for teachers [21]

In an effort to meet this need at the University of Cyprus, we completely redesigned from first principles our science teacher education program. The program described here was implemented for the first time as a whole in the 1998-99 academic year within the elementary education program offered to a total of 600 students at any one time by the Department of Educational Sciences. The program includes special science content courses specifically designed to meet the background knowledge needs of primary school teachers [13]. These courses are carefully linked to science method courses and a specially designed school practicum structure to enable implementation and continued refinement of a structured conceptualization of science learning and its facilitation in a formal environment that identifies and nurtures differentiation in a collaborative forum.

The special science content courses for teachers have provided an environment in which we can empirically refine our understanding of their academic needs. We originally used the insights gained by researchers elsewhere [15] to define substantial objectives for such courses [14]. We then designed a structure that allows us to continuously monitor the evolving nature of our understanding of these needs and the effectiveness of our conceptualization at any one time in promoting quality in the preparation of our teachers. In addition to the instructional function, all our courses have provided a context for research on the nature and facilitation of the learning and teaching of physics and a setting for the development of structured curriculum to promote these aspects of teacher preparation in a systematic manner [30].

The following commentary is a distillation of what we have learned and what we are currently trying to implement [12, 17-19]. The discussion below is not an exhaustive summary of all that should be done to prepare teachers. Practical matters, such as

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laboratory logistics and classroom management are not addressed. The focus is on intellectual aspects.

Intellectual objectives

Initial courses for teachers should emphasize the content that the teachers are expected to teach. A primary intellectual objective should be a sound understanding of important concepts and their formal representations. Equally critical is the ability to perform the reasoning that underlies the development and application of both concepts and representations. Conceptual understanding and capability in scientific reasoning provide a firmer foundation for effective teaching than superficial learning of more advanced material. Teachers should be given the opportunity to study introductory physics in depth, beyond what is possible in a typical introductory physics course. They need to examine the nature of the subject matter, to understand not only what we know, but on what evidence and through what lines of reasoning we have come to this knowledge [22].

Teachers should develop proficiency in both quantitative and qualitative reasoning. It has been demonstrated that university students enrolled in the standard courses often lack certain basic skills, such as the ability to reason with ratios and proportions and to describe the line of reasoning that has led them to a stated conclusion [22]. Courses for teachers should cultivate these skills, which tend to be overlooked in traditional instruction. Also important is the development of facility in the use and interpretation of scientific representations, such as graphs, diagrams, and equations. If they are to make the formalism of physics meaningful to students, teachers must be adept at relating different representations to one another, to physical concepts, and to objects and events in the real world.

Teachers must be able to solve the types of problems that are included in the typical introductory physics text. However, the main emphasis in a course for teachers should not be on acquiring facility with mathematical manipulation nor on developing procedures for precise determination of fundamental constants. As necessary as quantitative skills are, ability in qualitative reasoning is even more crucial. For example, teachers should be able to distinguish observations from inferences and to do the reasoning necessary to proceed from observations and assumptions to logically valid conclusions. They need to recognize what is considered evidence in physics and what is meant by an explanation. They must recognize the difference between naming and explaining. Problems in which the use of mathematical formalism alone suffices for a solution are not effective measures of conceptual understanding. Thus, instead of concentrating on the type of algorithmic problem solving that characterizes most physics courses, the instructor should assign problems that require careful reasoning and should insist that an explanation of the reasoning be part of the solution. Explanations of reasoning should form crucial aspects of any assessment. Careful analysis of student answers should provide feedback to instructors and students alike as to the development of student understanding and the various conceptual, reasoning and epistemological difficulties that tend to arise along the learning pathways of individual students.

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An understanding of the scientific process should be an important objective in a course for teachers. The scientific process can only be taught through direct experience. An effective way of providing such experience is to give teachers the opportunity to construct a scientific model from their own observations. Teachers should go through the step by step process of making observations, drawing inferences, identifying assumptions, formulating, testing, and modifying hypotheses. The intellectual challenge of applying a model that they themselves have built (albeit with guidance) to predict and explain progressively more complex phenomena can help teachers deepen their own understanding of the evolving nature, use, and limitations of a scientific model. Furthermore, we have found that successfully constructing a model through their own efforts helps convince teachers (and other university students) that reasoning based on a coherent, consistent model is a far more powerful approach to problem solving than rote substitution of numbers in memorized formulae.

In addition to the instructional objectives discussed above, which in principle are equally appropriate for the general student population, teachers have other requirements that special physics courses should address. For example, it is particularly important that teachers learn to express their thoughts clearly. The indiscriminate use of words that have both technical and common meanings hinders development of conceptual clarity. Teachers need practice in formulating and using operational definitions. To be able to help students distinguish between related but different concepts (e.g., velocity and acceleration, mass and volume, heat and temperature), they must be able to identify in words precisely and unambiguously what the significant differences are.

Teachers must also be able to anticipate common conceptual difficulties that students are likely to encounter in the study of a topic in physics or physical science. Such information may come from the teachers' own experience in learning the material or, if they have avoided the usual pitfalls, through knowledge of results from research in physics education and through careful and continuous monitoring of the development of their own students' understanding. To help students overcome specific difficulties, teachers need to be familiar with instructional strategies that have proved successful and that are likely to be effective with pre-college students. Again, direct experience is one way of gaining such knowledge; another is through awareness of research.

Courses for teachers should also help develop the critical judgment necessary for making sound choices on issues that can indirectly affect the quality of instruction. For example, teachers must learn to discriminate between learning objectives that are meaningful and those that are trivial. When instruction is driven by a list of objectives that are easy to achieve and measure, there is danger that only shallow learning will take place. Memorization of factual information often falls in this category.

Teachers need a framework for evaluating instructional materials, such as textbooks, laboratory equipment, and computer software. They should become familiar not only with the most popular texts, but also with others that the instructor considers exemplary. They should recognize the strengths and weaknesses of using the computer in various ways (e.g., simulations, microcomputer-based

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laboratories, interactive tutorials) [23]. Aggressive advertising and an attractive presentation often interfere with objective appraisal of intellectual content. We have observed teachers react with enthusiasm to an appealing format, while they ignore serious flaws, such as developmentally inappropriate objectives, inadequately sequenced content and a lack of accuracy in physics [4].

The ability to make wise decisions on matters such as the foregoing is important since, through service on professional committees, individual teachers can often have an impact that extends beyond their own classrooms. A poor curriculum decision can easily deplete the small budget most schools or even educational systems have for science without resulting in the anticipated improvement in the quality of the learning experience for students and the instructional experience for teachers.

Instructional methods

Teachers should be prepared to teach in a manner that is appropriate for the pre-college level. Science instruction for young students is known to be more effective when concrete experience establishes the basis for the construction of scientific concepts (1, 2). We have found, as have others that “hands-on” laboratory investigations guided by appropriate questions also help foster concept formation at the college level. Therefore, in addition to learning how to teach their own students most effectively, teachers benefit directly from instruction that is centred in the laboratory.

The curriculum used in physics courses for teachers should be in accord with the instructional objectives. If the capacity to teach “hands-on” science is a goal of instruction, then teachers need to work through a substantial amount of content in a way that reflects this spirit. However, there is another compelling reason why the choice of curriculum is critical. We have found that teachers often try to implement instructional materials in their classrooms that are very similar to those which they have used in their college courses. Even though it has not been our intent to have young students work directly with the materials that have been developed specifically for teachers, the curriculum has been used in this way.

Whether intended or not, teaching methods are learned by example. The common tendency to teach physics from the top down, and to teach by telling, runs counter to the way pre-college students (and many university students) learn best. The instructor in a course for teachers should not transmit information by lecturing. However, neither should the instructor take a passive role, but instead should assume responsibility for student learning at a level that exceeds delivery of content and evaluation of performance. Active leadership is essential, but in ways that differ markedly from the traditional mode.

The instructor’s role is characterized below by a few examples that are described in general terms. Instructional strategies in the context of specific subject matter are illustrated, either explicitly or implicitly, in several of the references that are cited in the article [8, 10].

The study of a new topic should begin with an opportunity for open-ended investigation in the laboratory in which teachers can become familiar with the

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phenomena to be studied. Instead of introducing new concepts or principles in the customary manner by definitions and assertions, the instructor should set up situations that suggest the need for new concepts or the utility of new principles. By providing such motivation, the instructor can begin to demonstrate that concepts are created as useful scientific tools and concept formation is a process in which the student must be actively engaged. Generalization and abstraction should follow, not precede, specific instances in which the concept or principle may apply. Once a concept has been developed, the instructor should present the teachers with new situations in which the concept is applicable. This process of gradually refining a concept can help develop an appreciation of the successive stages that individuals must go through in developing a sound conceptual understanding.

As the teachers work through the curriculum, the instructor should pose questions designed to help them to think critically about the subject matter and to ask questions on their own. The appropriate response of the instructor to most questions is not a direct answer, but another question that can help guide the teachers through the reasoning necessary to arrive at their own answers. Questions and comments by the instructor should be followed by long pauses in which the temptation for additional remarks is consciously resisted [24].

A course for teachers should develop an awareness of the conceptual and reasoning difficulties likely to be encountered by students. For example, research has helped identify numerous alternative ideas that are usually discrepant with the formal concepts of physics [16]. Some of these ideas result from a misinterpretation of daily experience [6], others from a misunderstanding of formal instruction [7]. Regardless of origin, certain alternative conceptual schemas are at such a fundamental level that, unless they are effectively addressed, meaningful learning of the relevant content is not possible. Teachers should learn to recognize such alternative conceptual frameworks and routinely use these as points of departure for their teaching. More recently, research has also shown that, during learning, a number of difficulties emerge that hamper students' efforts to construct meaningful knowledge. Teachers should also learn to recognize these difficulties and gain practice in implementing effective activity sequences for guiding students to overcome such obstacles to their learning [25].

Mere discussion of research findings, an approach that is often taken in Education departments, is not sufficient for this purpose. Teachers need to work through the material and have the opportunity to make their own mistakes. When student difficulties are described in words, teachers may perceive them as trivial. Yet from experience we know that often these same teachers, when confronted with unanticipated situations, will make the same errors as students and will themselves encounter persistent difficulties that will need to be overcome if an operational understanding is to be constructed.

Exposure to findings of research should also include critical examination of instructional strategies designed to address specific difficulties. The instructor should illustrate these strategies as the opportunity arises during the course. If possible, the discussion of a specific strategy should be postponed until after it has been used in response to a discrepant event that has actually occurred. Teachers are much more likely to appreciate important nuances through an actual example

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than through a hypothetical discussion. Without specific illustrations in the context of subject matter with which they are thoroughly familiar, it is difficult for teachers to envision how to translate a general pedagogical approach into a specific strategy that they can use in the classroom. Teachers need extensive practice in addressing common difficulties and in guiding learning procedures and this practice needs to be firmly grounded in their own learning experiences of science topics.

It is not only poorly prepared teachers who can profit from the type of instruction described above. Those with a strong background can also benefit. The experience of working through carefully structured curriculum that is validated through research can help all teachers identify the difficulties their students may have. Those who understand both the subject matter and the difficulties it poses for students are likely to be more effective than those who know only the content. Moreover, unless teachers have experience with learning science through active inquiry, they are unlikely to foster this behaviour in students.

Illustrative course structure

The brief description below of the science component of the elementary teacher education program at the University of Cyprus shows how we have addressed some common administrative problems. Although special courses for teachers can be organized in a variety of ways, the example illustrates an arrangement that has worked well with large student enrolment within a department of education that is part of a research-oriented university. The specific details are not essential for implementing the intellectual objectives and instructional methods discussed above.

At present, six semester-long pre-service courses have been developed to accommodate students with a wide range of previous preparation. Each course meets for 6 hours a week in a laboratory setting.

Two of the courses are designed as content courses placing greater emphasis on the development of conceptual understanding by teachers themselves in very specific subject matter areas. There are no prerequisites other than moderate facility with arithmetic and algebra. Often in one of these courses we focus on observational astronomy where teachers can carry out the whole process from collecting original data to defining useful concepts to constructing explanatory models that allow them to predict when and where they can see the moon and what phase it will be in. Astronomy is a useful initial motivator for two reasons: many of our students have not taken formal instruction in this topic before and are often intrigued by it; many of us have direct experience with many astronomical phenomena such as sunrise and sunset and the phases of the moon, yet only few of us have constructed explanatory models that allow us to use the sun to orient ourselves or to make predictions on the direction of the moon at different times or on the time of moonrise for different days. As such, astronomy is pedagogically useful as a context for illustrating the process of developing conceptual understanding by starting from evidence and using logical reasoning. In other content courses we teach topics such as light and shadow, electric circuits, magnetism and heat and temperature. In all these courses, even though the emphasis is on developing understanding by the teachers themselves, we

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continuously model a teaching approach which we call *Physics by Inquiry*. In this approach the curriculum provides the structure for student work. Teachers working through the curriculum have to make decisions on what to investigate, what equipment they will need, how to represent and make sense of their measurements, what concepts to define and how to use their understanding to make predictions. In this type of semi-structured inquiry, we as instructors function as facilitators listening carefully to student ideas and using semi-socratic dialogues to ask sequences of carefully structured questions to guide student thinking. We always respond to a question with another question, routinely referring the teachers to their experiments and to their reasoning for finding answers. This is the same instructional approach that we are also adopting in the school science curriculum that we are developing through a concurrent research program. Our students know this and are encouraged to participate in our curriculum design and development efforts as part of the third compulsory course, the teaching methods course. At the end of the two compulsory content courses, students with previously negative experiences and The teaching methods course serves as a reflective opportunity on their own learning but also as a bridge for formalizing, generalizing and transferring some of their own experiences with developing meaning into classroom practice. The course bridges over two gaps: the gap between their own experience with developing conceptual understanding and ways of implementing science as a process of inquiry and the discrepancy between science content courses at the University and routine practice in schools to which they become exposed during the subsequent school practicum. Teachers gain practical experience in addressing common difficulties and in guiding learning procedures through examples of specific learning strategies. As a preparation for the school practicum, students encounter and practice specific ideas for assessing conceptual understanding and use these to evaluate the effectiveness of teaching interventions through a systematic observation protocol that has been developed and validated over the years. They are thus equipped with the necessary armor to face the school system with purpose on the one hand, but skilfully avoiding controversy by always documenting their ideas and approaches on the other.

These compulsory courses are supplemented with two elective courses on school based research and evaluation and on communication and information technology for science learning. These courses are taken by 20-25% of our enrolled pre-service elementary teachers and aim to prepare specialists who are able to function as science resource teachers within a school district.

The school practicum in science takes place over a nine-week period and is taken as an opportunity for our students to put into practice inquiry based science and gain feedback as to the effectiveness of their implementation. In the mentor training program we emphasize use of the same classroom observation protocol as an instrument for providing feedback to our students. We also emphasize the importance of flexibility and the need for allowing pre-service teachers room for experimentation. The emphasis is more on implementing suitable strategies for knowing the extent to which a classroom intervention has been successful rather than on discussing particular content or approach which tends to take on an aura of evaluation that does not help the students need for confidence building. In the

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preparation period for students, we emphasize the importance of understanding the substantial learning objectives of every lesson and the importance of carefully designing questioning strategies that can guide children to reason for themselves and to develop the skills for autonomous investigative initiatives and control over their learning. In terms of classroom strategies we also emphasize the importance of giving children physical and temporal space to design their thinking approach and to reflect on their efforts. Teachers learn to intervene rarely, gradually and methodically with the sole aim to attain group and classroom convergence on learning outcomes.

One of the things we do not emphasize in our teacher training program is approaches to science curriculum development even though that is central to our research interests. The reason for this is a fundamental belief that effective curriculum development can only take place as a process of research undertaken by a multidisciplinary team involving teachers, curriculum specialists and scientists. We firmly believe that it is unrealistic to expect teachers to design their own lessons and at the same time expect those lessons to support quality and innovation in student learning.

Conclusion

The present difficulties in physics education can have serious consequences for the future of the knowledge society. The effect on the greatest number of students is during the pre-college years, particularly the late elementary and early middle school years. The point of view taken in this article is that improvement can take place only when the underlying problem of inadequate teacher preparation is successfully addressed. The debate about teachers as scientists in contrast with teachers as technicians, that has accompanied the transfer of teacher preparation from colleges to universities, has proven too simplistic and polarized. The type of instruction that can meet the needs of teachers is not available in the standard courses offered in most physics, other science or education departments. The traditional University structure of administering these courses as determined by course enrolments, credits, and grading standards encourages too much fragmentation and a general lack of coherence in seemingly disparate activities such as science content, teaching methods and school practicum courses. An effective mechanism for accomplishing this task is through special courses that aim for coherent, wholesome teacher preparation with a clear view of what is manageable by single individuals and what support they need to rely on to promote quality in education. The emphasis in these courses should be on preparing individuals to implement research-based curriculum promoting science as a process of inquiry by acting as cognitive coaches. Providing original experiences with developing meaning and conceptual understanding through inquiry and developing questioning and other skills related to facilitating learning and cognition should figure prominently in the objectives of any teacher preparation course.

The argument presented above has an important implication for university departments. It is unrealistic to expect faculty to dedicate a significant amount of effort to an activity not recognized by the academic reward structure. The general

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perception in some university departments is that serious teaching effort may even be penalized. The teaching program of a department of education is not the responsibility of its individual members. It is the cumulative responsibility of the common professional identity of the department and should receive communal attention that transcends perceived needs to protect intra-disciplinary boundaries, using as the ultimate reference criterion only the quality of the impact on the educational system as demonstrated by research.

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References

[1] Arons AB, Anatomy of a physical science course for non-science students, Journal of College Science Teaching, 1: 30–34, 1982.
[2] Arons AB, The Various Language, Oxford University Press: New York, 1977.
[3] Arons AB, A Guide to Introductory Physics Teaching, Wiley: New York, 1990. A significant portion of this book is directly relevant to the discussion in this paper. In addition to providing guidance for teaching specific topics, Arons identifies important intellectual objectives for introductory physics courses and describes instructional strategies he has found effective. There is also a brief discussion of special problems that need to be addressed in teacher education. The reader is referred to the bibliography at the back of the book for a list of his many articles on physics education and teacher preparation.
[4] Broderbund Software, Physics, San Rafael: CA, 1987. Sensei Software for Learning. This is given only as an example. This widely distributed, visually appealing program contains several conceptual errors. The teachers in our in-service program were so impressed with the visual presentation of the program that they failed to recognize that it could introduce serious difficulties to their students. For example, in the only screen display devoted to Newton's third law, two spheres representing the Earth and the Moon, are shown with force vectors of unequal length. This diagram appears immediately under a correct verbal statement of the third law.
[5] Galuzzo GR and Craig JR, Evaluation of pre-service teacher education programs, in Handbook of research into teacher education, Macmillan: New York, pp.: 599-616 1990.
[6] Goldberg FM and McDermott LC, Student difficulties in understanding image formation by a plane mirror, Physics Teacher, 24:472–480, 1986.
[7] Goldberg FM and McDermott LC, An investigation of student understanding of the real image formed by a converging lens or concave mirror, American Journal of Physics, 55: 108-119, 1987.

ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

[8] Griffith J and Morrison P, Reflections on a decade of grade-school science, Physics Today, 25: 29-35, 1972.
[9] Kahle JB and Boone W, Strategies to improve student science learning: implications for science teacher education, Journal of Science Teacher Education, 11: 93-107, 2000.
[10] Karplus R, Physics for beginners, Physics Today, 25: 36–47, 1972.
[11] Katz LG, Perspectives on the quality of early childhood programs, Phi Delta Kappan, 11: 200-205, 1994.
[12] Lawson RA and McDermott LC, Student understanding of the work-energy and impulse-momentum theorems, American Journal of Physics, 55:811-817, 1987.
[13] McDermott LC, Combined physics course for future elementary and secondary school teachers, American Journal of Physics, 42: 668–676, 1974.
[14] McDermott LC, Improving high school physics teacher preparation, Physics Teacher, 13: 523–529, 1975.
[15] McDermott LC, Teacher education and the implementation of elementary science curricula, American Journal of Physics, 44: 434–441, 1976.
[16] McDermott LC, Research on conceptual understanding in mechanics, Physics Today, 37: 24–32, 1984.
[17] McDermott LC, Rosenquist ML and vanZee EH, Student difficulties in connecting graphs and physics: Examples from kinematics, American Journal of Physics, 55: 503–513, 1987.
[18] McDermott LC, Research and computer-based instruction: Opportunity for interaction, American Journal of Physics, 58: 452–462, 1980.
[19] McDermott LC, Physics by Inquiry, Willey: New York, 1996.
[20] Miller JD, The measurement of civic scientific literacy. Public Understanding of Science, 7: 203-223, 1998.
[21] Nachtigall D, What is wrong with physics teachers' education? European Journal of Physics, 7: 26-44, 1990.
[22] Risley J and Redish E, Proceedings of the Conference on Computers in Physics Instruction, North Carolina State University, August 1988, Addison-Wesley: New York, 1989.
[23] Rosenquist ML and McDermott LC, A conceptual approach to teaching kinematics, American Journal of Physics, 55:407–415 1987.
[24] Rowe MB, Wait-time and rewards as instructional variables, their influence on language, logic, and fate control. Part one: wait time, Journal of Research in Science Teaching, 11: 81–94, 1974.
[25] Sigma Xi, An Exploration of the Nature and Quality of Undergraduate Education in Science, Mathematics and Engineering, a report of the National Advisory Group of Sigma Xi, CT The Scientific Research Society, New Haven, 1990.
[26] TIMSS, Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Report, International Education Authority ,1997.
[27] TIMSS, Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Report, International Education Authority, 1997.

ISBN 978-989-95336-2-2

[28] TIMSS, Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics and Science Report, International Education Authority, 1997.
[29] Trowbridge DE and McDermott LC, Investigation of student understanding of the concept of velocity in one dimension, American Journal of Physics, 48:1020–1028, 1980.
[30] Trowbridge DE and McDermott LC, Investigation of student understanding of the concept of acceleration in one dimension, American Journal of Physics: 49, 242–253, 1981.

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Innovative Ways of Combining Teaching ICT with Teaching Science: Video Taking and Editing by Students and Teachers

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Sianoudis JA, Sotiropoulos DJ and Tsiokanos AC

Introduction

Science and technology are omnipresent in everyday life and they play a very important role in today's culture. Because of their pre-eminence, school curriculum should try to comply with these new data. Students should study science and technology:

- Because the economic strength, the progress and the wealth of all modern societies is based on Science and Technology[1]
- Because science is an integral part of human culture and as it thrives on independent and creative thought, understanding science develops one's independent and creative thinking [2].
- Because education should aim to greater depth in pupils' scientific understanding [3]
- Because education should, also, aim to attract a greater number of young pupils to study science, so as future scientists and engineers emerge from them [1],[5]
- To gain knowledge about the material world, simply because it is both interesting and profoundly important – and to feel the sense of excitement that scientific knowledge brings [5].
- Because the understanding of the nature of science is essential if people are to make sense of socio-scientific issues and participate in the decision making process[3]
- Because the ever-growing importance of scientific issues in our daily lives demands a populace who has sufficient knowledge and understanding to follow science and scientific debates with interest, and to engage with the issues science and technology poses – both for themselves individually, and for our society as a whole[3]

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The knowledge on how to search for new information as well as the acquisition of such new information in the course of normal schooling, self-training, or re-training is of immense importance today. Indeed, the ability to acquire new knowledge is a vital skill for all citizens in modern society.
A growing number of schools in Europe already have computer laboratories utilising modern computers. Introductory courses on ICT are already integrated in primary school curricula or soon will be. Apart from that, PCs are present in a continuously growing number of homes, and the age children start using computers decreases continuously. It is about time, therefore, to revise existing or develop new ICT curricula. On developing these new curricula due attention should be paid to the fact that activities such as text editing or painting have already been introduced to the students in primary school. Something different, more advanced, and more exciting is needed, therefore, for the high school (and lyceum) curricula. We believe that one possible course of action would be to integrate in the curriculum ICT teaching with the teaching of different subjects, while at the same time to combine different learning methods by paying more emphasis to students' own actions and self-directed learning abilities.

Constructivism in action: the case for self-directed learning

According to **constructivist** theory, pupils cannot be considered as "tabula rasa". They have preconceptions or "alternative frameworks" (according to which they tend to think in order to explain whatever they experience), and which they therefore play an essential role in their learning process. **Constructivism** pays much emphasis on students' ideas, as these ideas represent the raw material that the students themselves are called for to **reconstruct**. Professors and teachers play a supporting role in this process. Meaningful learning demands that pupils construct their own knowledge.
Self-directed Learning is a didactic concept where students set their own goals, analyze a given problem, observe their own learning progress, and assess the educational results.
The innovative teaching approach suggested in this paper, aims to help students achieve the goal of self-directed learning. The students learn by their own actions for a change, instead of passively hearing teachers teach. Furthermore, students have to choose the content, evaluate it, decide which are the important points and which ones have less importance, they develop a teaching "scenario" and they execute it. They also have to collect the materials and apparatus needed for the experiment to be performed, set the experiment up, make sure that everything works and then start the shooting.
The video-editing phase follows and any corrections needed are performed. Students are asked to evaluate their own work, and if the end result does not satisfy them they may decide that the process should be repeated. Alternatively, they may decide to just alter the narration (boring voice) etc. Students develop abilities such as judging their own work and finding arguments to justify their opinion. They learn to hear their classmates and evaluate the arguments presented. All these abilities are considered essential for a modern citizen. Apart from that, the teaching

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approach suggested offers a very strong motive to the students. Their work will remain at school for other students to use it in order to learn, (or perhaps it may be uploaded via the internet to a streaming server so that other schools may have access to it. Students can also visit their own school page and show to their friends and relatives their own product. In case the same procedure will be performed in parallel in different classes or different schools, a competitive spirit will be easy to take hold. Teachers may also wish to cultivate such a constructive situation by splitting their class into two or more groups and institute a procedure in which all groups take turns in presenting their work. This way, students are given a stimulus to try to outperform the other groups.
In the process of doing so, students learn to collaborate with other members of their group, to evaluate their own work and to make the best of the assets they have available. Students, therefore, learn to develop collaborative characteristics, such as helping each other and to develop their social competence in working as a team. They learn by themselves and by taking into account the opinion of their friends and co-workers on their project. This whole procedure is also bound to enhance their mutual and social skills (group interactivity).

Innovative ways of using ICT at school

We have already explained the didactical merits of the innovative learning approach advocated, namely that it allows students to develop their collaborative spirit, learn to help each other and achieve social competence in working as a team. The practicalities of such an endeavour will now be expanded.
Digital video cameras and digital cameras (offering the possibility of limited video capturing) are nowadays cheap and common enough (even mobile phones have such capabilities nowadays). We believe that it is about time to start using media-editing application software in the classroom as a good new method for introducing ICT in everyday school practice.
The teaching approach suggested in this paper is part of an ongoing research, contributed by a number of the authors to the e-stream (Minerva) research effort. Several different didactical projects are currently running in parallel, involving students of different ages (from primary school students up to twenty-year-old ones). The main aims are (a) to find the difficulties faced by students of different ages, interests, and socio-economic backgrounds, and (b) to evaluate different teaching activities in order to find the most appropriate ones for students of different ages. Overall, this approach should have considerable impact on the way teachers prepare their lessons, which in turn, will modify the lessons themselves.
To help along these lines, we present some teaching scenarios for combining ICT (developing of media) with other school curricula. In the present paper, the emphasis is in combining teaching Science with teaching ICT, and therefore the examples are from science teaching.
As the media content is concerned, these can be categorised in 4 major categories as follows:

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A) Scientific experiments with the use of computers (sensors/actuators). These have two subcategories.

A.1 The teacher performs the experiment, the capturing, and the editing. The product is then used in class. As sensor equipment is not yet available in all schools, the cooperation of a TEI (Technological Educational Institution) or a University is (for the time being) essential for the shooting.
A.2 A certain experiment is assigned to the students. In this case, the procedure might take place in the school lab a university or a TEI (Technological Educational Institution) might lend the necessary equipment and perhaps a researcher to help if necessary, or it may be combined with one or more visits to a university/higher education training centre that has the equipment for the shooting

The scientific experiments using sensors that were recorded and subsequently used in this educational trial were designed developed and performed in the Department of Physics, Chemistry and Material Sciences at the TEI (Technological Educational Institution) of Athens, and were financially supported by the research program “Archimedes”.

B) Scientific videos: e.g. physics experiments, or instructions on constructing a device requiring a certain level of technological skill. This one has two sub categories.

B.1 The teacher performs the experiment the capturing and the editing and he/she uses the final product at his/her lesson
B.2 A certain experiment is assigned to the students. They should study the scientific topic decide on the “narration”, collect the material and apparatus needed, test them, perform the experiment, do the video capturing and proceed with the video-editing.

These two aforementioned categories (A) and (B) are considered to contain a high educational value. This is even more the case, when students are asked to create their own medium. Students will be responsible, in this case, for the end result. The teacher will be, of course, the one that will select the scientific topic deemed to be suitable for his class. In both these cases, (still under investigation):

- The students are asked to investigate and find the theoretical background.
- They will design and plan the content of the video.

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- They will decide (roughly or even vaguely) for the narration that may also appear as text.
- They should collect the necessary equipment/materials and test them in an experimental setup before perform the shooting.
- They perform the video shooting.
- They perform the video editing.

C) General knowledge video: the presentation of a well-known monument (there are plenty of such places in Greece e.g. Acropolis, Olympia, Delphi, a certain town) and its history.

This should be considered of contain a medium-level educational value. The quality of the video is an important factor to the success, in this case. In the present paper, we will not deal in depth with this category, as we believe it requires a very different approach that presents its own didactical challenges and all that warrants a new and separate study.

D) Videoing real time events to record (and) reproduce the information it is contained. This real time event might derived from one of the following:

a) Lectures: The lecturer and the topic he chooses are the factors that determine the educational value of the media. Seen in this light, the educational value of this approach does not differ much from attending the same lecture on a TV program. There is not much difference even from listening to this lecture on the radio since very little information is on the visual part. For some people reading the same lecture from a book, be that an electronic or a printed one, might be preferable. And this because they can stop and search for an unknown word, or re-read a paragraph that it was not clear enough. In this case, the quality of the video is not, really, all that important. The important information is to be found in the content, while the information contained in the image is of lesser value, and in certain cases the image might be even distracting (jewellery, clothing, gestures etc.)
b) A real time event such as a song competition, a sport event, students presenting something etc.
c) A school event such an excursion of a ceremony etc.

Normally such videos have limited educational value, as they only serve as an object to exercise and perfect the ICT-video capturing and editing proficiency of the students who take the video, while the real educational value is limited to that. The

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medium can be used for discussion about the subject e.g. the music, the presentation etc. The quality of the video is again of lesser importance as the details do not play such an important role. In this case, only some limited video editing is normally necessary. The medium is almost ready to use in the first place.
Such activities require the cooperation of teachers of different “specializations” and skills. The Science (or History) teacher is called to cooperate with the ICT teacher. There are reasons to believe that such activities make the learning process more interesting and, finally, the percentage of the knowledge remaining to the students is higher.
Activities like these can be performed after the normal class hours in a daylong school, at the “free activity zones” or in locations that students can visit at any time (as, for example, “houses of knowledge” or “science museums”).
Students can work in small groups. Working in small groups is, of course, most beneficial for the students because they learn to work in teams, to develop collaboration and communication skills, as well as to practice self-learning techniques. This approach encourages teachers to use information and communication technologies as well as collaborative tools, in order to widen the students’ opportunities while facilitating the interaction with each other and with distributed information resources. However the pedagogical challenge is to choose and assess the technology available and to use it in ways that are pedagogically appropriate and relevant to the learners.

Difficulties in using the new approach

In order to reveal the difficulties that would be faced by a teacher attempting to use this teaching approach, the decision was taken to organise and perform various teaching activities to test these tasks in practice.

1. Materials and equipment to be used in the experiment had to be collected and tested beforehand. This step is considered crucial. Multiple sets of the materials/equipment that will be used are absolutely necessary (e.g. batteries, lamps, materials that might be cut down, burned, or destroyed during the experiment, experimental tubes etc.)
2. The video-shooting equipment should be tested in advance, and the person using the camera should have pretty good knowledge of the capabilities and limitations of the camera. Using the camera manual and performing experiments in front of the camera will increase dramatically the time needed.
3. Special care should be paid to small details such as the background of the experiment, the surface on which the experiment takes place, but also to the hands of the performer (rings, watches, long nails with strange colours etc.) may attract the “eye” and shift the viewer’s attention from the experiment to something irrelevant
4. Normally the LCD screen on the video camera shows a slightly smaller frame than the one stored on the tape/PC. Connecting the camera to a personal computer is considered necessary, especially if we are dealing with small

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objects in scientific experiments. If we do not do so, things irrelevant to the experiment will appear in the video and will distract the child's attention. A video editing program can be used to crop "noise" but this increase the time and the effort devoted to the editing phase. This step should be omitted for outdoor shooting due to safety and mobility reasons (moving around with a laptop that operates, connecting with a camera)

5. The camera should be kept very steady, especially when videoing scientific experiments. A "professional tripod", a heavy and steady one, is recommended for this purpose.
6. The camera is best to be operated via remote control, due to several practical reasons

   a) If the tripod used is not a professional one the final image will suffer greatly as it would allow small movements and vibrations during the time of video capture (even if we handle the camera with care)
   b) If the performer and the "shooter" is the same person it allows him to start/stop the camera easier,

7. If the performer and the "shooter" are different persons and the video shooting is an indoor activity that is going to take place in a small area, a second screen will be needed to allow a full view of the shooting area to the performer.
8. For shooting scientific experiments professional lighting equipment is required to increase the amount of light available and in doing so to increase the depth of field of the image taken. It might be proven that setting up the lighting (avoiding shadows etc,) is a time consuming activity

The camera should be set to the mode that allows saving the video to the tape and simultaneously sending it to the PC. That means that 1 PC file and a tape file are produced at the same time (redundancy).

9. The camera should have a high resolution and the connection to the PC should be through a firewire exit. This produces a much higher resolution video in the PC than a USB connection. The resolution can be dropped at the final step (editing and compression) but the only way to add details, is to re-shoot the experiment.
10. It took us about 2 hours to set up the lights, PCs, Tripods, Cameras, find the right shooting position etc.
11. The videotaping could not go on one take (i.e. one shot). The possibility to get the narration recorded correctly while shooting is very low. The probability to also get the narration right might be higher if the text for the narration is prepared in advance and a second person reads it on an external microphone (if the camera allows it) while the experiment is being performed. We,

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therefore, need multiply takes (shots). Video editing is needed afterwards, of course. For the video editing a modern computer is recommended (The more the RAM it has and the more free disk space it has, the better. A second disk for the video is recommended)

12. If the video includes several steps, it is recommended to shoot it step by step and gradually store it in a different file. This ends up in editing smaller pieces, and putting them together at the end.
13. Moreover, finally yet importantly, we should mention that this procedure is time consuming. It took us 3 hours for about 8-15 minutes of row video.

Decision such as which video editing program will be used, which analyses etc should be used must also be considered.
The next step is video editing and synchronisation with the narration.

Conclusions

While the economic strength, the progress, and the wealth of all modern societies are based on Science and Technology, it is also well known that Science seems to be the most difficult, and the least interesting subject for most students. Considering its true size and its importance, Science is the single major subject in which only minimal amount of hours are devoted in the school timetable. Research has highlighted that "proper" (e.g. laboratory activity – based) science-teaching or such as the science teaching advocated in this paper, is extremely time consuming. Therefore, the first challenge is to find more teaching hours for science.
We also mentioned that introductory courses on ICT are already integrated in primary school curricula or soon will be. Therefore, new teaching approaches more advanced and more exciting could be considered for possible implementation. Techniques such as video capturing become easier and more common. We believe that by combining tasks in the way shown in this paper, will prove to be very beneficial to the students.
This teaching approach helps students to develop collaborative spirit, and to improve their self-learning skills. Students also develop their own judgment as to what is important and what is not, while learning to elaborate arguments to justify their opinion. These are important characteristics of adult people to have. Finally, students also acquire some (often quite considerable) technical expertise.
Another advantage of this approach is the following: Certain events (e.g. the Olympic Games or a school excursion to a certain place such as a centre dedicated to environmental education, or an art exhibition, or an event paying homage to an important artist or a famous author or poet) do not occur every day. Certain events might be rare or even unique and, in addition, they may carry an important educational message worth to be kept as a record. The emotional importance, to the students, to the effect that they themselves record something important or unique, should not be underestimated as it generates excitement.
In the case of recording laboratory experiments, it should be stressed that some such experiments cannot be performed in a normal school-lab. This is because (a)

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they demand very expensive equipment which can only be found in places where schools go for a visit and (b) experiments may be too difficult to perform at school due to several reasons (e.g. too dangerous to carry out or they demand a tutor with specialized knowledge to perform it). In these cases, the material developed by the students might be useful to the other classes who may be interested to watch it and learn from it.

The ultimate challenge faced by this type of teaching approach is to design activities that are suitable to different age-group students, as well as to students of different interests and abilities.

References

[1] Angelopoulos BG, Garyfallidou DM and Ioannidis GS, Streaming media in education International Conference ICL- Interactive Computer Aided Learning, Kassel University Press, 2004.

[2] Antonopoulos SG, Garyfallidou DM, Ioannidis GS, Plerou S, Stamatopoulos N, Valanidis N and Vavougios DG, A comparison of students' ideas on energy amongst high school leavers in Greece and Cyprus, 2nd International Conference on Science Education, Nikosia, 2003.

[3] Bell D, Beyond 2000: Science education for the future, in Millar R and Osborne J (Eds.), The report of a seminar series funded by the Nuffield Foundation, 1998.

[4] Brook A and Driver R, Aspects of secondary students' understanding of energy, full report, University of Leeds, 1984.

[5] Driver R, Young people's images of Science Open University Press, 1996.

[6] Feynman R, The Feynman lectures on Physics, Addison-Wesley, 1963.

[7] Patrinopoulos M, Imvrioti D, Dimopoulos V, Sotiropoulos D, Tsagogeorga A, Papatsimba L, Dimitriadis P and Kalkanis G, The Visualizing and measuring by the computer the operation of hands-on educational devices - The case of solar water heater. 6th Workshop on Multimedia in Physics Teaching and Learning of the European Physical Society (Division of Education), Ghent, 2001.

[8] Solomon J, Teaching Science, Technology and Society, Open University Press, 1993.

[9] Trna J and Trnova E, Cognitive Motivation in Science Teacher Training, in: Science and Technology Education for a Diverse Word – dilemmas, needs and partnership, 11th IOSTE Symposium for Central and East, 2004.

[10] European Countries, Lublin, M. Curie-Sklodovska University press, 2004.

[11] Verganelakis A, Who needs Physics, (in Greek), Democritus Nuclear Research centre, 1985.

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Web-Based Instruction in IT Hardware

Berezovska I

Introduction

Technology has radically changed the way educational institutions function in an academic environment and the services they provide. However, many universities feel the lack of equipment and limitations of scheduling. Recently Web-based instruction has become a viable alternative to classroom model that may improve educational opportunities and provide great assistance to overcome some of grand challenges to education.

The first challenge is speed. Our universities are simply too slow at what they do. To teach rapidly developing disciplines and IT courses in particular, an educator should, we quote al-Djahiz (an Arabian encyclopedist, the 8^{th} century), “keep pace with time when it flows, and fly with it when it flies”. It is obvious that Web-based instruction is a very suitable model to achieve this.

The second problem we face is the commercialization of education. More and more students have to pay for study at universities in our countries. Tuition fee is increasingly growing while universities have no funds to provide financial aid. To respond the needs of busy students working to get money, the instruction should be presented at times and locations convenient to them. Learning needs to be active, self-directed, collaborative, and situated in real-life.

And that is the third grand challenge: how do we deal with students? What is our role and what is our communication style? Most educators were and many of them are rather authoritarians than collaborators to students, their style is more didactic than liberal. Fortunately, introducing new teaching strategies will facilitate liberal changes in an academic environment, because most educational innovations require that students will take a more active role in the learning process. The students taking the Web-based course had to be highly self-motivated and well organized.

Now we come to the final challenge, which is the issue of access. It is very interesting to look back at the recent history of access. Article 19 of the Universal Declaration of Human Rights, which was adopted in December, 1948, states that, “Everyone has the right to freedom of opinion and expression. This right includes freedom to hold opinions without interference and to seek, receive and impart information and ideas through any media regardless of frontiers.” Many new educational models including Web-based instruction are developed to improve

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access and make the knowledge, a “global public good”, as widely available as possible.

Tutorial outline

The mastering of IT hardware is an important component of the IT literacy curriculum. To address some of the hardware-related skills, a Web-based tutorial, “Methods and Facilities of Information Technology,” was developed as a collaborative project with the faculty of Ternopil State Technical University (TSTU, Ukraine), Lviv Polytechnic National University (LPNU, Ukraine) and Rzeszow University (RU, Poland).

Access policy

The tutorial was designed as a component of “IT Hardware”, an undergraduate course, and is delivered through the campus networks (Figure 1).
Users are administered by Microsoft Active Directory and are sorted in three groups: Administrators, Teachers and Students. Courseware is stored on KNS (main server) working under Apache Web Server software. By courseware [1] we mean the collection of coordinated materials and tools specifically produced and used in education as instruments of instruction and delivery of curriculum. Administrators and Teachers can change all educational materials locally or by using hidden SMB shares. Students’ files, such as home-directories, are organized as DFS shares to be accessible from any point of TSTU network. Non-Students’ documents (i.e. educational materials) are available to Students in read-only mode.
The router works under Debian GNU/Linux Woody 3 or 4; rooting software is Zebra, Cisco’s alike system. Two 100 Mbit/s cards are used.
Software installed on the KNS main server includes Windows 2003 Server, Apache Web Server, and FTP-Internet Information Service. One 100 Mbit/s card and two 120 Gb HDD are used.

Content of the tutorial

The class was presented as a traditional 30-hour classroom course. The content covers the practice of IT in seven modules. Each module includes lecture notes and other information on the topic, recommended reading list, and assignments to reinforce comprehension or to practice skills. This course allowed for gradual but in-depth learning of concepts and principles in information technology. The seven sections of the course are arranged so that students progress from basic subject knowledge to the ability to overcome a particular IT-related challenge through proper selecting, using and adjusting IT hardware.
The first two modules include data compression methods and image formats. Students complete assignments to construct a redundancy-reduction code using the Huffman method and analyze the properties of an information source allowing data compression. They are also offered to draw pictures to understand which one of image formats (.gif or .jpeg) is more effective depending upon picture properties

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(for example, number of colors). The next three modules include CPU architecture, memory technologies and HDD storage devices. In the last two modules, students summarize their knowledge acquired during the course. They study the motherboard structure to understand the over-all architecture of PC and use monitoring tools to explore PC performance.

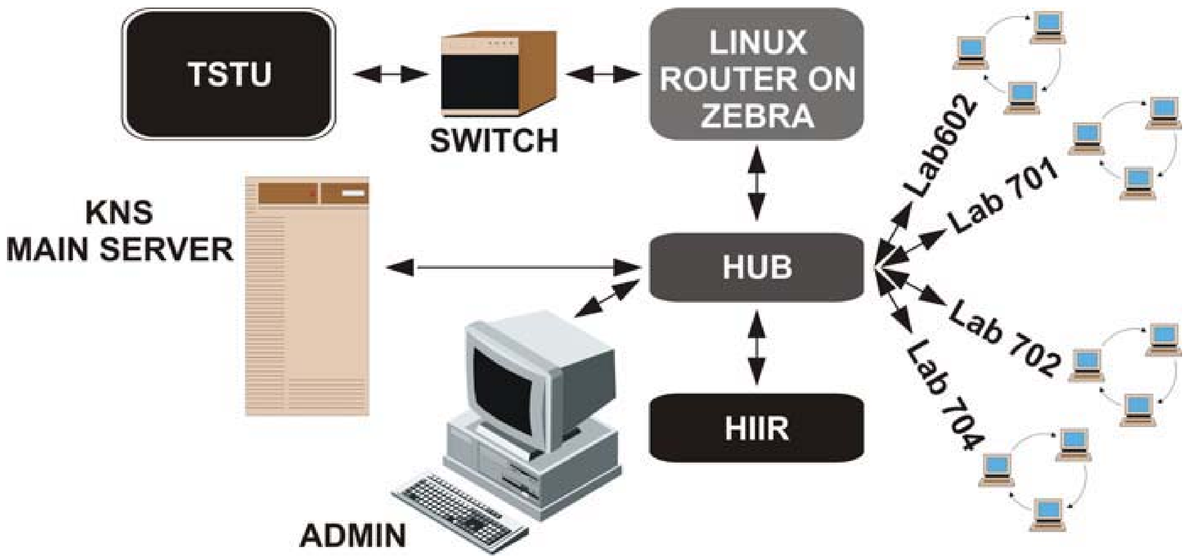

Figure 1. Access to courseware in TSTU network

Introducing the past into the present curriculum

We strongly believe that learning and understanding the processes of IT hardware evolution should occupy an importance place in the process of study IT technologies in order to make the link between the past and the present meaningful for students. When history of one or more hardware components or technology is directly tied to class activity, some positive changes in perception happen. But simply offering the students to go through the chronology of IT hardware (processors, memory, storage devices etc.) would not work, and every educator knows from own practical experience that requests which are not required formally pass unheeded.

Therefore we have made a special effort to indicate the basic concepts implemented in IT hardware (i.e., parallel processing, pipelining or pre-fetch) and show that, in many cases, today's IT solutions are based on the same basic approaches hidden by new names. This will help students to keep pace with IT progress and recognize well known ideas implemented in new-generation hardware that will appear after they complete their formal education.

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Benchmarking and diagnostic tools

We also consider benchmarking and diagnostic/testing tools to be of great instructional value, especially since necessary software, online help, tips and reference searchable databases are accessible online. However, there is a certain danger, because, as indicated in FOLDOC Free Online Dictionary of Computing [2], "in the computer industry, there are three kinds of lies: lies, damn lies, and benchmarks".

To interpret the relevance of benchmarking and diagnostic/testing tools and then to select proper tools accordingly to the educational needs, a teacher has to check requirements regarding:

- operational system;
- RAM and HDD space sufficient to install and run an application;
- user profile (some test applications can be run only by network administrators);
- availability of special chips providing the information to be analyzed by the application;
- duration of testing (too long tests may be ineffective);
- report modes, both test and graphic options are desirable;
- native language interface if possible.

The reasons to integrate benchmarking and diagnostic/testing tools into the tutorial and other IT-related courses are very pragmatic. Students can see the structure of PC, determine parameters of its components, analyze how well these parameters are coordinated, explore PC performance under different loads, and reveal PC problem areas.

The availability of too many benchmarks may become a problem because they often produce conflicting results when measuring performance characteristics of the same PC components. It is important to realize that this results from software implementation. The simplest solution would be selecting a single application to get comparable results with different hardware. However, the comparison of different benchmarks may allow noticing unusual details provided that specifics of software implementation are taken into account.

Benchmarking and diagnostic/testing tools are available at many Web-sites, but only few of them provide validated and refined information put all in one spot. The role of such resources is that they make possible top-down approach [3] to software selecting. For instance, an extensive archive is supported at **BenchmarkHQ** (*http://www.benchmarkhq.ru/english. html*).

General-purpose toolkits and device-specific applications serve different educational needs complementing each other (e.g. **SiSoft Sandra,** *http://www.sisoftware.co.uk,* and **HD Tach,** *http://www.simplisoftware.com*). The latter ones provide extensive data on individual PC components that makes them effective when students study these same components. In contrast, general-purpose toolkits help to summarize the knowledge of PC at large.

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Tutorial evaluation

The tutorial was evaluated using data gathered from a post-course survey. Questionnaires were completed by 45 students so that we could learn of beliefs and attitudes towards the Web-based instruction and materials developed during the project. Our analysis of questionnaires shows that overall participant attitude has been positive regarding the Web-based instruction in IT hardware. Observations made through this project include:

- Most students, 43 (95.6%), prefer Web-based access to assignments, and 2 students (4.4%) indicated that printed materials are more convenient to them;
- 44 (97.8%) students prefer to submit assignment reports in electronic format, and only 1 students (2.2%) printed his reports;
- Most students, 42 (93.3%), have responded positively to the idea of extending Web-based instruction to other courses; 3 students (6.7%) were indifferent.

Table 1 shows the survey results for why students preferred the Web-based instruction.

Since any student was allowed to view current results on completing assignments by all students, they were also asked to comment on this “open” reporting. 34 (75.6%) respondents strongly agreed that being informed about all students' accomplishments is very useful, because this makes them to compete. Students answered objective questions but also were given sufficient space to “explain” their responses. These responses have been essential in helping us learn more details. For example, many students indicated that they would like to have an authorized access to Web-based courses via the Internet.

Advantage *	**Number and percentage of responses**
Allows me to choose when and where to complete assignments	21 (46.7%)
Helps me to meet deadlines	11 (24.4%)
Decreases time to prepare reports	37 (82.2%)
Convenient access to educational materials	22 (48.9%)
Quick feedback to a teacher	25 (55.5%)

* Respondents could check more than one item.

Table 1. Advantages of Web-based instruction

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This general course evaluation was considered to be the best way to determine whether this "experimental" project was a good learning experience, what changes to consider, and whether the project should be repeated in subsequent semesters or extended to other courses.

Conclusions

The students were very satisfied with the course and with the Web-based instruction and support provided. We believe that this can be credited to three important attributes of Web-based instruction: more time for learning and reflection is available, individual attention stimulates learning, and motivation enhances the learning process.

We debate the quality of new teaching strategies versus existing classical models daily. It is too early to say about possible outcome of those debates. But, when we intervene in the existing system, we need be careful not to damage something that has actually worked rather well. Then the sensible approach, we think, is to experiment, be reasonably skeptical and adapt educational models to the particular field, to the particular discipline. The overemphasis on either classroom or technology-based models seems to be a mistake. It is an issue of choice, the way we teach, the way students study.

References

[1] Nahvi M, Engineering Education and the Courseware of Tomorrow: An Example from Undergraduate DSP Education, in Rudas IJ (Ed.) Proceedings of the 3rd International Conference on Information Technology Based Higher Education and Training; 2002 Jul 4-6; Budapest, Hungary. Budapest: Budapest Polytechnic, pp.: 5-15, 2002.

[2] Howe D, The Free On-line Dictionary of Computing. Imperial College Department of Computing, 1993. http://foldoc.doc.ic.ac.uk/foldoc/index.html

[3] Berchenko N and Berezovska I, When less is more: a practical approach to selecting internet-based resources for teaching it hardware, System-based Vision for Strategy and Creative Design, Bontempi F (Ed.). Swets & Zeitlinger, Lisse, pp.: 2119-2122, 2003.

Paper presented at the 2nd International Conference on
"Hands-on Science. Science in a changing education",
Rethymno, Creta, July 13 to 16, 2005.

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Conceptual Learning of Science and 3D Simulations

Divjak S

Introduction

CoLoS (COnceptual Learning Of Science) is a consortium founded in 1988, composed of research teams from 18 universities. Fields of interest of various CoLoS research groups are: physics, chemistry, electrical engineering, mechanical engineering, and computer science. The major goal of this consortium is to encourage and co-ordinate the development of teaching methods and to improve the knowledge and understanding of fundamental concepts with a special focus on intuitive and qualitative approaches. One of the methods that has been developed by CoLoS is based on the mimicry of nature and its fundamental principles. The computer is used for the visualisation of the molecular or atomic behaviour. The teacher or students can interact with the simulated system and in such a way obtain a better understanding. From the technical point of view this is achieved through 2D or 3D visualisation of simulated world, equipped with the needed control buttons, sliders and other possible interacting components.

3D Simulation of particles and non-rigid bodies

One of the most significant CoLoS authoring tools is xyZET [1], which was developed at IPN Kiel (Germany). This is an interactive, graphically oriented simulation tool that permits the presentation of objects and structures in 3D space. The basic building elements of these objects are particles that are defined by their mass, charge, and initial position and velocities. These particles can be connected with springs. In such a way more complex, non-rigid bodies can be presented. Different internal and external forces influence the particles in the system. Their behaviour can be observed during the animation. The basic phenomena from the domain of mechanics and electricity can be explored (kinematics, conservation of energy and momentum, Hook's law, gravity, charges, field lines and equipotential planes).

The conceptual learning of the particular phenomena can be achieved by incremental building of the first simple and then increasingly more complex bodies and structures, and by experimentation with various physical parameters. The

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teaching scenario can be included in accompanying and interacting hypertext. In such a way complete courses in the domains of mechanics and electricity have been created.
The Figure 1 displays a screenshot with the experiment comparing a mathematical and a physical pendulum. The 3D world with the experiment is visualized in a separate frame. Besides this the accompanying control frame and hypertext based tutorial is presented.

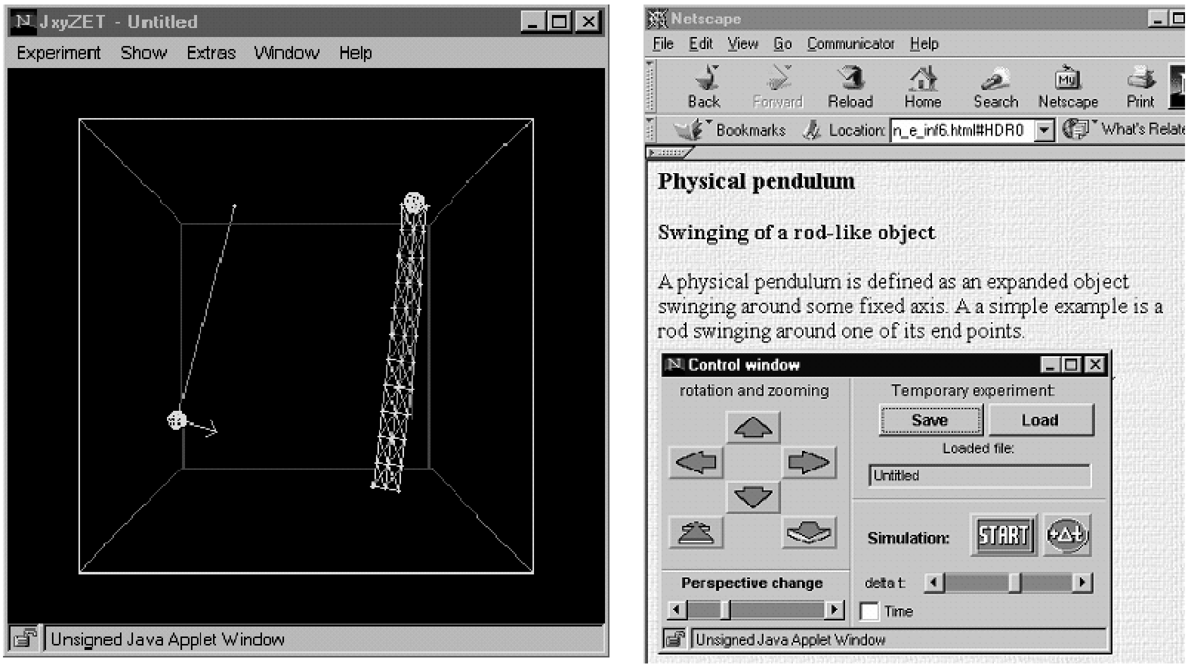

Figure 1. A screenshot with the simulation of a pendulum

The gallery of several hundred experiments includes some extremely complex examples with bodies consisting of more than 100 interconnected particles. Most of the experiments were integrated within the tutorials covering mechanics, resonance and electricity.
xyZET is an authoring tool running in MOTIF environment. Besides this, some additional platform independent java applets were developed at Ljubljana University. The final version was entitled JxyZET. The user interaction with experiments is achieved through buttons, menus, sliders and checkboxes that are I ntegrated in the tutorial. Several tutorials in the domain of physics, mostly written by H. Haertel and some by CoLoS group from Murcia (electricity, resonance), were adapted.

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Flexibility of JavaScript Controlled Simulations

The next chapter presents the advantages of using JavaScript functions in interaction with scriptable applets. Very good results were obtained by the so called Physlets, which were invented by Wolfgang Christian [3]. Physlets-Physics Applets, are small flexible Java applets designed for science education. They can be used in a wide variety of WWW applications. The graphics of physlets is simple and without details that could be more distracting than helpful. This keeps Physlets relatively small and very flexible. All Physlets can be set up and controlled with JavaScript, which means that they can be used for several application problems with small changes in the JavaScript. Data gathering and data analysis can be added when needed, through the use of inter-applet communication. Since Physlets are scriptable, the experiments can be modified just by editing the HTML.

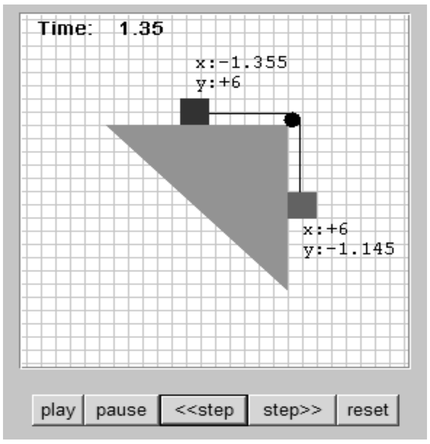

Figure 2. Physlet presenting 2 connected bodies

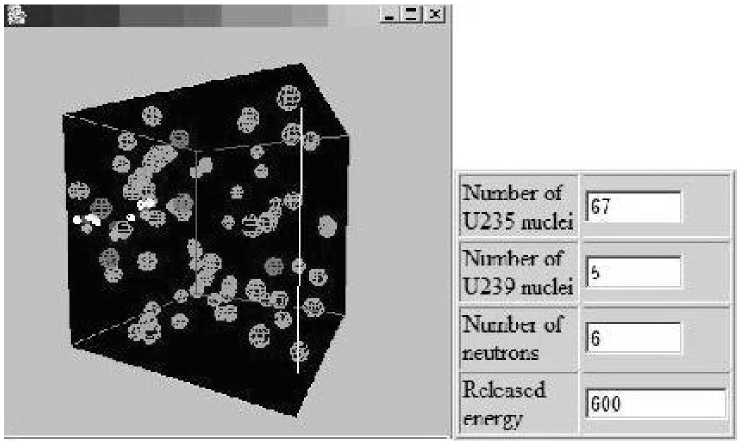

Figure 3. Simulation of a nuclear fission process.

Christian's concept of scriptable applets influenced further development of JxyZET simulation applet. The original JxyZET was expanded with some scriptable functions. This permits the definition of more complex elastic bodies built from several hundreds or even thousands of particles and springs. These bodies can be easily modified just by changing some parameters within the JavaScript code included in the parent hypertext. The usage of JavaScript permits the interaction of an user defined algorithm with the simulation tool, in our case JxyZET. Further research of JavaScript capabilities permitted some additional improvements and increased flexibility of this simulation tool, which was completely redesigned and renamed in Animator3D.

The achieved flexibility of Animator3D applet permits the development of experiments in different scientific domains because we can put the simulation algorithms in externally defined JavaScript and are not limited with the algorithms incorporated in the original applet. The following example is a simplified 3D simulation of the known nuclear fission process. The experiment consists of putting a quantity of U235 nuclei, some U239 nuclei and one neutron with a predefined

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velocity in a container. Every time a neutron collides into a U235 nucleus the later is split in two smaller nuclei (waste product) and two additional neutrons are created. In addition some new energy is released. U239 acts as an absorber. Every time a neutron collides into a U239 nucleus it is absorbed by the later. The experiment aims to find a balanced number of U235 and U239 nuclei so that the chain reaction neither dies because of disappearance of all neutrons nor it becomes too rapid (as in uncontrolled fission).

Photorealistic visualisation in 3D

One of the problems of such simulations is that the students have sometimes problems with understanding abstract visualisations even if they are presented in 3D space. The problem is how to decrease the gap between the real world which surrounds us and the abstract models which are used in simulations. One of the possible solutions could be to use a more realistic visualisation and to approach the abstract presentation stepwise. The interactive programs can be even more attractive if written in some more realistic 3D visualisation environment. There are several WEB technologies, which permit such visualisation. Considering the needs of interactivity, the focus of the research was oriented in Java3D.
The interactivity of the hypertext user with these demo programs can be easily achieved by means of JavaScript routines that interact with public functions within applets. The problem of such demonstrations is that the client computer should have installed corresponding Java runtime environment (for java3D) and therefore such courseware is less platform independent as is the case with usual interactive applets. Such approach is therefore more appropriate for classroom demonstrations during lectures (Figure 4).

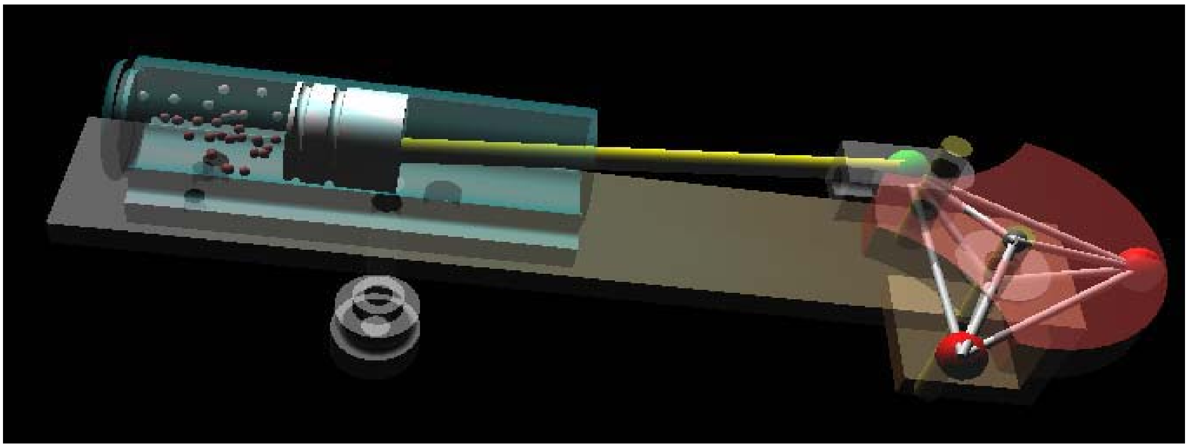

Figure 4. A 3D model of a steam engine

The transparency of the parts of this complex 3D model can be changed as shown in the figure. The figure shows the superposition of this 3D model with its abstract

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physical equivalent. In the cylinder a container with monoatomic gas is introduced. The length of the container (its volume) changes due to the pressure of this gas. The position of the piston in the cylinder depends on the volume of the container. The inertia wheel is substituted by several particles interconnected with springs. One of the particles of the wheel is connected with another spring to the piston.

Another interesting approach was used in the simulation of the already mentioned nuclear fission reactor. This simulation can be made more impressive by means of the following approach: The model of the nuclear fission reactor is represented by a 3 dimensional container which includes a quantity of U235 nuclei and one neutron with a predefined velocity. Besides this it includes two moderator rods (containers with some U239 nuclei), which can be moved up and down, thus controlling the reaction. In order to give a more realistic view the background of the experiment is presented with a textured plane along with a picture of the reactor, scanned from a textbook. By changing the transparency of this picture we can gradually move from the realistic to the more abstract view.

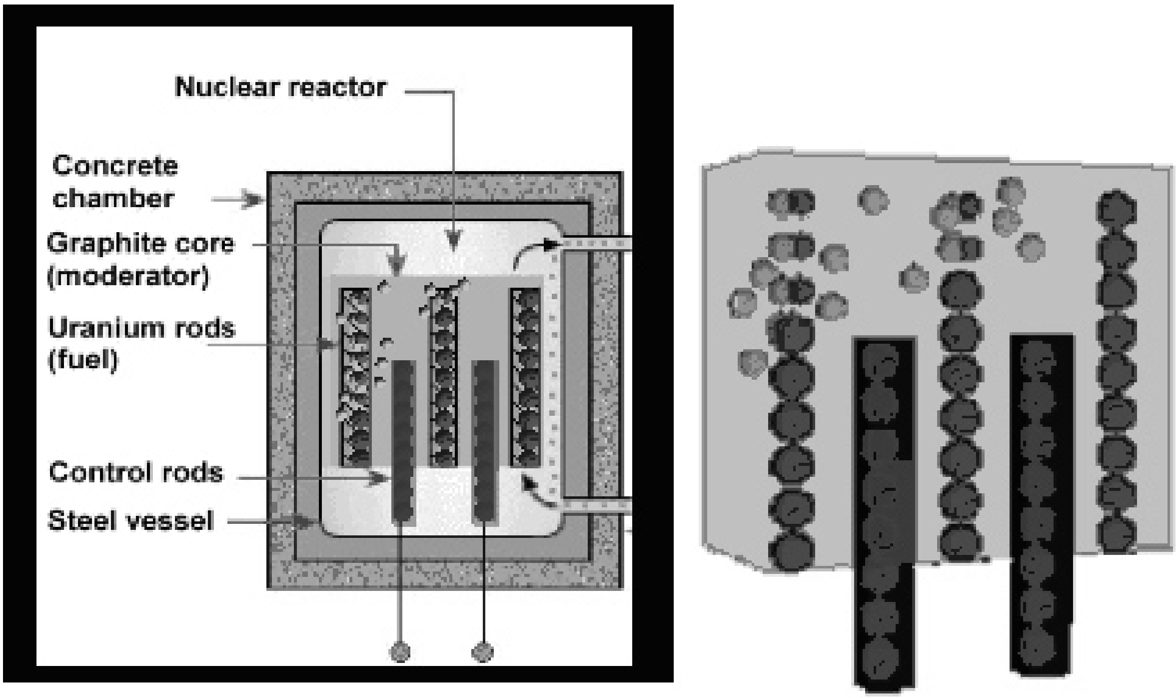

Figure 5. Example with nuclear fission reactor

The same technology can be used for a realistic presentation of the simulated physical phenomena and permits also education through play and fun. In fact such experiments resemble the well known computer games. The next figure shows such simulation of two colliding 3D bodies. The cars on the picture are in fact 3D models with corresponding masses and velocities. A student can study the fundamental rule of energy conservation by changing the physical properties of the visualised objects.

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Figure 6. Realistic visualisation of the collision between bodies

The presented visualisation technologies are not limited to teach physics and the same approach was tested in other domains, in particular chemistry, biology and even computer graphics and computer programming.

Conclusions

The interactivity of the hypertext user with Java based demo programs can be easily achieved by means of JavaScript routines that interact with public functions within applets. The problem of such demonstrations is that the client computer should install the corresponding Java runtime environment. When more advanced 3D examples (for java3D) are implemented such courseware is not platform independent, as is the case with usual interactive applets. Such approach is therefore more appropriate for classroom demonstrations during lectures.

References

[1] Haertel H, Physik 3D-Mechanik, xyZET, Ein Simulationsprogramm zur Physik, Begleitbuch, Springer Verlag: Berlin, 2000.
[2] Divjak S, Conceptual learning of sciences supported by Java compliant technologies, in Verdejo F and Gordon D, The virtual campus: trends for higher education and training. London: Chapman & Hall, pp.: 237-243, 1998.
[3] Christian W and Belloni M, Physlets: Teaching with Interactive Curricular Material, Prentice Hall Series in Educational Innovation 2000.

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Environmental Education in Greek Schools: The Viewpoint of the Local Coordinators

Kimionis G and Michaelides PG

Introduction

The institution of optional Environmental Education activities in Greek schools covers almost three decades. There are worries however in relation to the existence of the necessary structures, the institutional and legislative frame, and the conditions for its further development and proliferation.

The realization of Environmental Education projects in schools faces many organizational and institutional problems. The rather low percentage of participation of students indicates that the majority of them, the future citizens, have not profited from the advantages of Environmental Education. Moreover the small percentage of teachers that voluntarily undertake to carry out Environmental Education projects (Michaelides, Kimionis, 2000a) indicate that favourable conditions or motives attracting them to participate in such projects are rather missing.

Many constitutional and legislative regulations refer to the environment, its protection and its conservation. In the National Educational Law anyone may distinguish that the acquisition of knowledge and the development of positive attitudes towards the environment is quoted as an essential objective of Greek education (Michaelides, 1993). To what extent this is really occurring has not been investigated thoroughly.

According to recent surveys important steps towards the promotion of Environmental Education have been made. Mainly during the last decade (institution of local Coordinators for the Environmental Education in each regional Directorate of Education, integration of Environmental Education in the Curriculum, foundation of Environmental Education Centres). Still important problems remain and they generally function as an obstacle to the spread and application of the Environmental Education in schools.

In general the integration of Environmental Education in the educational systems of European countries is realized step by step, and small percentages of students develop an awareness which Environmental Education would provide with Spyropoulou 2001

The undefined content and the lack of limitation on the subjects of the Environmental Education projects are quoted among the most important problems as far as the application of Environmental Education is concerned. Furthermore the

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obscurity concerning the sense of Environmental Education, the lack or the insufficient training of teachers, the lack of motives and the lack of teacher's free time. (Papanaoum, 1997, Giannakaki 2000, Papadimitriou, 1995).

Methodology

The current research was conducted through a questionnaire, which was sent to all the 64 Environmental Education Coordinators in Secondary Education Directorates of Greece, by e-mail or fax, from December 2004 until April 2005. Only 41 answered, many after repeated phone calls and inquiries. This is by itself remarkable and needs further investigation.

Results

From the 41 returned questionnaires 26 (63.4%) were from men and 15 (36.6%) from women.
The higher percentage (51.2%) of Coordinators who answered, are working as teachers for 20-30 years, while 41.5% have 10-20 years of service. The 2.4% are working 5-10 years and the 4.9% are working 30 years and above.

Years	Frequency	Percent
1	2	4.9
2	12	29.3
3	3	7.3
4	2	4.9
6	2	4.9
7	3	7.3
8	2	4.9
9	2	4.9
10	3	7.3
11	4	9.8
14	6	14.6
Total	41	100.0

Table 1. Years of responsibility as Environmental Education Coordinators

The duration of service in the position of Environmental Education Coordinators is presented in Table 1. As it appears in that table, there is a high percentage of Coordinators with 2 or more periods of service in this position (every period is for a term of 3 years). There is also a percentage continuing to have this position (14

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years of service) from the introduction of the institution of the above responsibility. Consequently, it can be considered that the sample of the people participating the research posses enough experience on the subjects concerning the course and application of Environmental Education.
In any case despite the experience they have acquired in this position and the fact that most of them consider that they have sufficient, even satisfactory training (Table 2), still many of them feel that they need further training (Table 3), acknowledging the need for further knowledge concerning this position.
The questionnaire included specific questions on how the coordinators judged their competency and the degree of their satisfaction from the operation of Environmental education, prominent problems, etc. The results are summarized in Tables 2 to 10.

Question: How do you consider your training concerning your position?		
	Frequency	Percent
Sufficient	16	39.0
Satisfactory	23	56.1
Not satisfactory	2	4.9
Insufficient	0	0.0
Total	41	100.0

Table 2. Training concerning the position of Coordinators

Question: Do you believe that you need more training?		
	Frequency	Percent
Yes	37	90.2
No	4	9.8
Total	41	100.0

Table 3. Need of further training of Coordinators

	Frequency	Percent
Very	22	53.7
Mediocre	18	43.9
By no means	1	2.4
Total	41	100.0

Table 4. Satisfaction with the number of Environmental Education projects

	Frequency	Percent
Very good	3	7.3
good	29	70.7
Mediocre	9	22.0
Poor	0	0.0
Total	41	100.0

Table 5. The level of the application of Environmental Education

It appears from the answers of Coordinators that, when they refer to their area of responsibility, where their personal contribution is strong, they seem to be satisfied with the number of projects which are carried out (Table 4) and they consider the application of Environmental Education as satisfactory (Table 5). However, when they refer to the situation nationally they describe a more unpleasant situation (Table 6) and they declare that they are "a little" satisfied in a percentage of 68.3%. In the question: what is, according to your opinion, the most important problem that

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the Environmental Education face, a high percentage (53.7%) reports “the institutional”. A percentage of 22.0% reports “the economic” while a percentage of 17.1% reports “the organizational” problem. Moreover, some (a percentage of 7.3%), report as the most intense problem, according to their opinion, that of "*evaluation*" or "*teacher’s training*", even the "*pedagogic -instructive*". Coordinators consider also that the existing institutional framework is from "a little" as "by no means" sufficient, so that they cannot complete the objectives of their mission based on such a frame (Table 7). Only 7.3% consider that is “very sufficient” and 2.4% that it is “Very much sufficient”, while 2 individuals did not answer.

	Frequency	Percent
Very much	0	0.0
Very	10	24.4
A Little	28	68.3
Very little	2	4.9
By no means	1	2.4
Total	41	100.0

Table 6. Satisfaction for the existing situation of Environmental Education in our country

Roughly the same perceptions prevail also in the answers to the question if the existing institutional framework facilitates the work of the teacher for the completion of the Environmental Education projects (Table 8). A high percentage of 68.3% consider that it facilitates "A little" the teachers and a percentage of 22.0% consider that it facilitates "Very little".

We should mention that the current institutional framework was put into practice with the Ministerial Decision 57905/G2/4-6-2002, fifteen years after the official introduction of Environmental Education. Until then, the institutional framework illustrating the application of Environmental Education was derived mainly from the governmental law 1892FEK101/31-7-1990 and the Ministerial Decision F16/102/G1-308/3-4-91 and G2/4867/28-8-92. Someone would expect that the new framework would take under consideration the experience of past years of application of Environmental Education and would fulfill the expectations and needs of the Coordinators of Environmental Education and the teachers who are involved in Environmental Education. It seems though that nothing of the above is occurring, according to the answers of Coordinators, as they were illustrated in the questionnaire of the research.

The Environmental Education Coordinators consider as problematic factors, undermining the participation of teachers, the lack of motives (73.2%), the absence of further training (65.9%) and the lack of free time (70.7%). They also note that teachers are in desperate need specialized training (Table 9).

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	Frequency	Percent	Valid %
Very much	1	2.4	2.6
Very	3	7.3	7.7
A Little	25	61.0	64.1
Very little	7	17.1	17.9
By no means	3	7.3	7.7
Total	39	95.1	100.0
Missing System	2	4.9	
Total	41	100.0	

Table 7. Institutional framework with regard to the Environmental Education Coordinators

	Frequency	Percent
Very much	0	0.0
Very	2	4.9
A Little	28	68.3
Very little	9	22.0
By no means	2	4.9
Total	41	100.0

Table 8. Institutional framework with regard to the teachers

Question: Do you consider that the teachers need further training?		
	Frequency	Percent
Very much	19	46.3
Very	22	53.7
A Little	0	0.0
Very little	0	0.0
By no means	0	0.0
Total	41	100.0

Table 9. Teachers need of further training

Do you consider that the state…		
	Frequency	%
encourages the application of I.E.	16	39.0
is indifferent for as the application of Environmental Education	18	43.9
impends the application of Environmental Education	7	17.1
Total	41	100.0

Table 10. The intention of the state

The desperation and disappointment of Coordinators is reflected intensely in their answers to the question regarding the contribution of the state towards the application of Environmental Education. A percentage of 43.9% considers that the state is “indifferent” and a percentage of 17.1% that the state “impends” the application of Environmental Education. Only 39.0% supports that the state encourage the application of Environmental Education in Greece (Table 10).

Conclusions

The answers of the Local (regional) Coordinators responsible for the Environmental Education show a disappointment and a sense of lack of support from the state concerning Environmental Education. The institutional framework does not seem sufficient neither to the teachers, nor to the Coordinators of Environmental Education. The impression they have is that the state in fact is indifferent or even impends the application of Environmental Education in schools since there are not, according their opinion, the essential and favourable conditions that would motivate the teachers, support the Coordinators and encouraged really the application of Environmental Education. Therefore, the reform of the Institutional Framework to take into account the past experiences of the operation of the Environmental Education and the viewpoints of the teachers and of the local Coordinators, as well

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as that of the staff of the Centres for Environmental Education seems necessary. Further training is of the most important factors to support the Environmental Education. Its importance is pointed out from everybody and many of researches (Flogaeti, 1993, Kimionis 1995, Michaelides-Kimionis 2000b, Michaelides et al, 2002) refer to its necessity. The continuous and sufficient training of teachers in the Environmental Education will give impulse and will contribute positively in the application of Environmental Education.

References

[1] Flogaeti E, Environmental Education, Athens, Hellinikes Panepistimiakes Ekdoseis, pp.: 211-230 (in Greek), 1994.
[2] Giannakaki S, Organization and Policy for the Sustainable Growth, Diikitiki Enimerossi, 5: 120-126, 2000.
[3] Kimionis G, Geographic Informative Systems as Instructive Tools in the Environmental Education, Postgraduate Thesis, Department of Primary Education University Crete, Rethymno (in Greek), 1995.
[4] Michaelides P and Kimionis G, Participation of Students in Optional Programs of Environmental Education Projects, in Proceedings of the Congress on Environmental Education in the Content of 21^{oy} Century: Prospects and Possibilities, Papadimitriou V, (Ed.), Larissa, pp.: 111-119 (in Greek), 2000b.
[5] Michaelides P and Kimionis G, Fifteen Years of Environmental Education in the Prefecture Rethymno, First Assessment, Conclusion and Reflections on the Future, in Mpagakis G, (Ed.), “Optional Educational Programs in the School Education”, Metechmio publ, Athens, pp.: 350-358 (in Greek), 2000a.
[6] Michaelides P, Kimionis G and Charalambidou F, The Participation of Pupils in Environmental Awareness Activities, in 3rd Pan-Hellenic Congress in Didactics of Natural Sciences and Application of New Technologies in the Education, Rethymno, pp.: 108, 2002.
[7] Michaelides PG, Subjects of Environmental Education in the Public school, Synchroni Ekpaidefsi, 71: 71-81 (in Greek), 1993.
[8] Ministerial Decision 57905/Γ2/ 4-6-2002.
[9] Ministerial Decision, F.16/102 Γ1-308/3-4-91.
[10] Ministerial Decision, Γ2/4867/28-8-92, Schools Activities.
[11] Official Journal Of The Hellenic Republic, Law 1892,111,13, vol101/31-7-1990.
[12] Papadimitriou B, Teachers and Environmental Education, Pedagogiki Epitheorissi, 22: 215-231 (in Greek), 1995.
[13] Papanaoum Z, Environment and Education from Viewpoint of Teachers: a Empiric Investigation, Paidagogiki Epitheorissi, 28: 171-193 (in Greek), 1997.
[14] Spyropoulou D, Appraisal of Environmental Education for the Decade 1991-2000. Epitheorissi Ekpaideftikon Thematon, 5, 155-164 (in Greek), 2001.

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Optics and Pool: Play the Game

Lima CFS and Costa MFM

Introduction

In this communication we will present an experimental work to be carried out by students, from even the early ages of basic school, in a non-formal environment. Using a pool table (a game well known to many students) students will perform a series of experiments learning and demonstrating the laws of light reflection.
The idea of associating the use of a pool table to the teaching of geometric optics is based on the need to make the teaching process more appealing on behalf of the students. Being pool a popular and appealing game it would be possible to teach physics concepts in an apparently informal or non-formal context. This assembly is also simplified due to the fact that only day-to-day materials are used, reducing its final cost as we only need to perform a few reversible changes to a pool table.

How to bring together pool and optics

To a regular (or especially designed) poll table is attached a flat mirror system, that is placed along the table borders. Laser pointers aligned over the table will allow us to visualize the incidence and reflected beams' path, as it is shown in Figures 1 and 2.

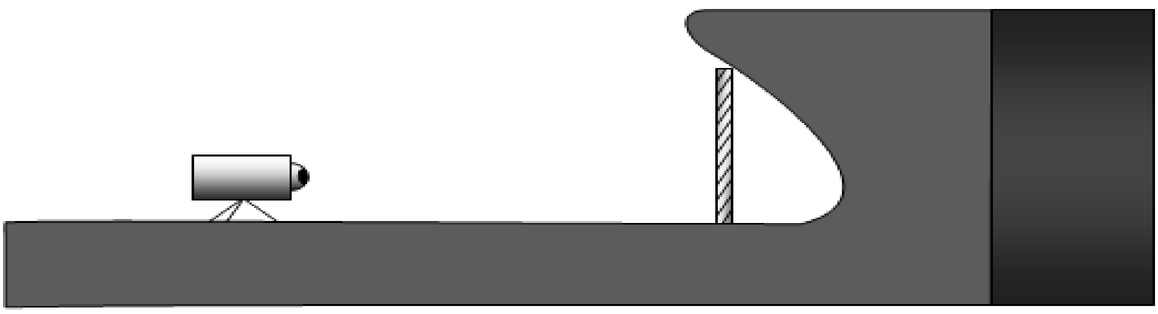

Figure 1. Adaptation of a mirror to the pool table walls

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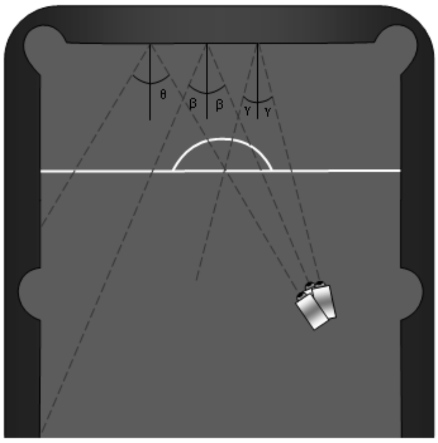
This way, it is possible to predict the ball's path by applying the laws of reflection, as it is shown in Figure 3.
In a subsequent stage, the used mirrors will be made spherical concave and convex, and adapted to the pool table, being the experiments and calculations preformed in a similar to those preformed with the flat mirror system, as shown in Figure 2.



Figures 2. Scheme of the application

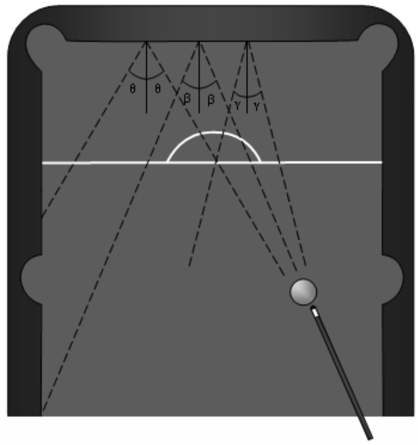


Figure 3. Prediction of the ball's path

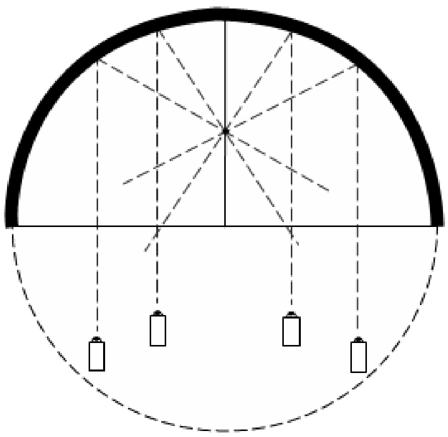


Figure 4. Adaptation of spherical concave mirror to the pool table

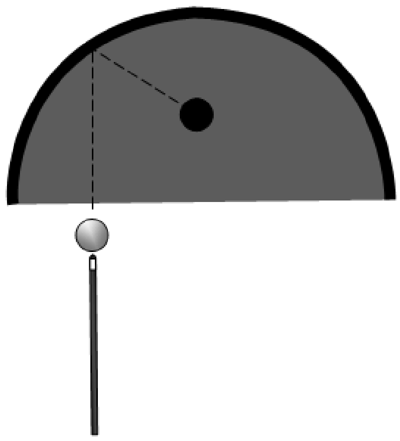


Figure 5. Prediction of the ball's path in a spherical concave table border

As it is possible to see, in a pool table with this shape, all the balls moving through a trajectory parallel to the straight sides of the pool will always enter the hole made on the table, if it is positioned in the focus of the analogue mirror (Figure 5.).
At the time of the curve mirror experimentation we can also explore geometry related concepts like, for instance, the determination of focal lengths.

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How to achieve the activity' objectives

With the implementation of this system it is meant for students to take conclusions about the laws of reflection by comparing the ball and luminous beam paths.
Other of our goals is to raise the interest of the students to a subject like optics, using a well know and always fashionable game, played from youngsters to older people, in every contexts of the society.
Using this popular game, with the proper adaptations, it is also possible to use this equipment in the study of many other concepts, like:

- the reflection laws (as it was shown above);
- the optical fibers – as it happens in the optical fibre, the ball will move in the pool table, bouncing along the borders, as the light beam reflect along the fibre.
- mechanical energy conservation -using a spring to push the ball it is possible to relate the ball velocity with the force applied to the spring resulting in different total trajectories of the ball (number or re-bounces that will be intuitively related to the energy lost during the bouncing and re-bouncing process).
- linear momentum conservation. This is surely one of the first ideas we may have when thinking about a pool table. However the previous observation of the light reflection process will help the full understand of this process - using several ball's students will study and understand linear momentum conservation in collisions.

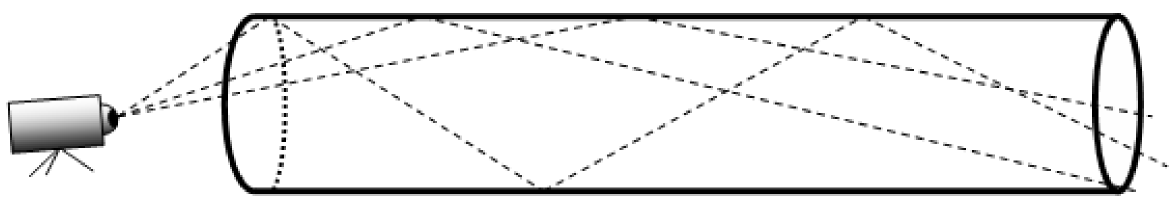

Figure 6. Scheme of light propagation in a optic fiber

One of the advantages of this equipment is that it is possible, with small adjustments and a bit of imagination, to create new combinations that may allow the exploration and study of many different concepts. In a more developed stage of the experimentation of this system we can create more challenges such as making the pool ball reach a certain position, after a given number of hits (an equivalent to the same number of light reflections).

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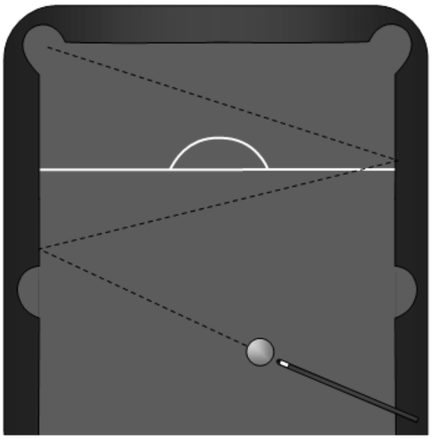

Figure 7. Adaptation of the pool table to optical fibres study

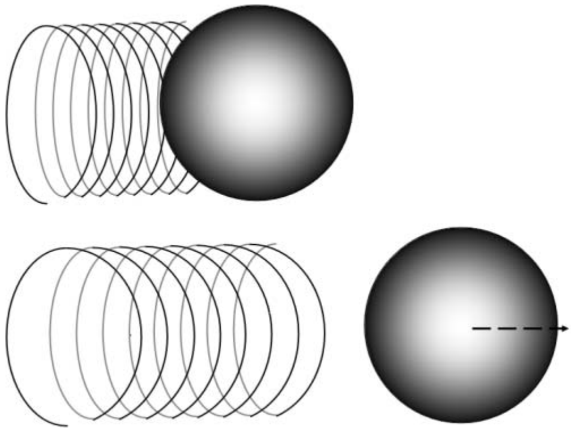

Figure 8. The use of springs allows the adaptation of the pool table to the study of energy conservation

The objective can be the conception, by the students, of systems (including adaptations of the pool table) or procedures to study some defined phenomena with the establishment of the correct strategy: the elaboration of the strategy for the study of a subject implicates a good knowledge of it.

Conclusion

Learning in a non-formal or informal context often is easier and more effective, especially if the activities involved relates to former knowledge or experience from the students. Furthermore it is essential that the fun side of it is complemented by serious analysis that should always lead to the establishment of clear conclusions.

Acknowledgement

This work enrols in the frame of activities of the Hands-on Science network.

References

[1] Eugene H, Óptica, Fundação Calouste Gulbenkian: Lisboa, 1991.

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Hands-on Science in Romania, Act II

Sporea D

Introduction

During the second year from the starting of “Hands-on Science” project we focused on the development of the Romanian network, on the diversification of the activities run under the project umbrella, and on the improving the visibility of the project achievements. New associate members joined the team, and meanwhile the groups involved into science teaching small projects spread across the country. The paper exemplifies the main results, underline the experience gained in this period and points out to the plans we have for the next year. For some specific results see the papers of some Romanian teachers contributing to this volume.

Activities and outcomes

Considering the success of the previous year as it concerns the use of the graphical programming environment LabVIEW in building real and virtual experiments for physics teaching we continued our efforts in spreading this practice. The new schools were enrolled into this programme, and, a part of the teachers who take master courses and have the possibility to study the programming, we encourage teachers from other towns to start a self study campaign and we are offering consultancy when needed. Additional results in using virtual instrumentation in classrooms are also reported at this Conference (e.g. Mrs. Garabet and Mrs. Ruset reports). Our pragmatic approach in using this software tool was to complement the programming facilities with training kits and dedicated sensors, to assist teachers in building real experiments. Following this line, training aids for mechanics and electricity were purchased in the project frame and were offered to partner schools (Figure 1)

A team of two high school teachers, leaders in using LabVIEW for both real and virtual experiments, made two trips in less developed area in Romania (Valea Jiului county where, after mines closing, a high unemployment rate is registered, and Ramnicu Valcea county in a rural region) in order to introduce the philosophy of the “Hands-on Science” project to interested school teachers. In the mean time, they presented the results they have using virtual instrumentation and PC-base data acquisition. The most remarkable fact concerning this initiative was their demo visit to a village with a dominant romaine population (ure. 2). The interest of the

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audience was astonishing. We expect to be able to promote more such exchange visits in the near future.

Figure 1. Training kits and special sensors offered by the project to the "Grigore Moisil" Theoretical High School in Bucharest

Figure 2. Demonstrating hand-on experiments at a romaine school in Ramnicu Valcea County

The interest towards the project is demonstrated also by the organization of science contest for secondary school students in the Slatina town, where young people participated with great enthusiasm in building their own small experiments (see Mrs. Vladescu' paper). The contest focused the interest of a great number of very young and innovative students, and their work was rewarded both at the national science fair organized in Bucharest (Figure 3), and at the local level as they were invited to "perform" during the celebration of the Europe' Day on May 9.
In order to make as accessible as possible the demonstration of advantages of the PC-controlled experiments, we started to build a small portable demo laboratory based on a National Instruments data acquisition board, operating over the USB connection. This approach coupled with a set of sensors can be used for onsite training sessions. We have to thank to National Instruments Company for its generous support of this endeavour. The team from "Grigore Moisil" Theoretical High School demonstrated also this teaching aid to a teacher's conference in May 2005.
The same dedicated team organized by the end of April a science fair at national level. More than 160 students participated at both secondary degree and high school level from almost all regions of Romania. Microsoft Romania generously sponsored the travel of students and teachers in Bucharest and offered awards. The science fair "Hands-on science@moisil.ro" included the developments of real and virtual experiments, design of web pages with science related content, experimental mock-ups, live demonstrations. In Figure 4 is presented the experiment developed by a group of high school students, set-up used for the investigation of microscopic objects by coupling a CCD camera to a PC. Very simple but educationally efficient mock-ups were presented by school children having a great interest in science. In Figure 5 a simple electrical motor built with

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trivial materials was demonstrated. The study of hydrostatic pressure was demonstrated by a team from Slatina town (Figure 6), while their older colleagues report an investigation of the drinking water quality in various wards of Bucharest (Figure 7).

Figure 3. Innovation and technical skills proved by secondary school student from Slatina

Figure 4. Investigation of an insect morphology with a PC-controlled microscope

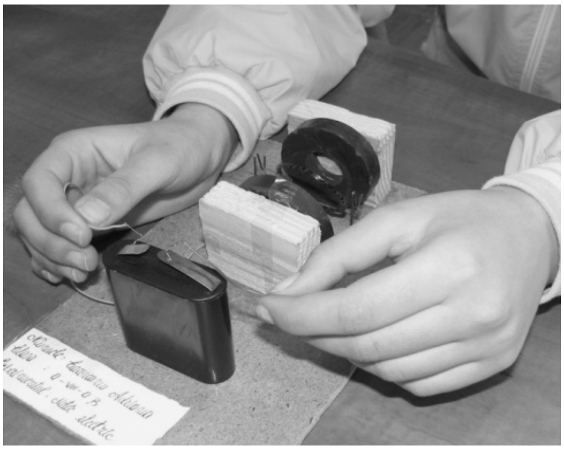

Figure 5. A simple and efficient electrical motor

Figure 6. Demonstrating pressure in liquids using trivial components

During the last year, most of the activities carried out in Bucharest were centred on the newly created science club. The Club gathers several high schools having different structures (i.e. theoretical high schools, vocational training centres) and focuses (natural sciences, economics, etc.). The Club was initiated by the Tudor Vladimirescu High School, but soon other educational units joined the stream (Figure 8). In this way, as the participation grown up, we are organizing almost every month a meeting, having different hosts and centred on specific subjects. More information can be found in Mrs. Pausan's paper. What is very interesting is the fact that each participant brings his experience and "culture" and various means

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of expression are encouraged. So, a complex, very non-formal interaction is established between teachers and students. The way they approach science teaching is extremely complex starting from reports on a selected theme, experiments, debates, poster sessions (Figure 9), exhibitions, and finishing with small pieces of poetry on science written by students or even short plays with scientific message. The most exciting thing was that some of the performances were played in foreign languages.

Figure 7. Young chemists answering questions on the drinking water quality in Bucharest

Figure 8. The open of the "Science Fun Club" at Tudor Vladimirescu High School in Bucharest

An interesting experience was delivered by the club activities at the High School "Kiritescu" in Bucharest where the central theme of the activities run was consumer protection. Within this frame, groups of school students demonstrated chemical tests used for the quality certification of food stuff (Figure 10). A second subject was pollution of the environment. We have to highly appreciate such an approach as it proved very pragmatic and from the educational point of view oriented towards community needs.

In some cases live experiments were carried out targeting basic phenomena. In Figure 11 the line forces of the magnetic field are beautifully materialized.

As the experimental kits available to an average ranked high school are quite in a short supply in Romania we took the opportunity to organize in the frame of some science club sessions some demo exhibition with classical experiments (Figure 12). In this way, students from different high schools had the possibility to access some experiments not available in their respective schools.

The operational capabilities of the Romanian network were strengthen by a generous donation received from EXFO, Canada, a manufacturer of testing equipment for the optical communication industry. The instrumentation received includes both emitters and powermeters, operating at two wavelengths which will be used to diversify the activities of the "mobile" demo laboratory, by including training sessions on optical fiber communications principles and the most important tests carried out for such systems. We expect that in the next year more on site training

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sessions will be performed in different parts of Romania, mainly in regions with economic problems, to give a chance to a pool of less privileged students.

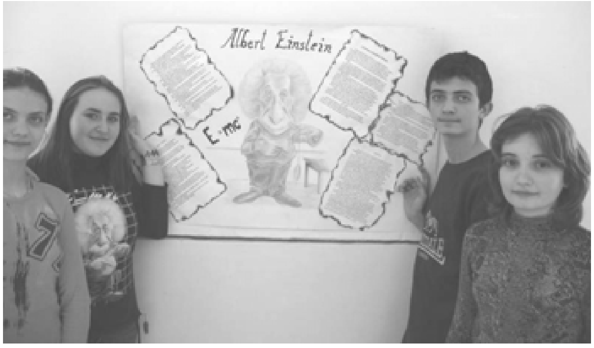

Figure 9. Participants to the poster contest having as subject the "life and activity of Albert Einstein"

Figure 10. Students from a high school on economics concerned about consumer protection by scientific evaluation

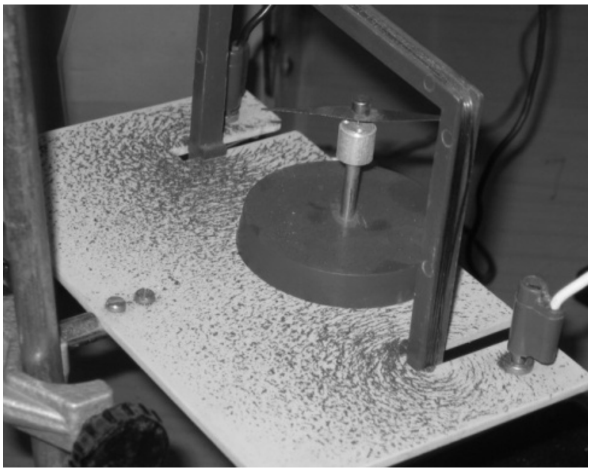

Figure 11. Visualization of the magnetic field through a classical experiment

Figure 12. Exhibition of laboratory experimental kits

During the last year we tried to encourage also the production of written training aids both in a print form (Mihaela Garabet and Ion Neacsu – "Experiments in the Physics Laboratory", printed in Romanian) and in electronic format ("Papers of the First National Science Fair", also in Romanian). Both materials were distributed for free to schools or during conference presentations.
As our efforts were also directed towards the dissemination of the project results we deliver a talk at an international conference on education held in Romania, and which was published in the conference proceedings [1]. On the same line, an interview with the Hands-on Science network Professor Manuel Costa was published in a well known Romanian magazine dedicated to science issues – "Stiinta si Tehnica".

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Our interaction with media diversified as D. Sporea delivered a presentation on the project at a local TV station in Bucharest. The training sessions run by Mihaela Garabet and Ion Neacsu in schools from the Jalea Viului Country were also extensively covered by the local television.
Our policy included also the development of local and regional links on science teaching. Within this frame, we participated with a paper to a NATO/UNESCO sponsored Advanced Research Workshop held in Hungary [2]. Following this meeting our Institute, which is coordinating the network activities in Romania, applied and became a member of the Network of Youth Excellence-NYEX. In the same context the author took part to the “Science in Society Forum 2005”, organized by the European Commission in March 2005, where new contacts were established. In June 2005 the author was also invited to attend an international workshop on science education in primary schools in Serbia. On this occasion a review of the Romanian achievements in teaching science in schools is planned. This meeting also will be an opportunity to establish regional links and start some forms of cooperation.
Another direction of our work is related to an extended web-based research we carried out concerning the “meanings” and “the ways of implementation” of science literacy. The paper was presented at the workshop organized by the “Hands-on Science” network in Malta, in January 2005 [3].
In order to support the network efforts and to promote its results a proposal was sent in May 2005 to the European Commission asking for approval of an exhibition booth at the November 2005 Conference on communicating European Science. According to our strategy the booth will include presentation of the network achievements in various forms (posters, multimedia presentations, mock-up, printed material and e-materials as training aids, short films, etc.).

Acknowledgements

The author wishes to acknowledge the contribution of the Romanian “Hands-on Science” network members for their support in organizing and running the mentioned activities. Special thanks go to Mrs. Mihaela Garabet, Mrs. Emilia Pausan, and Mr. I. Neacsu, high school teachers in Bucharest for their enthusiasm and competence.
The support we received through donations from EXFO, Canada and National Instruments, USA is also gratefully acknowledged.

References

[1] Sporea D and Costa MF, Science Teaching in High Schools – the Comenius “Hands-on Science” Project, in Proceedings of the International Conference on Education WORD EDU 2004: Education Facing the Contemporary World Problems, Editura Universitatii din Pitesti, 2004.
[2] Sporea D and Sporea A, The Romanian Experience within the Comenius “Hands-on Science” Project, The 2nd NATO-UNESCO Advanced Research

ISBN 978-989-95336-2-2

Workshop (ARW No. 980515) and the Satellite of the UNESCO-ICSU 2005 World Science Forum, Eger, Hungary, 2004.
[3] Sporea D and Sporea A, Web Resources on Science Literacy, European Workshop on The Challenges of EU' Enlargement on Science Literacy and Development, Malta, 2005.

Paper presented at the 2nd International Conference on
"Hands-on Science. Science in a changing education",
Rethymno, Creta, July 13 to 16, 2005.

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Hands-on Science Activities for the Teaching and Learning of Mechanical Energy with 6th Grade Primary School Children in Greece

Tsagliotis N

Teaching and learning about energy

A teaching and learning approach of the "energy" concept in science education is considered to be important because it constitutes a fundamental process, which allows predicting and interpreting the behavior of a wide variety of physical systems, referring to diverse branches of physics and/ or other areas of science (*inter-phenomenological character of energy*). Moreover, the understanding of socio-scientific issues, such as energy supply and use within a sustainable development approach, appears to be of equal importance nowadays (*socio-cultural character of energy*).

Within the context of "school science" or science curriculum "energy" is treated as a rather compulsory topic for secondary science. Nevertheless, it constitutes a disputable and controversial issue for primary science education, mainly due to its abstract nature, which is difficult to become concrete or even reified to a certain extent for the age group of 10-12 year-old children. There appears to be a lack of consensus in primary science education with respect to the developmental appropriateness of the concept and the "correctness" of possible "simplifications" and/or approximations (Trumper, 1990). In most cases energy is associated with sources or properties of certain object e.g. batteries and fuels rather than concepts like heat and light (Duit, 1984). There appears to be a tendency to conceive energy as a property of living organisms commonly associated with motion or a physical endeavour, which seems to be strongly linked with the meaning ascribed to the word "energy" (*energetic*) in everyday situations (Solomon, 1992). Moreover, "energy" is often used as a label to attribute different meanings to different contexts e.g. "something happening" "something going on", "giving-taking energy", "make something go or stop" etc. (Brook, 1986).

It is often claimed that energy seen as "*the ability to do work*" and the focus on the conservation law, have not been very successful in the promotion of a substantial and functional understanding of the "energy" concept (Duit, 1986). It has been claimed that even when secondary students are taught and somehow recall the

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second law, they often fail to answer questions which require deeper conceptual understanding of the law (Solomon, 1992). Furthermore, learners tend to avoid referring to the conservation law when they analyse the behaviour of given physical systems (Driver and Warrington 1985). This lack of understanding with respect to the law of conservation is often attributed to the fact that it is counterintuitive, in the sense of being inconsistent with everyday experience (Solomon, 1992). In other words, it appears that learners have difficulties in conceiving the idea of "closed energy systems", and if that is the case for secondary science, perhaps it can be equally considered as an "epistemological obstacle" for the teaching and learning of "energy" in a primary science context.

Nevertheless, there appears to be a shift in the emphasis from teaching about forms and transformations of energy *per se*, to the analysis of systems depicting a process, based on the idea of energy transfer and change (Chisholm, 1992). It is also claimed that an approach of "energy degradation" should be present in association with the conservation law (Duit, 1986) and that could be started at the last two grades of primary school (11-12 year-olds). This is based on the premise that understanding energy degradation might enhance the development of understanding about the conservation law (Duit, 1986; Solomon, 1992) or at least it can create a sort of a fruitful foreground. In this inquiry, "energy" is seen through a context of "change-degradation", providing foreground hints for energy conservation, within a primary science education approach.

The teaching intervention approach

In the design of the teaching intervention, the *"Model of Educational Reconstruction"* has been taken into account, in an attempt to balance approaches that pay attention to the science subject matter structure with those that mainly focus on learners' perspectives, abilities and needs (Kattmann *et al.*, 1995; Duit, R. and Gropengießer, 2004). It is claimed that the overall aim of the model is *"to identify the connections between scientific knowledge and the students' alternative frameworks in everyday life and also to re-construct meaningful relations which may get lost in the course of scientific and teaching activities"* (Kattmann *et al.*, 1995). The most valuable feature of the model appears to be the intimate interaction of its three main components: a) *the analysis of content structure*, b) *the empirical investigations* and c) *the construction of instruction*. Thus, science subject matter appears to be a reference position in order to understand the learners' perspective, but also the latter may constitute a reference position to facilitate more adequate understanding of the science point of view and vice versa (ibid.). In the course of development of the teaching intervention several teaching and learning strategies have been employed such as: extension of existing views and application in new situations, development of scientific understanding in parallel with existing notions or even recognition of appropriateness and/or applicability of explanatory frameworks in various situations (cf. Scott *et al.*, 1992).

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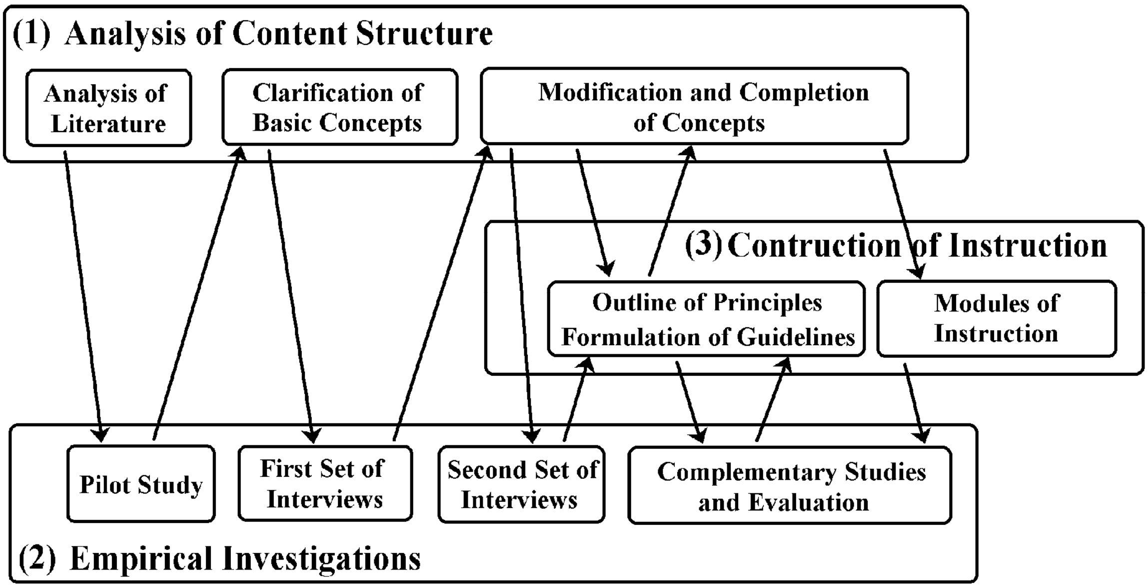
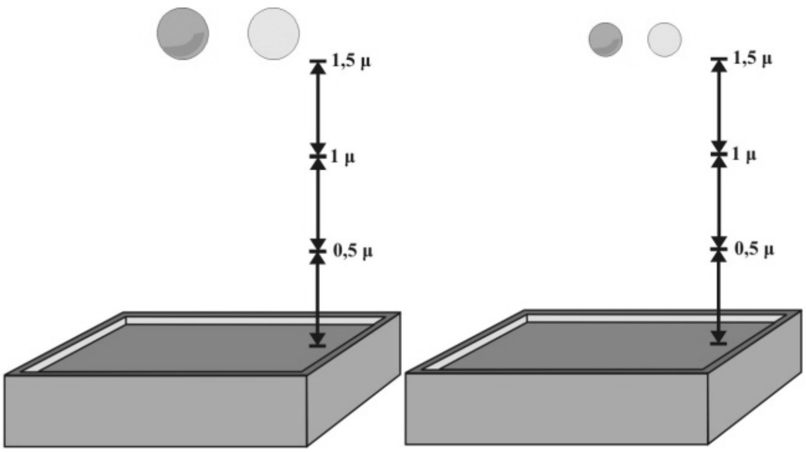


Figure 1. The Model of Educational Reconstruction

The teaching intervention about mechanical energy lasted for a series of 12 teaching hours and dealt with concepts like *work*, *dynamic energy*, *kinetic energy*, *wind energy*, *energy change* and *energy degradation*, within a context of practical investigations such as the following:



- dropping balls on wet sand, of various weights and from different heights, study the craters they create in the sand and make inferences about dynamic energy and its relation to weight and height.
- examination of everyday toys (e.g. jumping toy frogs with elastic tails, moving toy cars and wind up toys, which have been deconstructed studied in class, investigating elastic and metallic plates that "store" dynamic energy and "change" it to kinetic energy).

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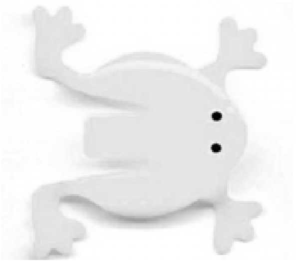
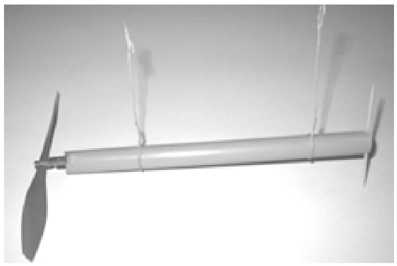
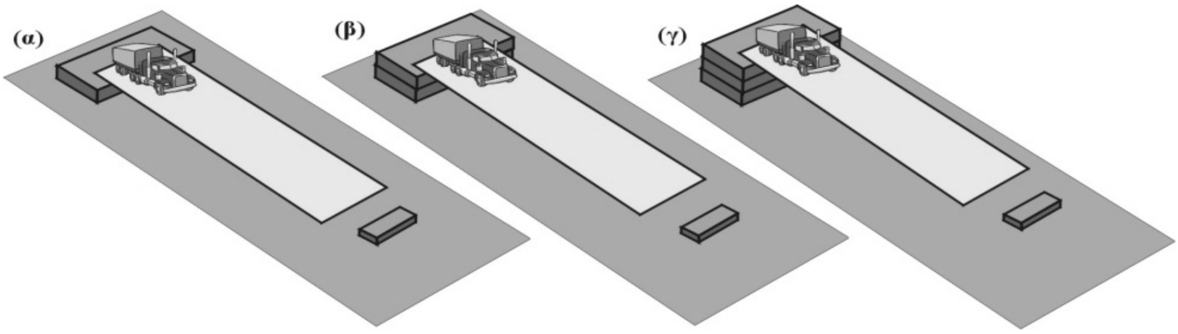
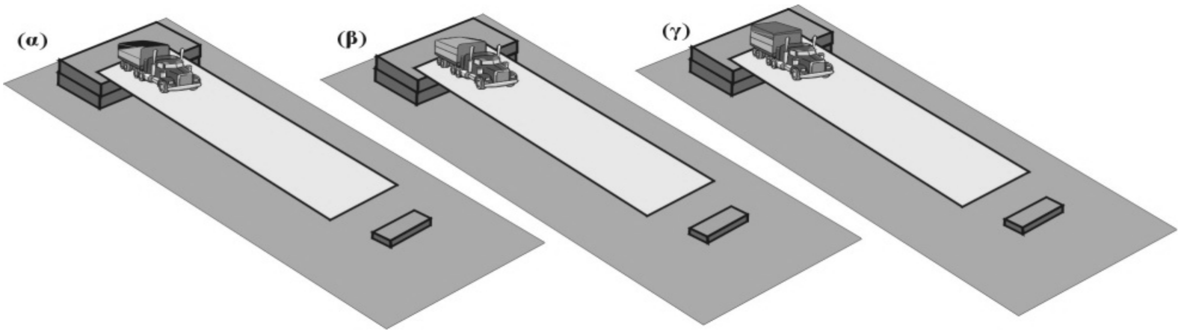




- construction of toys as project work (e.g. aeroplanes, catamaran boats and toy cars moving with “rubber band energy”) (cf. Taylor, 1998; Tsagliotis, 2005)
- studying kinetic energy with lorries rolling down the slope at different heights and from the same height with different masses





- similarly, studying kinetic energy with a marble rolling down the slope at different heights and with marbles of different masses from the same height, moving a paper cup at a distance

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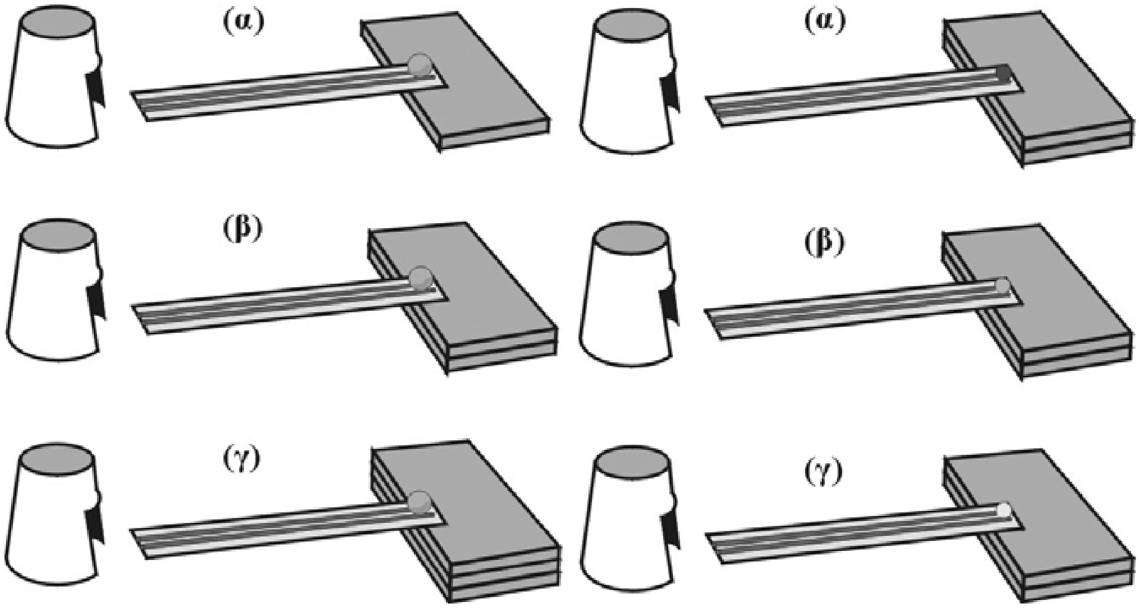
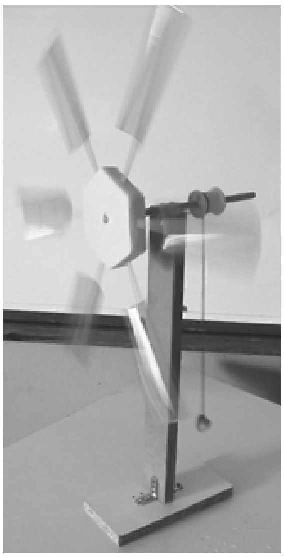
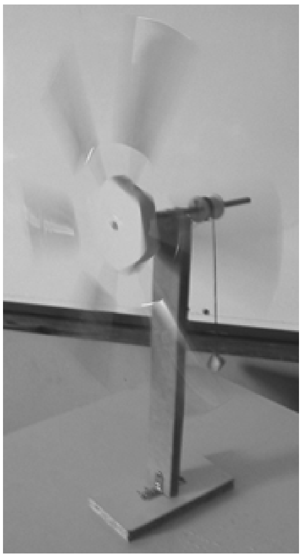
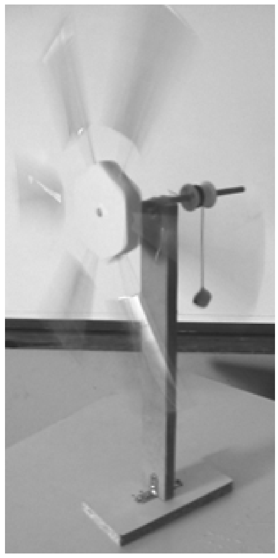


- "*wind energy*" in the case of sailboats and wind mills (constructed in class to lift up weights) was discussed as an "application" of mechanical energy and as an example of energy change and degradation.







Research approach

From a practitioner-researcher's standpoint (Schön, 1983), research has been carried out in an educational setting of a 6th grade of primary school with 35 children, divided into two classes (18 and 17 respectively). The overall aim is to provide insights into a particular teaching and learning environment throughout a certain period of time and to understand and describe aspects of conceptual change about mechanical energy with 11-12 year-old children in a primary science classroom. In other words, according to Niedderer *et al.* (1992), this inquiry aims to

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describe *“selected states”* of children’s ideas and conceptions before, during and after a teaching and learning process, in order to understand the variety of these conceptions and the ways they evolve and change.
More specifically, the research questions of this inquiry are the following:

- What variety of conceptions or ideas do children have about mechanical energy?
- What kind of changes in children’s ideas and conceptions about mechanical energy can be pointed out?
- To what extent does a conceptual framework of “energy change and energy degradation” enable children to understand aspects of mechanical energy?

Sixteen (16) out of the total of 35 children, selected to be of mixed ability, have been interviewed before and after the teaching intervention with the *Interview-About-Instances* technique (Gilbert *et al*., 1985), using the same set of interview cards. The instances depicted on the set of 10 interview cards for mechanical energy came from everyday activities (i.e. man pushing a heavy box), children’s playground (i.e. children playing on the seesaw, swinging, going down the slide, child throwing a tennis ball bouncing on the floor), sports (i.e. weightlifter), natural phenomena (i.e. a stone going down a hill slope) and human constructions for the use of mechanical energy (i.e. a water mill, a wind mill and a sailing boat). The same children were interviewed again six months after the completion of the research episode using a second set of 4 interview cards, which depicted both similar but also differentiated instances from those of the earlier set.
The interviews have been fully transcribed and are analysed in three levels. At *first level* the *Pre-Intervention Interviews* and the *Post-Intervention Interviews* are analysed separately, in order to elicit a variety of qualitatively different conceptions about the depicted instances before and after the teaching interventions on mechanical and solar energy. At *second level* the elicited conceptions are to be compared within the context of each depicted instance, in order to identify conceptualisation differences, in an attempt to reveal the dynamics of conceptual change. At *third level* the conceptions of particular children-cases are considered across the interview cards, both in pre and post intervention interviews, in an attempt to obtain deeper insights in children’s evolution of conceptions and conceptual change. The post-interviews, taken 3 months later, will be considered separately and in combination with the 2nd and 3rd levels of analysis. The *NVivo* software from *QSR* has being used in the coding and analysis of the interview data (cf. Gibbs, 2002).

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Findings and discussion

Findings indicate that *before the teaching intervention* mechanical energy appears to be seen as an “action”, an “activity” or a “human endeavour”, strongly associated with motion and “pace”, whereas things that are not moving “have no energy”. *After the teaching intervention* mechanical energy appears to be seen as “stored energy” (dynamic energy) when “things are high up” or when they are “stressed”, “pushed down” or elastically deformed, but also as “energy of motion” (kinetic energy) which is related to the “speed of objects” or to the “pace they have while moving”. *“Energy change”* appears to be discerned in the card-instances as dynamic-kinetic-heat change [e.g. rock rolling down the hill slope], whereas *energy degradation* is seen though “energy change to heat” due to “friction” [e.g. swing, seesaw, wind mill, sailing boat,] and “crashes” “fading” [e.g. rolling rock, water crushing on the water wheel]. In this sense *energy degradation* is seen as energy which “is put out of use” or is “incapacitated” for a useful cause or result, “turned into heat”, which cannot be easily used further.

Such aspects of change on children’s conceptions about energy from the pre and post-intervention interviews can be seen through a framework of multiple *variations* of conceptions about energy, discerning different aspects of situations and phenomena, which come into focus, are the matised by reflection and appear to be context dependent. Within a *dynamic approach* to conceptual change, children appear to experience and discern some varied features of mechanical energy, in terms of characteristics and aspects that come to the fore and remain into focus, within the particular context of the depicted instances of the interview cards. As Marton (1990) has argued, *“within the internal dynamics of a conception of something, a restructuring is taking place and one meaning develops into another”* and that appears to be a gradual and on-going procedure.

The notion of *multiple varied conceptions* can be seen as a challenge to a theory of conceptual change, which assumes *conceptual stability* and does not focus on the dynamics of awareness (Pong, 1999). If multiple, varied conceptions are context dependent, it appears more important to be able to recognise a context, discerning some of its features into focal awareness, and in this sense evoke an *appropriate* conception, in terms of *conceptual appreciation*, delimited by the particular context (cf. Linder, 1993).

References

[1] Brook A, Children’s understanding of ideas about energy: a review of the literature, in Driver R and Millar R (Eds.), Energy Matters, University of Leeds, pp.: 33-45, 1986.
[2] Chisholm D, Some energetic thoughts, Physics Education, 27: 215-220, 1992.
[3] Driver R and Warrington L, Students’ use of the principle of energy conservation in problem situations, Physics Education, 20: 171-176, 1985.
[4] Duit R and Gropengießer H, The model of Educational reconstruction - Science Subject Matter and Educational Issues in Harmony / Research and Development Intimately Linked. ESERA Summer School, 2004.

ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

[5] Duit R, Learning the energy concept at school – empirical results from Philipinnes and West Germany, Physics Education, 19: 59-66, 1984.
[6] Duit R, In search of an energy concept, in Driver R and Millar R (Eds.), Energy Matters, University of Leeds, pp.: 67-101, 1986.
[7] Gibbs GR, Qualitative Data analysis: Explorations with NVivo, Open University Press: Buckingham, 2002.
[8] Gilbert JK, Watts DM and Osborne RJ, Eliciting Student Views using the Interview-About-Instances Technique, in West LHT and Pines AL (Eds.) Cognitive Structure and Conceptual Change, Academic Press: London, pp.: 11-27, 1985.
[9] Kattmann U, Duit R, Gropengießer H and Komorek M, A model of educational reconstruction. Paper presented at the Annual Meeting of the National Association of Research in Science Teaching (NARST): San Francisco, 1995.
[10] Linder CJ, A Challenge to Conceptual Change. Science Education, 77: 293-300, 1993.
[11] Marton F, The phenomenography of learning-a qualitative approach to educational research and some of its implications for didactics, in Mandl H, De Corte E, Bennet N and Friedrich HF (Eds.), Learning and Instruction, Pergamon Press, pp.: 601-616, 1990.
[12] Niedderer H, Goldberg F and Duit R, Towards Learning Process Studies: A Review of the Workshop on Research in Physics Learning, in Duit R, Goldberg F and Niedderer (Eds.), Research in Physics Learning: Theoretical issues and empirical studies, Institute of Science Education: Kiel, pp 10-28, 1992.
[13] Pong WY, The Dynamics of Awareness, Paper presented at the 8th EARLI conference, Göteborg University: Göteborg, 1999.
[14] Schön D, The reflective practitioner, Basic Books: New York, 1983.
[15] Scott PH, Asoko HM and Driver R, Teaching for conceptual change: A review of strategies, In Duit R, Goldberg F and Niedderer H (Eds.), Research in Physics Learning: Theoretical issues and empirical studies, Institute of Science Education: Kiel, pp.: 310-329, 1992.
[16] Solomon J, Getting to know about energy in school and society, The Falmer Press: London, 1992.
[17] Taylor BAP, Exploring Energy With Toys: Complete Lessons for Grades 4-8, National Science Foundation: Learning Triangle Press, 1998.
[18] Trumper R, Energy and a constructivist way of teaching, Physics Education, 25: 208-212, 1990.
[19] Tsagliotis N, Mechanical and Solar Energy Projects … in Action. A science fair, in the 2nd International Conference on Hands-on Science: Science in a changing education, 13-16 July, Rethymno, University of Crete, 2005.

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Boring but Vital – How Should We Teach Our Students about Chemical Safety?

Cartwright HM

Introduction

Safety should be an influence on every aspect of the way that science is taught, both at school and in College or University. However, while this is easy to state, it is not always easy to put into practice.

All competent science teachers appreciate the importance of safety, but students may regard it as an irrelevance, or as an inconvenience that gets in the way of "real" science. They might be required to wear a lab coat and use safety glasses in the laboratory, but only comply with these rules because they are mandatory. Students tend, especially in their teens, to doubt the need for protection from chemicals, and to be particularly uninterested in protection from themselves and from their co-workers. By contrast, school administrators may take exactly the opposite position, fearing litigation were an accident to occur in a laboratory in which safety precautions were not being followed to the letter.

Both students and administrators may, for quite different reasons, see safety as a separate matter from the underlying science. In fact, science and safety are inextricably linked, as several case studies in this paper will illustrate. These case studies are drawn from a variety of real incidents reported on the media or on the Internet. In most cases those concerned have deliberately not been identified.

Case Study A

A chemistry laboratory activity on the web describes a potentially valuable exercise for science students in a high school. Groups of students are given a hypothetical budget of $20,000, and are then issued with promotional literature and catalogues from science suppliers. Their task is to furnish from scratch an imaginary science laboratory.

Among the stated aims of the exercise is that the students should "...review the safety equipment needed for a chemistry lab", which suggests that safe working will be a key consideration. However, in the exercise no indication is given about how safe working within the laboratory could be promoted.

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In fact, the task of buying equipment for the imaginary laboratory appears to be completely detached from its subsequent operation, though in fact the two should be closely linked; safety should influence the purchasing decisions at every stage.
This exercise is potentially valuable. It would be regarded as an interesting challenge by typical students, but the way that it is presented plays down the importance of safety. The exercise may give students the impression that safety is an extra that can be bolted on once laboratory design is complete. This is an unfortunate - and potentially dangerous - view.

Integration of safety into teaching

Safety should be a part of everything that we do in the practical science laboratory. In this paper, we consider first the principle reasons why safety is so crucial in the school laboratory, beginning with the most obvious reason – the need to avoid accidents.

Safe practice

It is clear that chemistry students, and those who study other subjects but must use chemicals in their practical work, need to learn about chemical hazards so that they can carry out experiments safely. Instruction designed to ensure safe working not only protects students, but also the school in the unfortunate event of an accident. Case Study B illustrates how inadequate or inappropriate preparation for a practical demonstration can have serious consequences.

Case Study B

"I never saw anything like it," said student Diana S, who was in the chemistry lab when the blast occurred.
This second case study concerns an accident in a school chemistry laboratory. The local news media reported that:
A beaker exploded Friday after a chemistry experiment went awry at X High School, sending out a fireball that burned three students and a teacher.
The explosion occurred [as a] teacher was attempting to perform a common experiment that uses methanol and mineral salts to show how different metals produce different colors of flames.
She told the class, "This is why fireworks turn colors," and proceeded to pour material into a glass beaker…..the teacher [then] attempted to ignite methanol in some coffee cup-sized glass beakers. "When they failed to ignite, she began to add more methanol. … there was an explosion as the undetected flame ignited the fresh vapors," fire officials said.
It appears that the teacher in this instance had not fully appreciated the danger to both herself and to her students of what she was doing. Methanol burns with a flame that is hard to see, especially in a well-lit room. Evidently the accident was a result of her failure to recognize this, or to be aware that far safer methods for conducting flame tests exist.

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Understanding chemical properties

It is essential to ensure safe working conditions in order to avoid accidents of the type outlined in Case Study B, but there are further reasons why safety should routinely be integrated into teaching, among them the opportunity that safety instruction provides to reinforce other aspects of science.
When a substance poses a risk to those handling it, this risk is a direct reflection of the substance's chemical or physical properties. Because the hazards that the substance presents are determined by its structure, as students learn about safety they can simultaneously be developing their knowledge of chemistry itself. The safety message and the chemical understanding reinforce each other.

Case Study C

Tuesday was just the second day of class at Y High School when teacher M began his science experiment, which had always been exciting but safe. Instead, a 5-gallon glass water cooler bottle shattered, sending shards of glass flying across the room and 22 students to local emergency rooms.
This was another incident illustrating the dangers of using methanol in other than well-controlled conditions. The reaction of local officials was perhaps surprising.
Officials quickly determined that the explosion was simply an unfortunate accident.
"Unfortunate" the event certainly was, and "accident", in the sense that it was unexpected, was a good description of what had happened. However the combination of these words into the phrase "unfortunate accident" seems to suggest that the incident could not have been foreseen, which would not appear to be the case.
"This was an approved demonstration experiment," High School principal D said. "What went wrong nobody can tell at this point."
A local University Professor provided a more detailed explanation of what had gone wrong:
"Methanol is …. used in a variety of experiments because it burns clean and, under normal circumstances, is quite controllable. The problem with methanol, a volatile liquid, is that it gives off vapors at a low temperature, around 50 degrees. It has a "wide flammability range" which means that there doesn't have to be a thick concentration of vapours for a fire to ignite."
Notice in this explanation the degree to which the accident might have been anticipated through a knowledge of the properties of the chemical involved. Methanol "burns"; it is "volatile", it generates significant quantities of vapour at modest temperatures and has a "wide flammability range". If these properties had been known to the students and kept in mind by both them and their teacher, the "unfortunate accident" might have been avoided.
As one of the students in class subsequently is reported to have commented:

"And people ask me why I don't like chemistry."

while a parent commented more perceptively

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"An accident isn't really an accident. It's someone else's mistake."

Long term appreciation of safety

Every substance that exists is a chemical. However, consumers are often impressed when a product contains "no chemical additives", or that "no chemical fertilizer was used in the production of this grain", since there is an increasing desire to avoid "chemicals" in food.
This illustrates the deep apprehension - and misapprehension - that exists amongst members of the public about chemicals. Quite reasonably they wish to avoid putting themselves or the environment in danger, but lack the basic knowledge required to make reasoned judgments about whether their actions may do this.
Many difficult environmental and ethical scientific issues exist on which there are wide differences of opinion among the public: genetic manipulation, the greenhouse effect and global warming, the enlargement of the ozone hole, the discovery of residues of contraceptives and agricultural fertilizers in drinking water, the widespread use of colorants in food and more.
Ideally, decisions about such matters would be taken by the population at large, not by scientists alone or (much worse!) just by politicians. However, without an adequate understanding of safety or, more broadly, science, people make decisions on the basis of gut feelings, or incomplete knowledge.
Within a few years of studying science at High School, students will find themselves with the power to influence decisions, as voters, or even the chance to put forward possible courses of action, as lawmakers. In order to assess realistically the hazards associated with a chemical, an understanding of safety and the ability to make a realistic judgment about the potential hazards of an operation or chemical are vital.
The failure to make justifiable assessments of risk is illustrated by the several chemicals that are discussed in Case Study D.

Case Study D

The Food Standards Agency (FSA) in the UK is a government-funded body responsible for ensuring the safety of all consumer foods.
In February 2005, the FSA became aware that a batch of chili powder used in the preparation of a range of foods had been contaminated with Sudan I. Sudan I, a bright red dye licensed for use in a variety of products but not, in most countries, in food, had apparently been illegally added by suppliers in the Indian subcontinent to a batch of raw chili powder to make it appear more appealing. More than 450 food products in the UK suspected of contamination were removed from shops within days but the problem quickly emerged in other countries as products that might have been contaminated before export were identified.
The rapid action taken by the FSA in the UK, and by similar bodies in other countries was understandable. The IARC had previously reported that Sudan I had been found to be carcinogenic in mice following its subcutaneous administration,

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producing tumors of the liver. It was thus judged by the FSA to be dangerous to health.
But was the action taken by the FSA a realistic and proportionate response to the dangers posed by Sudan I, or just one that the public would expect and approve of?
Although the IARC stated that Sudan I was carcinogenic by subcutaneous administration, it also reported that tests by oral administration in mice and rats were negative.
Food Standards Australia similarly indicated that the dye did not present an immediate or serious risk:

"There is ..... no evidence that [Sudan I dye] can cause harm in humans, particular at the low levels found in these foods."

In view of the very low level of any Sudan I residue and the fact that any contaminated food would have been swallowed rather than administered subcutaneously, it is reasonable to conclude that the real risk posed by the contamination was almost certainly negligible.
Despite this, there was a high level of concern among consumers in Europe. The public response to the withdrawal of food products was revealing. On 10th March an anonymous poster on Irishhealth.com wrote

"What worries me is what other dangerous additives are in food. If you look at the list of ingredients on some of the packaged foods, some of the items listed are barely pronounceable."

The implication that a chemical whose name one cannot articulate is somehow more dangerous than one whose name one can, is surely not a view that a scientist would have sympathy with.
Irishhealth.com reported that

".... many people contacting the authority .... wanted to know whether they could check the ingredients on packets of food for [Sudan I]. But as it should not be in food in the first place, it is obviously not listed. "

This sort of query from consumers reveals both a deep level of mistrust about "chemicals" in foods and a serious of understanding about how one might assess any dangers.
A further illustration of how difficult it is for the general public to know what chemicals are or are not safe is provided by the NTP (National Toxicology Program).
In its 11th RoC report, released on Jan 31, 2005, the NTP identified 2-amino-3,4-dimethylimidazo [4,5f]quinoline and phenylimidazopyridine as potential carcinogens; both may be formed when meat or fish is grilled at a high temperature or barbecued. Sudan I is not listed by NTP as a carcinogen, but these chemicals produced by barbecuing are.

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It is illogical, though perhaps understandable, that many people would be happy to continue to barbecue meat and fish, but at the same time would feel nervous about eating a commercial product contaminated with a dye which represents perhaps only a modest danger and is present in foods at levels so low as to be close to or below detectable limits.

This reluctance or inability to accurately assess the harm that a chemical might pose is deeply embedded, as a further example illustrates.

Acetaldehyde is classified by NTP as one that is reasonably anticipated to be a human carcinogen.

Should we therefore be trying to avoid all exposure to acetaldehyde? In fact, it would be extremely hard to do so: acetaldehyde is used as a flavoring agent and adjuvant. It is added to milk products, baked goods, fruit juices, candy, desserts, and soft drinks to impart orange, apple, and butter flavors. It is used in the manufacture of vinegar and yeast and as a fruit and fish preservative. It is found in trace amounts in all ripe fruits and may form in wine and other alcoholic beverages after exposure to air. It is found in leaf tobacco, tobacco smoke and automobile and diesel exhaust.

It is a product of alcohol fermentation and is a metabolic intermediate in higher plants. It is a volatile component of cotton leaves and blossoms. Acetaldehyde occurs in oak and tobacco leaves and is a natural component of apples, broccoli, coffee, grapefruit, grapes, lemons, mushrooms, onions, oranges, peaches, pears, pineapples, raspberries, and strawberries.

There are numerous other sources, including cheese, cooked chicken, rum, room deodorizers, marijuana, cigarette smoke, burning wood, forest fires, volcanoes, rosemary oil, mustard, and ambient air. It is clear that this is a ubiquitous chemical Despite that, it is listed as a hazardous air pollutant by NESHAP and a potential occupational carcinogen.

This lengthy case study illustrates how difficult it is to assess potentially harmful chemicals and determine how one should react to their presence in the environment. Only in the easiest of cases, for example exposure to cigarette smoke, are the hazards well documented and means of avoidance simple to understand.

However, exposure to moderately harmful chemicals is very widespread, indeed it is virtually unavoidable, and the scientific training needed to make informed decisions regarding such exposure resides with only a small proportion of the population. If safety becomes more deeply embedded in science teaching we may be able to create a population more able to make the critical judgments about chemical exposure.

What are we doing wrong?

Science has a mixed public image. Scientists have been responsible for great advances in society, but for great threats too.

At school, science may have a "nerdy" image, and enthusiastic science teachers can try to raise its popularity by engaging in spectacular and flashy experiments, to create excitement about the subject. Such experiments are often memorable,

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perhaps in proportion to how dangerous they are, and may succeed in increasing interest in science.
Nevertheless, they are not without their disadvantages. From them, students may get a distorted picture of both science and safety. They may come to believe that the dangers in chemistry are readily observable and controlled: "See, the chemistry teacher gets this spectacular explosion right every time, she never blows her hand off". Conversely, they may come to believe that chemistry is the science of danger, full of hazardous and unpredictable materials.
Neither view is the whole truth, but much of the rather poor reputation that chemistry has can be traced back to this kind of unbalanced view of the threat that chemicals pose. Safety depends upon context: chlorofluorocarbons (CFCs) are inert at ground level, yet present a hazard in the stratosphere where they destroy ozone. By contrast, ozone itself is harmful to both animals and materials at ground level, yet life would be virtually impossible without its presence in the upper atmosphere. Some understanding of science is necessary to understand how such chemicals can be both safe and harmful.

How can we improve safety?

As the earlier case studies illustrate, one of the most important responsibilities of the teacher is to develop in students an understanding of safe practice.
With suitable instruction and encouragement students will work more safely in the laboratory; they will more readily comprehend the properties of substances if they understand that safety and chemical structure are linked; they will be able to make more reliable judgments about important scientific issues in the “outside world” if they have been well versed in safety matters; and they will be more likely to see the chemistry teacher's flash-bang experiments for what they are - demonstrations of the properties of exceptional chemicals, not a demonstration of how everyday chemicals can be expected to behave.
Improving students' understanding of safety so that they both learn effectively and work safely requires an attack on several fronts. While many of the suggestions below are straightforward, there will perhaps be some ideas for improving safety in the classroom you have not tried.

1. **Safety is not optional, so cannot be open to negotiation between students and teacher.** More than in any other area, it is essential that safety rules be clear, unambiguous and rigorously enforced. The requirement to work safely should be as central to the course as the use of textbooks.
2. **Students should be provided in advance with safety data where appropriate, but also encouraged to search for data on-line or in books so as to become familiar with sources of data, their structure, and the abstraction of relevant information from them.**
   Time required for initial instruction on how to search will be time well spent. However searching must be done with care - simply typing "Ethanol MSDS" into a search engine will generate hundreds of thousands of hits, but the data

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must be in a form that students can understand without additional help. Detailed MSDS data are difficult to interpret, so a short list of web sites that provide data in a suitably simplified form is helpful.

The HSci Safety web site [1] provides data on a number of common chemicals in a format that is readily interpretable, and suggestions for additional chemicals for inclusion on the site are welcome.

It is valuable to assess web sites before they, or particular pages from them, are recommended for use, otherwise the information that they provide can be counterproductive. For example, the otherwise very helpful site LabSafety.org reports that

> "While many lab accidents involve methanol—an extremely flammable liquid also known as methyl chloride—........"

3. **Safety should not be treated as an after-thought, tacked on at the end of the instructions for an experiment.**
   Whenever the risks presented by a chemical are being discussed, an attempt should be made to spell out the physical and chemical reasons *why* a chemical is dangerous, not just the fact that it is.
   Diethyl ether presents a considerable fire and explosion risk. This should be explained by making it clear that the ether is very volatile (due to its low molecular weight and the comparatively low intermolecular forces in the liquid), that it forms a heavy vapour that can travel across benches and settle in sinks (molecular weight significantly higher than that of air) and that it burns very vigorously (formation of carbon dioxide and water from organic compounds is usually very exothermic). The linking of safety matters to properties should enhance student understanding of both, as well as encouraging them to think!
4. **The health and safety hazards of all substances involved in a procedure should be researched and noted down by students before the experiment is begun.**
   If students have discovered for themselves that they will suffer burns if the chemical is spilled on the skin, the message seems to have more of an impact than if they are merely told about it. An occasional check on students' safety research before they start work will encourage them to do a good job.
5. **When environmental issues can be introduced into a discussion, they should be treated in an unbiased fashion, neither emphasizing nor downplaying the risks.**
   Encourage students to interpret environmental problems in terms of the way the chemicals behave, not just the fact that chemicals can, under certain circumstances, be harmful.
   For example, CFCs are stable and harmless at ground level, but harmful in the stratosphere and so have largely been phased out of use in refrigerators, deodorants, etc. It would be simple to explain that CFCs have been found to damage the upper atmosphere by destroying ozone, but it is surely better to explain why there is a problem.

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What particular properties of a CFC are responsible for its classification as a pollutant? If CFCs are banned, can we estimate how many years will pass before they no longer present a hazard? The lifetime of CFCs in the atmosphere is very long; what feature of these compounds and their behavior is responsible for this? When chemicals such as CFCs are banned, how can we judge whether alternative chemicals will be any better? Might the environmental impact of alternatives be different but perhaps just as harmful?

By tackling a topic in this way, the safety issues are integrated into a study of chemistry and the environment, making the whole exercise both more effective and more interesting.

6. **Students must be encouraged to appreciate that environmental issues are almost always complex.**

   For example, DDT concentrates in body fat and has had a serious effect on the reproductive capabilities of wildlife near the top of the food chain in many parts of the world. Consequently it is now rarely used.

   However, common replacements for DDT are inferior in terms of mosquito control, and it is legitimate to ask what level of suffering amongst humans and their livestock is permissible to obtain a given improvement in the welfare of surrounding wildlife. There is no easy answer to such a question, but students will gain much by being given the opportunity to consider it.
7. **Students should be asked to take sides when debating issues of safety.**

   By doing so they will learn to appreciate the complex nature of environmental decision-making and be better able to make a reasoned judgment in the future.
8. **Links between safety and ethical issues should be addressed.**

   Who is responsible if a hazardous chemical is dumped illegally in a water course, or if an industrial company allows toxic waste to contaminate its land? The answer is obvious, but not all pollution problems can be so easily laid at someone else's door. Who is responsible if a municipal water supply becomes contaminated with residues of contraceptive pills, as is now happening in many western countries? In some senses the risks presented by chemical contamination are only a small part of a story since most chemicals produced industrially are harmful only if used in inappropriate ways.
9. **Everything is chemical – this should be made clear from the start of a course, as soon as students learn what a chemical is.**

   The belief that "chemical" fertilizers are harmful while "natural" fertilizers are safe reveals a gross misunderstanding of what the term "chemical" means. A blanket view of the safety of chemicals is neither necessary nor wise. The chemicals that are given "E numbers" when added to foods include many that are therapeutic, yet it is common to hear people arguing that the fewer E-numbers a food contains the better it must be. It is helpful if positive images of chemicals are presented, for example their use in recycling, to counteract the inevitable negative examples.
10. **Where possible, the hazards that a chemical may pose should be related to its position on the Periodic Table and to the behaviour of those chemicals close to it on the Table.**

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Students learn almost as soon as they encounter the Periodic Table that all elements in group I produce corrosive hydroxides and that those in Group 8 are inert and therefore generally safe. The hazardous properties of chemicals can be considered alongside other properties, such as mass or degree of metallic properties. It is also often helpful for students to be asked to compare two substances, both chemically and in terms of the hazards they might present.

11. **A standalone safety course should not be used to replace more traditional approaches unless there are strong arguments in its favour.**
A course devoted entirely to safety is almost inevitably theoretical rather than practical, but the best way to learn about safety is by learning from a competent teacher in the laboratory. When a purpose-built safety course is offered, those teaching “standard” science courses may feel that safety has been adequately covered elsewhere and that they need give little further instruction, or just rely on showing a CD once a term.
12. **Within a group of students the burden of finding out about safety should not fall on a just one.**
It is tempting for a group of students to assign the task of researching safety issues to one of their number, while the others get on with the experimental side of the task. However, the experimentalists may then fail to appreciate the safety implications of what they are doing, or overtake the safety expert in the group and encounter a problem before the relevant safety information has been located.
13. **Students should spell out, in written form, the health and safety implications of the experiment before they start work.**
The analysis should explain *in their own words* how the students will minimize or eliminate relevant risks - a few printed pages of MSDS data should not be regarded as sufficient to demonstrate an understanding of the problems that might arise.
It is helpful to ask students to speculate about "what could go wrong?" Suppose the beaker of flammable liquid they are using is knocked onto the bench and breaks, spreading liquid across the bench; is there a source of ignition nearby? If a fire ensured, are there other chemicals on the bench or shelves above it that might also catch fire and perhaps lead to a major incident?
14. **Approaches should be tailored to the needs of different groups of students.**
Clearly a group of ten-year olds will need a different approach from a group of seventeen-year-olds, but so too will a group of chemists need an approach that is different from that required for a group whose interest is in geography or biology.
15. **Both processes and properties should be discussed.**
Runaway reactions are responsible for accidents in industrial laboratories and in university teaching laboratories each year. Discussing these reactions provides an excellent core topic around which the interplay between kinetics and thermodynamics can be discussed.

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References

This section contains references to a small number of online sources of information on safety. The Internet is a somewhat less reliable source of data than the printed page, but is undoubtedly cheaper and generally more convenient. With care, therefore, in the choice of web sites, the web can provide an effective means of securing safety data for all the common chemicals used in the laboratory.

[1] The HSci database of chemical information for students provides data on a small but growing number of chemicals that are widely used in school and College laboratories. Suggestions for additions to the database are welcomed by the database owner and are normally dealt with rapidly. http://ptcl.chem.ox.ac.uk/~hmc/hsci/hsci_chemicals_list.html

[2] The Safety Database of the Physical and Theoretical Chemistry Laboratory at Oxford University contains a wide range of safety data, covering not just chemicals but reactivity and other risks, a chemical glossary, data regarding choice of protective gloves and similar information. http://ptcl.chem.ox.ac.uk/MSDS

[3] The Siri web site contains links to a large database, much of it provided by suppliers of chemicals. There are numerous further useful links. http://www2.siri.org/msds/index.php

[4] The Occupational Safety and Health Administration and its sister agency NIOSH provide extensive background data, and is a useful resource for those investigating policy rather than just the safety of specific chemicals. http://www.osha.gov/

[5] The U.S. Environmental Protection Agency web site is a second source of general information about a wide range of environmental and safety issues. http://www.epa.gov/

[6] The EPA and OSHA web sites are sufficiently complex that, if you intend to use them in class, it is wise to do some preliminary research so that you can readily direct students to useful information if they get lost!

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Science with a Difference – Organising Planet Walk in Malta

Marks JB

Introduction

Malta is a small island in the middle of the Mediterranean Sea. The island is renowned for its heritage – museums, churches, archeological sites, megalithic temples and plenty more for the islanders and many a visitor from abroad to see and to appreciate in terms of a cultural and historical experience. However, the issue that is being discussed in this paper focuses on the scientific aspect of what Malta can offer.
Some important points that one can ponder upon are:

a) What does ‘Science’ stand for in as far as the Maltese population is concerned?
b) How big an issue is ‘Science’ in Malta?
c) What importance do the Maltese give to science education?
d) Which are the sites on the island that one can visit in order to increase one’s motivation towards the appreciation of the fact that science can be fun and is alive?

Science in the Maltese context

In order to try and answer the above questions briefly, one may begin with a general example. The issue of the environment in Malta may be considered. Many Maltese have become aware of the importance of keeping our environment clean. Government regulations regarding waste management and pollution overall, have helped a lot in this regard. Reading the regular Environment Section articles of the Maltese weekly newspaper “The Sunday Times” (2004-2005) gives full evidence of this. But, on the other hand, does the general public necessarily relate waste management to ‘Science’? Even to this very day, when the word ‘Science’ is mentioned, more often than not, a science class comes to people’s minds. Perhaps even an experiment conducted in a laboratory may relate well to what one understands by ‘Science’. Some may associate ‘Science’ with the reading of long,

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maybe abstract or difficult to understand text, with calculations involving sometimes easy or at other times difficult mathematics.

Science in Maltese schools

In Maltese schools, students are taught General Science in their primary classes, going on to do the separate sciences throughout their secondary education. The National Minimum Curriculum emphasizes the importance of instilling in our students, a greater awareness of the role of science and technology in everyday life through

- arousing curiosity concerning natural phenomena and stimulating the asking of questions about them,
- presenting science as a systematic means of asking and attempting to answer questions arising from observations,
- recognizing that different students can experience science differently.

(Ministry of Education, 1999, p.49)

In fact, a Science Centre exists within the Department of Curriculum Development of the Education Division in Malta. In a recent interview conducted during the month of June 2005, with the teacher in charge of this centre, it was confirmed that the work of the centre is aimed at developing the curriculum related to primary and secondary science and helping to better implement it in schools. The centre provides ongoing in-service training for science teachers in primary and secondary schools – training aimed at improving teaching methodologies so as to try to teach and reach all students. When asked about whether specific school outings were set by the department, for schools to be prompted to indulge in educational visits, the response was that with more decentralization, state schools have been given autonomy to act on their own. It is up to the teacher to decide where to take the students and to choose the type of visits which are expected to be most beneficial for that particular class and level of education.

Indeed, educational outings have always been organized for school children of different ages. Educators know that "good practice has always looked outward from the classroom and has drawn on the known experience of children to illustrate and instruct" (Hopkins, 1968, p.1-9). Specific reference to such outings was made in a B.A (Educ) dissertation written in 1981. Some of the outings with a scientific aspect were described and analysed for effectiveness. Amongst these outings, the authors mentioned a ship repair facility, a brewery, a printing press, the Meteorological Office, the Government milk production facility, the power station, an edible oil production plant and the Natural History Museum.

Today, other establishments have been set up like, for example, a Nature Theme Park, which includes a mini zoo (Guzeppina Deguara Primary School website). During an interview with the Headmistress of a Junior Lyceum Secondary School, some other outings with a scientific theme were identified. Students had actually

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visited these places during the scholastic year 2004/2005. These included the Plant Propagation Unit, where plants are propagated by tissue culture, a National Nature Reserve, and also a Centre for the Study of Marine life. Progress definitely brings about changes and additions. This Headmistress said that students are taken out on scientific outings three times per scholastic year. She said that school outings are a possibility but they are not obligatory. In fact, some teachers prefer to do experiments in the laboratory, to taking their students on outings.

If one looks closely at the places that students are taken to visit, one realizes that except for the Natural History Museum, the rest are either private enterprises or Government establishments where one needs to ask for permission before entering.

However, one must also mention ‘Science Week’ in Malta, which is another scientific activity that has gathered momentum these last years. It is a hands-on exhibition organized “to get people interested in science in a fun way” (The Malta Independent, April 2005).

When one considers all of the above, one can say that while it can be that not all the Maltese can relate all scientific issues to Science yet policy makers do realize the importance of Science and science education. It is the expression of this importance into even more practice, which is what is highly desired and yearned for. With the importance of science that exists in every aspect of one’s life and the great need to increase public awareness of science as well as interest in everything around us, one can never say that one is doing enough.

Why Astro-Club?

At the beginning of the scholastic year 2004-2005, the author of this paper made a call to students at the institution where she lectures in Physics, suggesting the start of an Astronomy Club with the aim of increasing awareness that science can be done with a difference. The choice ended up on Astronomy because it has a sense of wonder and mystery linked to it – something that all of us are intrigued with. A number of young people aged sixteen to twenty two, were enthusiastic about the idea and formed the group, some also bringing their friends with them. The group consists of twenty members, boys and girls, and meets every week.

Ever since the first meeting, the group of youths has shown a lot of energy directed towards what can be done for Malta, in relation to science. Their motto is the same as described by Mayo (2002): “Making a difference in the science education community”

The group decided to call themselves Astro-Club and the Logo they designed for their club can be seen in Figure 1. During an HSci conference held in Cologne in 2004, the author of this paper, as advisor to the group, had learnt about ‘Planet Walk’. The idea of setting up ‘Planet Walk’ in Malta was mentioned to Astro-Club members. The group showed a lot of enthusiasm at the possibility of working at something scientific, on a large scale. They saw a great challenge in working to make project ‘Planet Walk’ a reality and bring it to completion.

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Figure 1. Astro-Club Logo

What is Planet Walk?

One of the most incomprehensive aspects of Astronomy is, in fact, the large distances involved. Even our own solar system's distances are quite hard to imagine. In 'Planet Walk' a number of monuments, starting with the Sun, is set up in such a way that visitors can get the feel of how the solar system is organized, by walking from one monument to the next. The distances between the monuments are in the same ratio as the actual distances between the Sun and the planets in the solar system, but, of course, scaled down. The planets are also scaled down in size and this truly adds perspective to the 'Planet Walk' (Walking through the Solar System, 2005). What makes 'Planet Walk' so fascinating is the fact that it helps to physically experience the solar system "in a way that no other medium (book, computer) can. Anyone can directly grasp the dimensions of the solar system" (Planetenweg, 2004).

A number of planet walks are already in existence in the world. There are definitely planet walks in Germany, Sweden, the United States and also in the United Kingdom. It is of interest to know that the first planet walk in the world was set up in 1971 in the German city of Hagen and the largest model in the world is in Illinois, USA (scale 1 : 125,000,000), which extends for a distance of 64 kilometers (Planetenweg, 2004)

The Project: The work of Astro-Club members

As one can imagine, it is no joke to take up an initiative such as 'Planet Walk' and bring it to completion. Astro-Club, being a non-Governmental, non-profit making organization, working on a voluntary basis, realized that the biggest problem was going to be one of financing the project. The members, therefore, applied for the Youth Programme: Action 3 of the European Union and were fortunate enough to get recognition for what they aim to do and thus received some funding. However, these funds are not enough to finance a project that involves the setting up of ten monuments, including the sun, together with a plaque near each monument showing some basic information about each planet. The group is thus working at trying to get more funds – mainly from those who will be the future beneficiaries of 'Planet Walk', namely the general public, including school children, all of whom will gain from the 'Planet Walk' experience once this is finished. They are also contacting important institutions, with the aim of finding more sponsors.

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The group has done a lot of research. This will be used as base knowledge to set up the monuments that will be a unique set, specifically designed for Malta. The group also intends to contact members from other local astronomy groups, in order to discuss their work with the members of these groups and thus get feedback for their project. Thus, if any changes need to be done, they will be done before the monuments are set up.
After a study of the various places where best to set up ‘Planet Walk” on the island, a nice promenade by the sea, extending over 2 kilometers, has been located. Astro-Club members talked to the Local Council under whose jurisdiction this site falls and, after a committee meeting, the Council approved the Planet Walk Project. An adequate scale was chosen for the distances between the monuments and also the relevant sizes required. Table 1 shows the actual diameter of the sun and each planet, as well as their distances from the sun, and the relative scale values to be used for Planet Walk.

	Diameter (Km)	Model scale size (cm)	Distance from sun ($x10^3$km)	Scale distance in walk (m)
Sun	1,390,000	200.00		
Mercury	4,878	0.70	57,910	19.59
Venus	12,104	1.74	108,200	36.59
Earth	12,756	1.84	149,600	50.60
Mars	6,794	0.98	227,940	77.09
Jupiter	142,984	20.57	778,330	263.24
Saturn	120,536	17.34	1,426,940	482.60
Uranus	51,118	7.36	2,870,990	970.99
Neptune	49,528	7.13	4,497,070	1,520.95
Pluto	2,320	0.33	5,913,520	2,000.00
scale	1 : 695,000,000	1 : 295,676,000		

Table 1. The Sun’s satellites

The group set to work hard in coming up with various designs of the monuments, visiting local artisans and getting feedback about the feasibility of their designs, as well as the costs involved. However, a major difficulty has still to be overcome. A permit is required from the Malta Environment and Planning Authority (MEPA), which is the regulatory body in Malta, to set the monuments on site once they are completed. At the moment Astro-Club is working with the Council’s architect in order to decide on the final design of the monuments and their layout and in drawing final plans to be submitted to MEPA for approval. The group is trying to avoid disrupting the promenade as much as possible, so that the costs will be reduced and so that approval will be easier to obtain.
A lot of work still needs to be done. The group is also trying to promote awareness amongst the Maltese. A publicity campaign has been launched and members of the group have already appeared on two popular television programs explaining the project and its aims. The group intends to continue to work hard through the summer months, bringing the project to completion by the end of this year.

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The wonder of astronomy

This project has made more evident once again, that science can be approached with enthusiasm. Astro-Club members joined the group because they were looking for something more than what was being offered to them elsewhere. This need not have been just Astronomy. It could have been that they were looking for new friends through the club, for example, but those who looked only for something outside astronomy left the group, once they got what they wanted. Those really interested in Astronomy stayed on and have a great desire to see the fruits of what they started. This has been expressed by the members of Astro-Club themselves, in answers that they gave to a questionnaire, which was used to get feedback from the group.

Foundations of scientific knowledge

The following are some responses to questionnaire that undoubtedly need further reflection.

> M1: ‘ I joined the group because I like astronomy a lot…., since I was a child. I think that we should be able to finish our project but problems may arise due to lack of money and time.’
> M2: ‘Astronomy is one of the subjects I really get interested in.’
> M3: ’I joined the group to broaden my knowledge about Astronomy and also to meet new people and make new friends. I have been interested in Astronomy since I got to know that there are other planets besides our Earth and got to know about the Universe and what it is made up of. I believe that if everyone makes an effort we will be ready by the end of the year.’
> M4: ‘Originally I joined Astro-Club because I was interested in Astronomy. I’ve been interested since I was 12 years old. It is possible to get the project done. Our pace is slow at the moment, due to exams. This makes it less likely for us to get it done; not unless we work really fast through the summer’.

These quotes show that these members have built their foundations of astronomy quite some time earlier on. But we have to be careful of what we really mean by ‘foundations of scientific knowledge’. Indeed, the word ‘foundations’ may be misleading. One can interpret the word as a base, consisting of concepts and skills, which, once acquired at an early age, can secure the construction of the whole edifice of scientific knowledge. However, it can also be argued that while a strong conceptual base is a prerequisite for this construction, yet the latter cannot take place without the establishment of a long-term relationship between the world of science and the child. The implication is that early childhood education should work at creating the right attitudes towards science. It is attitudes that are even “more important than a strong conceptual base since they are the motivators for children’s engagements in science activities. Intellectual curiosity, for example, is such an attitude” (Hadzigeorgiou, 2001).
On the other hand, it is interesting to look at some answers to the question, ’What is Science to you?’:

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M1: For me science is part of my life. I like to study it a lot, especially Chemistry and Biology. I like to learn about our mysterious world and universe.
M2: Understanding the facts of life, the answer to why certain things happen.
M3: Science is what I see. It provides answers to certain things and gives solutions for a better life.
M4: Science is knowing what is around you, why things happen the way they do…it is logical and requires reasoning. It provides answers to many of our questions - though not to all… Science could ultimately lead to discovering more about yourself.

These are answers coming from people with an enthusiastic attitude towards science. Astro-Club members are simply emphasizing the importance of Science for ALL. "The greatest insight into the way scientific knowledge is acquired will be gained by students if they themselves are engaged in real science activities. This will include not only their personal investigative work, but sharing their ideas and results at meetings and contributing to and reading journals" (Driver et al, 1997, p.147).

Conclusion

What Astro-Club members are actually doing is making 'Science' part of their everyday life experience. "Science is an adventure that people everywhere can take part in, as they have done for many centuries" (Science for All Americans: Benchmarks On-line, 2005, p.12)
Moreover, the formation of the club is giving the club members a better chance to grow socially through meeting new people with similar interests. Together they can learn to co-operate with each other, forming part of a team. They learn how to gain the courage to discuss and ask questions, exposing their ideas to criticism. Through the meetings they gain confidence at clearly communicating their views, also evaluating and improving their critical thinking skills and independent thought.
The high enthusiasm generated in the expectations for the project to work, is helping to improve the attitude of the members of the group towards science. Some members have explicitly said, in their questionnaire answers and during informal meetings, that they look forward to the weekly meetings. They have learnt that science is not necessarily a set of facts or a pack of notes to be memorized. Whitehead (1929) rightly believed "that any subject should first come alive and become stimulating before the student can establish a long-term relationship with it". It is, indeed, such a relationship that educators wish for every child or student under their care.

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Figure 2. Newton's Third Law

In as far as the advisor's role is concerned, this is a position that must be handled with care. A good balance must exist between the advisor as a member of the group and the professional who is there to give advice when required. All members need to feel comfortable as they talk to the advisor and air their views. It is the job of the advisor, as the mature individual in the group, to initiate and maintain interest in what is going on and in what needs to be done. Through brainstorming, one realizes how many ideas the members come up with. Young people are indeed a wellspring of ideas. The advisor has to guide the club members so that right choices are made, emphasizing the practical perspective of the plans and the jobs that need to be done in relation to the project.

In conclusion, it is hoped that not only will Planet Walk in Malta be a pleasant experience for all visitors to the site, but that, more especially, it will be one of those sparks that will generate wonder and enthusiasm for science, thus laying a solid foundation for a life-long interest and understanding in Science. The author also wishes that there would be more Astro-Clubs and Planet Walks, budding in other countries. One must find the courage to take the plunge, similar to what Astro-Club is doing now in Malta. One must remember that unless one acts, one cannot expect anything back.

Newton's Third Law of Motion that "for every action there is an equal and opposite reaction", gives us more reason to be sure of this.

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References

[1] Bonello C and Falzon M, Community Resources for Science Teaching, Unpublished B.A. (Educ.) dissertation, Faculty of Education, University of Malta, 1981.
[2] Driver R, Leach J, Millar R and Scott P, Young People's Images of Science, Open University Press: Buckingham, 1997.
[3] http://schoolnet.gov.mt/mxlokkprimaryc/outings.htm
[4] Hadzigeorgiou Y, The Role of wonder and 'Romance' in Early Childhood Science Education, International Journal of Early years Education, 9: 63-69, 2001.
[5] Hewitt PG, Conceptual Physics, Pearson's Educ.: San Francisco, 2002.
[6] Hopkins MFS, Learning through the environment. Longman's, Green, 1968.
[7] Mayo LA, Running an After-School Astronomy Club, Mercury, 31: 14-22, 2002.
[8] Ministry of Education, Creating the future together: National Minimum Curriculum, Malta: Klabb Kotba Maltin, 1999.
[9] http://www.sternwarte-wetterau.de/platenweg/index.html
[10] http://www.project2061.org/tools/benchol/ch1/ch1.htm
[11] The Malta Independent on Sunday, Mistaken for a judge, I met young scientists, 10 April 2005.
[12] The Sunday Times, Environment Section, 2004-2005.
[13] http://starryskies.com/articles/dln/3-98/sagan.html
[14] Whitehead A, The Aims of Education, Macmillan: New York, 1929.

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Motivation and Hands-on Experiments

Trna J

Cognitive motivation in science education

Motives are the psychological characteristics of a personality [1] which we consider to be the internal cause of behaviour. Motives are factors which awake, keep going, and focus the behaviour. Motives consist of elementary structures of consciousness which are called needs. Needs are the elementary motives, which we can imagine as a condition of a lack or abundance in an organism, causing tension in an organism which is directed and starts activity. Motivation is a psychological process, in which motives (needs) are implemented into the behaviour and experiences of an individual (by outside factors):

Motivation → Motivation → Behavior

At the beginning of the motivational process there is the "inner state of tension" and at the end is the "final action". Motivation is localized intro-psychologically in a human's consciousness, but it is also closely connected to a human's relations with subjects and phenomenon in their environment. Motivation results in certain, aimed activity.

The structure of needs is hierarchically arranged according to development of individual, evolution of humanity, and interaction between an individual and their environment. Important classification [2] of needs according to Maslow AH (1954):

- Physiological needs.
- Need of security.
- Need of solidarity and love.
- Need of appreciation.
- Need of self-fulfilment (included cognition need).

Needs develop progressively during the ageing process. If the basic (physiological) needs are not satisfied, it is impossible to satisfy higher needs. It is also important to note that everyone has their own hierarchy of needs which forms the spectrum of motivation. Factors affecting motivation can change during one's lifetime.

There are two ways to increase the need, impulse or incentive of a person. Impulse is an inner initiative marking some change in the body or mind. The example could

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be the feeling of thirst, the need to drink, when the body's organs signal a lack of liquids. Homeostasis is the condition of an organism when organs do not signal any lack and no impulse is apparent. In the condition of homeostasis (without impulse) the need can be increased by the use of an external initiative-incentive. An example of this situation is when the appearance of something to drink increases our thirst, this occurs without signals from the internal organs indicating the need for liquid. Incentives are very important, especially in the field of education.

Incentives can be positive or negative. Positive incentives increase and satisfy needs at the same time. When we are thirsty, the positive incentive is a soda machine. If we have the coins and we know how to use them, we can get something to drink. The same machine becomes a negative incentive if it doesn't work or we do not have the money. Negative incentives increase the need, but do not satisfy it.

Incentives are simple, or complex depending on the number of needs they affect. Simple incentives affect only one need. Complex incentives affect more than one need at the same time. Every kind of need has a whole group of incentives which increase the need. However, it is important to notice that certain incentives work individually and have different impacts.

There is usually more than one incentive present at one time. They are influencing each other and this interaction increases and decreases their impact. There is also a possibility of a development of individual by alteration of the efficiency of incentives and their combinations during the development of a student [4]. Teaching provides a typical complex incentive, in this situation for learning, with a variety of interacting needs and other motives.

Interest is an important complex motive, especially from an educational point of view. It is based on a variety of needs. These needs can be innate or acquired. Interest can develop from different groups of needs, while the same groups of needs can become the source for different kinds of interests. A further, important characteristic of interest as a complex motive is the close connection between the motivating and emotional elements. Interest causes inner positive motivation when the activities (objects, phenomenon), which are the subjects of interest, increase and in the same time satisfy that group of needs which is the basis of interest. The entirety of this motivational process is followed by strong positive emotions, experiences of pleasure and self-satisfaction. There is also a connection between the interest and the willing capability of an individual. Interest and will are directly proportional. From an educational point of view, the process of the development of interest is important, especially in general learning, but also in certain subject studies, e.g. science.

Teaching and learning are complicated activities, implemented in schools typically in a social context, when a student reacts to the achievement requests of the teacher and school. In education, we can put forward three special groups of dominant needs in students which are being continuously developed:

a) Social needs.
b) Achievement needs.

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c) Cognitive needs.

The group of social and achievement needs usually includes the needs of identification and positive relationships (especially the teacher-student and the student-student relationship), status, influence, competence, realized goal of successful performance, and the avoidance of failure. Social and achievement needs lead to external motivation of the student which has a high motivational impact and which quite often contains a dominant motive. This boosted motivation can be both positive and negative and this is its biggest disadvantage. Luckily this negative motivation isn't included in the group of cognitive needs on which we will concentrate.
Each part of teaching (e.g. undertaking experiments) usually boosts social, achievement, and cognitive needs all together. The teaching is complex incentive which induces these groups of needs depending on the individual structure of the personal sphere of needs.

Cognitive motivational teaching techniques

Cognitive needs are the basis for cognitive motivation which is the inner motivation of students and it is always positive. It often leads to development of interest in studying a certain subject. Because this form of cognitive motivation increases student interest so much and appears more frequently, it is important we should use such a technique in our teaching.
Cognitive needs of students exist also in science education at school and also out of school. Science teachers have the possibility to instigate the cognitive needs of students. The students' cognitive needs are induced in the students by the educational process and hence the teacher plays an important role in affecting the students' cognitive motivation [5].
These cognitive needs we compared with students' school activities in science teaching. This led to the set of science cognitive motivational teaching techniques (CMTT) given below through which students can be motivated:

1. Stimulation through unconscious perception and experimentation.
2. Use of models of natural objects and phenomena.
3. Solving problem exercises and projects.
4. Demonstrating simple experiments and toys.
5. Seeing paradoxes and tricks.
6. Watching films, video programs and computer programs.
7. Experiencing humour in science.

The characteristics of each of the mentioned science CMTT have a certain special incentive effect on one or more desired cognitive needs.

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We want to get students' interested in science education even though they may be more interested in different school subjects, or in non-school activities (art, sports etc.). Motivational teaching techniques which do this are interdisciplinary CMTT. They are similar to science CMTT (because interdisciplinary CMTT also stimulates internal cognitive motivation), but not using pure science incentives. These techniques use facts or situations which stimulate a student's interest based on the stimulus from different fields of studies.
Classification of interdisciplinary CMTT is based on a spectrum of subjects and activities which can be used for motivation. By comparing these subjects and activities with science components, we discovered interdisciplinary CMTT which can stimulate interdisciplinary cognitive motivation:

8. Use "Science for life" (health, food, energy, environment etc.).
9. Application of science knowledge in technology.
10. Exploitation history related to science discoveries and scientists' lives.
11. Reading sci-fi literature and watching sci-fi films.
12. Application of science and art.

For each interdisciplinary CMTT, there is a certain characteristic interdisciplinary connection.

Simple experiments with everyday objects

The distinctive quality of a simple experiment is transparency of presentation of physical phenomenon base. This transparency is given especially by the three following factors:

1. Reduction extra phenomena which may occur within an experiment.
2. Qualitative ness of an experiment when students' attention is not taken away from phenomenon base to unnecessary measure.
3. Easy realization by students who perceive an experiment by every sense.

The significant group of simple experiments is group of experiments with everyday objects. So the transparency of phenomenon base observation is supported thanks to the fact that students know these objects from their daily life, so their attention is not taken away from the demonstrated experiment and they can concentrated on it. These simple experiments with everyday objects can be marked as hands-on experiments.
Also undemanding technical realization of simple experiments with everyday objects is an important quality. This brings students a great opportunity to conduct simple experiment by themselves at school as well as out of school. It also results in development of manual skills of students.

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We must not omit economical undemanding ness of a simple experiment with everyday objects. Many schools still contend with insufficient equipment with expensive commercial aids which can be partly substituted by usual low-cost items.

Motivational incentive

The fundamentals of scientific research are observation and experimentation. In science education, teachers' demonstrations and students' experiments are also very important. It should be obvious that every correctly chosen and appropriately used experiment is valuable for motivation of students. Nevertheless we can still find one group of experiments with even higher motivating potential: simple experiments.

Simple experiments can be a complex incentive in activating cognitive needs such as problem solving, modelling of natural phenomena, the needs of our senses and muscular activity etc. This simultaneous activation of some cognitive needs can result in a strong motivating impact. Qualitative ness of a simple experiment activates students' cognitive need of problem solving and thus its consequent activity leads to the pursuit of problem solving. These cognitive needs are activated particularly by paradoxical experiments, tricks and toys.

A paradox is a phenomenon which creates a conflict between experience and perceptions of reality. It is a multiple incentive which can activate sensory activity (students focus their attention because of the conflict created with their previous experiences) and the need to solve the problem (which is closely connected with the paradox). We can begin to understand it after a deeper study of natural laws.

Paradoxes and other surprising phenomena are often elements of magic and tricks, commercially utilized in entertainment (e.g. equilibrium of bodies, rotation of bodies, and light reflection in mirrors). It is usually a combination of perceptive illusions and/or demonstrating imitations of our senses. The principle of commercial utilization of tricks is to keep the fundament of paradox a secret. If we use a few tricks, it is necessary to explain the fundamental ideas.

Evidence of the motivational efficiency of toys as simple experiments is their successful commercial utilization in the form of toys for both children and adults. Bubble makers, yo-yos, click-clacks, and kaleidoscopes are example of these toys.

Preconceptions and misconceptions

From the pedagogical-psychological constructivist view there is significant use of simple experiments with everyday objects known by students from their daily life. Thanks to this knowledge students have often already formed correct preconceptions. In this case we can use these correct preconceptions and base teaching on them.

Significant problems of education in natural sciences are students' misconceptions. They strongly keep from effective teaching and bound understanding of physical phenomena. They are also source of students' motivation loss for science education. There exist several teaching techniques leading to get over students'

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misconceptions. This contains follow-up therapy which is not much effective while misconceptions are quite stable.
Simple experiment can be important preventive instrument against misconceptions forming. Misconceptions have their matrix in difficult situations when many overlapping or often even contrary phenomena come through. Then it is difficult to find out the simple relation leading to the correct preconception. If a simple natural phenomenon is presented to students in a simple experiment with transparent phenomenon, the correct preconception can be formed and thus we can avert creation of misconceptions. This conclusion leads to use of simple experiments in primary science education in the lowest age.

Creativity and skills

Simple experiment allows for the creation of alternative variants of an experiment and open space for the creation of new experiments. Use of simple experiments in education therefore supports development of students' skills of experimentation and develops their creativity.
One of other possibilities of use of simple experiments in education is simulation of natural phenomena which helps us survey and verify physical relations without precise measurement with difficult measuring instruments. It is about making changes in specific parameters of an experiment for better cognition of phenomenon base or possibly for determination of dependent character among quantities describing the given phenomenon. In this way we can deduce or verify relations for the given phenomenon within teaching. Experimentation leads students not only to effective cognition but also to the development of manual and intellectual skills.
Teaching aids for the simulation of attributes of buoyant hydrostatic force made from polystyrene (a set of blocks) by author can be used as an example of simple simulative aids.

Teaching technology using simple experiments

Analysis of a teaching stage and method appropriate for the best implementation of an experiment has to be made for optimization of educational effect of a simple experiment use. A simple experiment can be used in every stage of teaching. For example, paradoxical experiments are best applied in the motivation stage, both in initial and running motivation. In the explanation stage we use simple experiments for initial periods when demonstration of phenomenon base is needed. Simple experiments can be used also in the fixation stage when we can apply them effectively for students' creativity development. Students can create their own alternatives or even new experiments. These experiments will be integrated also into application and diagnostic stages.
Use of simple experiments is optimal in direct students' experiments. Simple experiments are appropriate also in some special teaching techniques with ICT use:

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(a) Videos with simple experiments: Simple experiments can be demonstrated by video projection. Projection of these experiments can be used as:

- initial and running students' motivation,
- supplement of real demonstration experiments (time saving, safety),
- instructing for the students' following experimenting,
- projection without sound with students' comment in fixation and diagnostic stage etc.

(b) Simple experiments on the Internet: many of web pages contain the presentation of simple experiments. This can be used within the fixation teaching stage when students search for these experiments by themselves and then present them in class or use them as an inspiration for the creation of their own experiment modification.
(c) Records of students' experiments: individual students' performance during demonstration of simple experiments can be recorded by camcorder for motivation as well as for the experience stages of teaching. These records thus can be analyzed with students from a physical and technical view.
(d) Experimentation instructions: photos or short videos with descriptions and experimentation instructions can serve students and teachers as simple experimentation instructions and simple aids making instructions. PP presentations on PCs and data projectors are appropriate.
(e) Web presentations: photos or videos with simple experiments can be placed on school web pages. Thus the project of students' presentation in the field of simple experiments can be realized.

Resources of simple experiments

The above mentioned ideas of simple experiments use in science education have to be compared with real situation at schools. Can teacher get information about simple experiments as much as necessary and does he use them in teaching?
Methodical publications with simple experiments have been published recently. Simple experiments are a base of some videos, e.g. "Physics in Experiments" [8]. In 2005, "Fair of Inventions", the tenth year of national conference of school physical and science experiments in the Czech Republic will be held. An important part of the conference is formed by simple school experiments and their description is published. Methodical journals publish periodically articles about the use of simple experiments. Some commercial companies are specialized in making simple aids for school experiments. Teaching aids for simulation of principles of flying created from polystyrene by author and made by commercial company as example. Attention is paid to simple experiments also on the international level. We can see it on web pages. The international interest is also demonstrated by a three year organized all-European conference "Physics on Stage" where the majority of European countries present their physics and science school experiments. Many of them are just simple experiments with usual things. Documentation from these

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conferences is available on web pages [7]. Use of the experiments in teaching depends primarily on individual teacher. Our research shows that simple experiments with usual things together with ITC attract more and more attention.

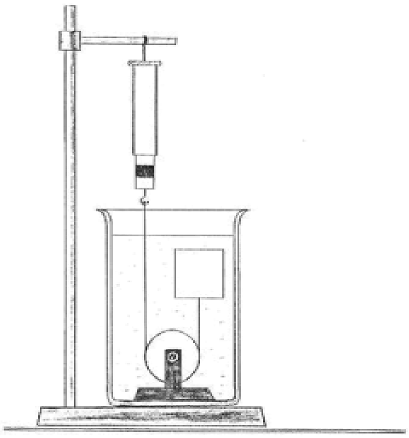

Figure 1. Polystyrene block in liquid

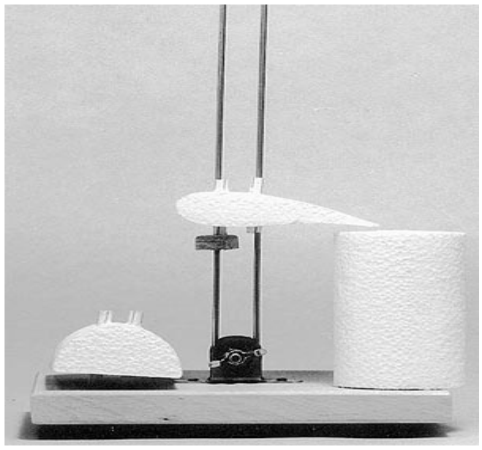

Figure 2. Principles of flying

The author of this article created and put together several quite extensive sets of simple experiments and aids exploiting everyday objects and materials from daily life. These are especially experiments with coins, plastic syringes, toilet paper, polystyrene and matches. These sets of experiments show, among others, that everyday objects and materials can effectively serve for school experimentation in most fields of physics and science. These experiments are recorded on videos [8].

Teacher skill to experiment

How is it necessary to prepare science teachers in the field of simple experimenting [6]? The character of science experimenting generally brought us to conclusion on the necessity of acquiring experiment skill in three stages:

1. Scientific experiment skill (skill of 1st order) - complex qualification to carry out scientific experiments.
2. School experiment skill (skill of 2nd order) - complex qualification to carry out school experiments.
3. Skill to teach students to experiment scientifically (skill of 3rd order) – technology to teach students by using school experiments.

The skill to simple experimenting is located into second and third stages. Science teacher have to obtain detailed information about simple science experiments and about their role in science education. Not only knowledge but particularly the

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acquiring the skill to experiment simply is very important [3]. Five acquiring stages exist in the training of science teacher's skill to simple experimenting:

(1) Motivation stage: Completing of professional interest and attitudes towards simple experimenting.
(2) Stage of subject orientation in acquired skill: Acquiring knowledge necessary for the experiment skill (thought item of skill). Creation of experimental habits (sensual and motor items of the skill).
(3) Stage of "crystallization" of new skill: Solving of simple applied tasks of simple experimenting.
(4) Stage of completing the skill and its including into wider contextual frame: Solving of complicated applied tasks of simple experiments.
(5) Integral stage during which the new skill is integrated into skill structure: Solving of teaching problem situation etc. in school practice.

Completion and integration stages are conditioned by several-year field experience of the teacher and that's why acquiring experiment skill is not possible to finish as soon as pre-gradual training of teachers.

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References

[1] Atkinson J and Raynor JO, Motivation and achievement, Winston and Sons: New York, 1974.
[2] Maslow AH, Motivation and Personality, Harper & Brothers: New York, 1954.
[3] Royer JM, Cisero ChA and Carlo MS, Techniques and procedures for Assessing Cognitive Skills, Review of Educational Research, 2: 201-243 (1993).
[4] Shayer M, The Long-term effects of Cognitive Acceleration on pupils' Achievement, King's College: London 1996.
[5] Trna J and Trnova E, Cognitive Motivation in Science Teacher Training, in Proceedings of the International Conference Science and Technology Education for a Diverse Word – Dilemmas, Needs and Partnership, 11th IOSTE Symposium for Central and East European Countries; 2004 Jul 25-30; Lublin, Poland. Lublin: M. Curie-Sklodovska university press, pp.: 223-224, 2004.
[6] Trna J, Science Experiment in Science Teacher Training, In: Proceedings of the International Conference Science and Technology Education in New Millennium. 3-rd IOSTE Symposium for Central and East European Countries, 2000 June 15-18, Prague, Czech Republic, PERES Publishers: Prague, pp.: 201-206, 2000.

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[7] http://www.physicsonstage.net
[8] http://www.ped.muni.cz/wphy/

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Science Interpretation in High School

Villar R and Dorrío BV

Introduction

Interpretation as a methodology for the studying of heritage was defined [1] by professionals in the national parks of the USA [2] in 1957, as an educational activity which attempts to reveal meanings and relationships through the use of original objects, by first hand experiments and illustrative mediums instead of the mere communication of facts.

Within this context, the principles proposed are based on the relationships between the objects and the experience of the participant, involving an integrated transmission of the information by using diverse strategies and endeavouring to create incentives to awaken interest [3]. This informal tool of learning is used more and more in archaeological and nature parks, as well as in zoos, aquariums or museums [4].

One of the objectives of interpretation is to help the participant to develop a deeper understanding, appreciation and awareness of the activity in question and/or the values that are trying to be transmitted; thus converting the activity into an enriching and pleasant experience [5]. In general, the interpretation of heritage [6] is a creative exercise based on the knowledge of the interpreting process and of the matter to be dealt with, by putting into play resources with clear, short and attractive messages that create an impact on the participant.

On the other hand, the carrying out of didactic activities developed outside of the traditional academic framework, such as museums, interpretation centres, exhibitions, etc. prove to be highly beneficial for the comprehensive education of pupils, but specialized equipment and appropriate technical resources to ensure a service of quality is needed [7]. Its evaluation is complex and the methodologies need to be adapted to what is being considered in each case. There are some methodological proposals which tend to form generic models in relation to a specific discipline but they can turn out to be a good starting point [8].

Based on this philosophy, we organised an activity for pupils between the ages of 12–18 which attempted to divulge the scientific method applied to the study of Prehistory from a methodological and practical perspective: prehistoric investigation as an interdisciplinary science - archaeology, geology, biology, physics, chemistry, topography, etc.- and as an example of the application of a scientific method within the human sciences [9].

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We selected an interpretive methodology so that in a pleasant and attractive manner, it allowed us the transmission of appropriate messages and the highest impact possible on pupils in relation to the knowledge to be transmitted [1, 7, 10, 11]. Thus, we designed an active exhibition for a learning centre, looking for participant's implication, and encouraged or guided by monitors with the main aim of fostering in pupils interest and facilitating their immersion into the subject of archaeology.
The main novelty of the proposal consisted in creating a tailored exhibition integrating interpretive principals and mediums for a perfectly defined public from a formal education and dealing with a theme not usually dealt with in interpretive activities. In the activity we also attempted to recreated, in the centre's entrance hall, the realistic environment of a Prehistory archaeological excavation, possibly the most known of tools used by archaeology, and to relate the contents of the activity with the curriculum of the pupils and their daily experiences. We also attempted to show the visitor the wonders of these special historic places and convert them into active defenders of Heritage.
Even though our experiences with school groups and the general public in the divulging of other disciplines in the human sciences, such as art, history, architecture, museums, photography, etc. were normally based on principals and objectives of a didactic nature, our experience became an essential tool for assuming the challenge of applying interpretation in this area and with these characteristics.
The main sustaining elements of the interpretative and participation principal were the creation of several panels with thematic meaning, the disposition of hands-on elements, the construction of an archaeological crate which allowed us to take a plot of land from a real site to the school and the projection of an audiovisual in which was shown the site taken as reference and a demonstration of carving stone Paleolithic tools.
In this manner the participants not only had to read, but they also could touch the earth, charcoal, bones, different stones, smell smells, distinguish dampness, manipulate, measure etc. offering a real possibility of understanding and living an archaeology investigation, an alternative that is not common in daily life.
In this essay, we present the methodology used in the assembly of this interactive set-up with the site in the educational centre. The analysis of the results of a voluntary questionnaire carried out on the majority of those who attended is shown, reflecting the degree of satisfaction and use of the activity.

The activity

The cognitive and attitudinal aims of the activity were orientated on: clarifying concepts, presenting the Paleolithic site of *Chan do Cereixo* (Gondomar, Pontevedra), a site not investigated of the earlier Paleolithic era, one of the oldest in Galicia, according to the characteristics of the material recovered twenty-five years ago; increase interest in Prehistory; demonstrate archaeology as an interdisciplinary science and make society interested in the study and conservation of heritage.

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The location available was the entrance hall of the Auga da Laxe Secondary School (Gondomar), one of five secondary educational centres in Val Miñor (Pontevedra-Spain), with pupils of between 12–18 years old, which included in its curriculum a prehistoric subject. The activity was organised by the Instituto de Estudos Miñoranos and was co-financed by the Dirección Xeral de Investigación e Desenvolvemento of the Xunta de Galicia within its activities of Science and Technology Week 2004.
The messages that were to be transmitted and the medium for its divulging was organised around the corresponding interpretive signs, audiovisual mediums, as well as hands-on and demonstrating materials. The space available was organised according to its functions: a reception area for groups of students, another for presenting an audiovisual, another explicative area in which was shown the interpretive panels with the material on show, objects which could be manipulated, etc. The pupils' visits were attended by specialised monitors who were part of the activity organisation and supported by voluntary pupils from the host centre. This was done in such a manner that the entrance hall of the centre became a combination of a small interactive museum and a real archaeological site as well as for the carrying out of normal teaching work.

Figure 1. Working on the site

The criteria for the preparation of the necessary material were methodologically ambitious, aiming for a complete vision of investigation and paying special attention to the participants. Therefore, for this group from the public who are learning, we designed sheets-activity guides, for personal use and which they later to take to their classrooms, giving them an opportunity to continue to work within a formal academic environment, as well as serving as a means of reinforcing the activity. There were also samples in the hall, which were plasticized, for free use by those accompanying the group or the general public.

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These sheets had the function of serving as a guide during the activity, clarifying questions and stimulating participation by presenting fourteen simple activities-games to be done during the visit, looking for the solutions within the actual interpretive set-up, whilst others were to be solved with the help of a teacher in the classroom. They also contained a selection of bibliography and links for those participants interested in knowing more about the contents of the activity.
Once a date and time had been arranged, a group of pupils, of no more than 25, were received by a monitor who introducing him/herself and presented the activity; on having given out the sheets, the guide commenced the tour by presenting the Palaeolithic site of *Chan do Cereixo* with diagrams and photographs of two light boxes situated at the entrance, this being the first surprise, realising that a place known to them had, up until now, a value they did not know of- Palaeolithic sites in the open air do not show visible signs in the outside. Together with the monitor, the voluntary pupils of the host centre, acted as helpers, offering the material, explaining the handling of equipment, giving out and collecting surveys, etc.

Figure 2. Visiting the exhibition

Afterwards, the pupils became involved in the investigation of the site (Figure 1), beginning with its survey: understanding the meaning of terms and its methodology, using some of the necessary equipment: GPS, compass, aerial photographs, orthophotographs, stereoscopic photography which they could see with the stereoscope, diagrams, etc.
On having familiarised themselves with the site, they began their investigation which was based on the following elements (Figure 2):

a) The interpretive panels: were often used for analysing the scientific methodology used in the archaeological field. They were headed by a

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sentence – a subject that in a simple and attractive manner, gave the message which was intended to be transmitted by the panel. The comments and illustrations that followed: photos, drawings, sketches, diagrams, etc. were for displaying and closing - not amplifying - the message of the sentence - a subject, which was not longer than three lines.

The subject matter displayed on the panels were: surveying, excavation, auxiliary sciences in the reconstruction of the natural environment, palaeontology, geology, palaeobotany, carpology, anthropology… and the question of chronology in its two perspectives: methodologies of relative chronology, archaeological method (typologies, stratigraphy, etc.), and methodologies of absolute chronology -C^{14}, dendrochronology, potassium, argon, palaeomagnetism, uranium – thorium….

Figure 3. Carving workshop

b) Expositive elements in display cabinets, such as replicas of stone tools, samples of stone raw materials, work elements from the archaeological team, part of a tree trunk with growth rings which could be counted and a sample of a stratigraphic column for observing the horizons which the ground forms and a commentary on its differences.

c) In the central part of the space, an archaeological crate measuring 2 x 2m representing the development of an excavation was situated: the surface was divided into work units of 1 x 1m and identified by numbers and letters of the Cartesian system of coordinates, with the remains of a Palaeolithic field site and archaeological work tools. Plan 0 was established to measure the depth of the objects, making available a complete topographic station and a telescope rod. Once the participants were familiar with the methodology of the fieldwork, they were able to take measurements using

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the equipment and integrate a set of concepts from diverse scientific disciplines.

d) The visit ended with the projection of an audiovisual of the Palaeolithic site of *Chan do Cereixo*, in which was also shown a demonstration of Palaeolithic stone carving. This practical activity was previously carried out by pupils from the secondary school host centre (Figure 3), by designing a specific material which had been adapted and allowed them to follow the process: raw materials, origin, technique, products obtained, functionality…

Before the leave taking, they were asked to fill in a small questionnaire, individually and anonymously, which was used as a tool for judging different aspects related with the activity.

Analysis of the activity

The questionnaires used for the evaluation of the activity were designed by the *Dirección Xeral de Investigación e Desenvolvemento* of the *Xunta de Galicia* for their own use and even though they referred to different parameters – divulging of the activity, satisfaction, participation, subject matter and organisation-, the excessive standardisation in the wording of the questions is confirmed.

We analysed the questionnaires of a population of around 500 participants, in which 94% of them defined themselves as a captive public for having to visit within the obligatory times of school hours. We will concentrate our essay on the results obtained from this group of pupils, which are of an average age of 14.75 years old.

The chronological distribution of the population in relation to educational cycles shows a higher frequency of secondary school students (Obligatory Secondary Education, between 12 and 15 year olds, both inclusive) (70.45%) than that of pre-university studies (from 16-18 years old) (29.55%). In the distribution by sex, we have a balance between women who attended (52.45%) and men (47.55%).

The evaluation obtained from the degree of active participation (Figure 4), shows in general that 50.00% did not participate, against 46.00% that did participate and 4.00% that did not on considering that the activity did not allow it. The analysis of participation by ages shows that the pupils aged 12 registered a higher percent of participation, the value falls progressively up to the age of 16, at which is registered again another peak of participation that is higher than 50.00%, in the remaining age groups, the participation barely reaches a third.

Undoubtedly, the factors related to this aspect are diverse and complex, but in general we consider the influence of the physical frame in which the activity was developed, very conditioning for the normal functioning of the centre, imposing serious time limitations on the duration of the visit, having to be out of necessity 50 minutes long, the same as the length of the school's classes, so that group changes did not cause problems.

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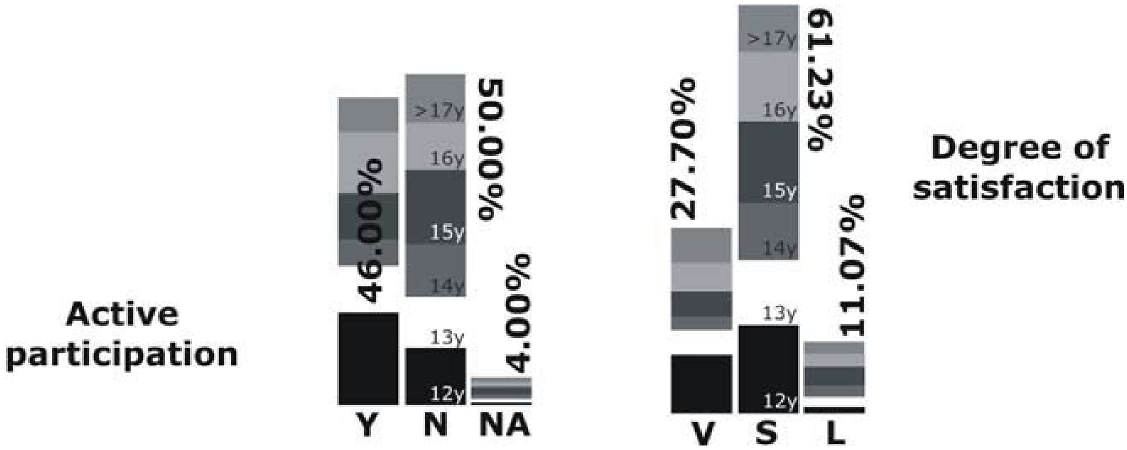

Figure 4. Active participation and general degree of satisfaction by ages

The evaluation of the staging and the service given to the participants were collected in questions in relation to the preparation of the location, the material available and the service given to the public. The results are reflected in Figure 5, and it is highlighted that 73.16% of the participants consider that the preparation of the location was Good (G) or Excellent (E), 19.00% considered it Standard (S) and 7.84% as Passable (P) or Bad (B). In relation to the material available for manipulating, 76.00% considered it Good or Excellent, 15.20% considered it Standard and 9.00% as Passable or Bad.

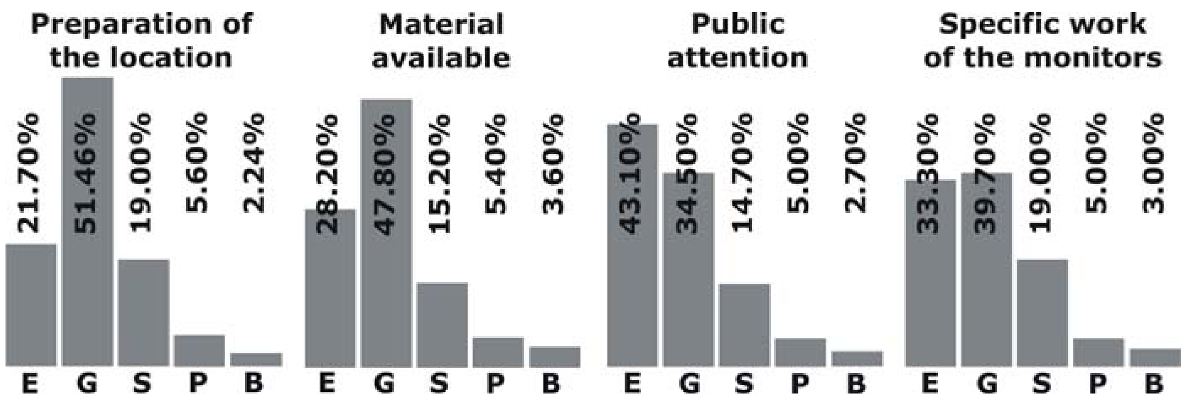

Figure 5. Evaluation of the staging and service given to the participants

Finally, a high percentage of the participants that considered as Good or Excellent the service given to the general public (77.60%) ratifies the high degree of general satisfaction found in the activity (Figure 4): 88.93% considered it Very satisfactory or Satisfactory, while 11.07% considered it as Little satisfactory. In relation to this, the individual high evaluation of the specific work of the monitors (Figure 5) who guided the activity (73.00% considered it Good of Excellent) is coherent with the degree of general satisfaction found of the visit and confirms important diverse methodological questions in the designing of divulging activities: an interpretive

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methodology is effective and valid for transmission and communication and implies an intermediation of a specialised interpreter, that is to say, it establishes a direct treatment between the subject, object and the interpreter, offering a high quality service which obtains a high evaluation by the users [7].
The evaluation of the support material, the abovementioned sheets-activity guides, shows that a high percentage of the participants acknowledge a certain utility (54.00%), being more than those who considered it Very useful (28.50%) and those who saw it of Little use (17.50%).
Finally, there was a parameter that tried to obtain information about the coherence of the contents with the general theoretical idea of the proposal, reflected in the title of the activity, and on the public's expectations. The results show that in 69.50% of the cases the expectations of the contents were satisfactory as Very Much and Enough, mean while the rest were only satisfied as Somewhat (22.00%), Hardly (3.00%) and Little (5.00%). This parameter is in relation to the level of previous knowledge that the public has of the subject, considering that the results evidence an important degree of divulgation of archaeology, even though there is a new factor in this activity: an open scientific and interdisciplinary focus that normally constitutes a side less known generally on a school and public level.

Conclusions

The results obtained throughout this interpretive activity of prehistoric investigation are interesting and allude to different aspects of the activity and in general show highly satisfactory results in regards to the objectives proposed initially, after having taken into account the abovementioned limitations. In particular the questionnaires reveal a high degree of satisfaction by the participants in aspects related to the election and proposal of the subject, the set-up of the activity and the services offered (interpreting monitors), which confirms the great effectiveness of a mediating agent which works in the interpretation of contents. This does not mean the explaining of concepts, but the transmission of messages, attitudes, values and sensations in relation to the material and the actual experiences of the public. Other parameters such as participation, were highly conditioned by the physical framework for carrying out the activity, in which was simultaneously produced a formal educational act enforcing environmental and temporal contributing factors in relation to the visit. It is well known, that the availability of a space specially designated for non formal educational activities is an essential condition for the correct development and the attainment of the objectives foreseen [13,14]. In our case, this important factor did not lessen our achievements of the activity. In accordance with the results, the activity seems to have awakened the interest of the participants and they generally thought that the experience was worth it.

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References

[1] Tilden F, Interpreting our heritage, Chapel Hill: North California, 1957.
[2] http://www.interpnet.org/
[3] Beck L and Cable T, The meaning of interpretation, Journal of interpretation research, 7: 7-10, 2002.
[4] Lee C and Brown A, Bibliogaphy of interpretative resources, Journal of interpretation research, 8 (Special Issue), 2003.
[5] Sharpe GW, Interpreting the Environment. John Wiley & Sons: London, 1982.
[6] Aldridge D, Guide to Countryside Interpretation, Part I: Principles of Countryside Interpretation and Interpretive Planning, HMSO for Countryside Commission and Countryside Commission for Scotland, 1975.
[7] Legendre R, L'Éducatión totale. Montréal: Ville – Marie, 1983.
[8] Allard M and Larouche M, La evaluación de programas de interpretación de la historia destinados a los grupos escolares en los lugares históricos canadienses. Reunión Anual del Comité Educación y Acción Cultural (CECA), ICOM-Ecuador, 1994.
[9] http://webs.uvigo.es/eventos/h-sci/arqueoloxia.htm
[10] Torrance EP, La enseñanza creativa, Santillana: Madrid, 1986.
[11] Hargreaves A, La investigación en la era postmoderna, Revista de Educación, 312: 111-130, 1997.
[12] Ham SH, Interpretación ambiental. Una guía práctica para gente con grandes ideas y presupuestos pequeños, Fulcrum: Colorado, 1992.
[13] Villar Quinteiro R, Museos y Didáctica: estado de la cuestión en Galicia, Revista de Museología, 29: 15-19, 2004.
[14] Dartington Amenity Research Trust, Interpretation in visitors centres, Surrey, 1984.
[15] Korn R, Introduction to Evaluation: Theory and Methodology, in Berryy N and Meyer S (Eds.): Museum Education: History, Theory and Practice, The National Art Education Association: Reston, pp.: 220-238, 1984.

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The Effect of Using Simple Equipment on the Acquisition of Plan Map Concepts in the Vocational Schools

Fathi-Azar E

Introduction

The most notable characteristics of vocational schools in Iran are to prepare skillful technicians to involve in the industrial development of the country. In this connection, the surveying course was offered to eleventh grade students in the vocational schools. The course introduces planimetry, altimetry, topographies, and other kinds of surveying, four hours a week during a semester. However, the planimetry is the main part of the course, which is called “plan map” with the following main objectives:

1. The student knows common terms used in the plan map construction and interpretation.
2. The student demonstrates skills in finding azimuth, scales, and other necessary variables in making plan map.
3. The student uses the theodolite device correctly.
4. The student properly measures leveling.

The students construct and make a proper plan map in a given area.

Background

In the past few decades many science program, has been available to represent science as a direct or laboratory – based experience rather than to present science as only a body of knowledge (Hudes and Moriber, 1969). "When students have direct experiences with materials and events, each comes from that experience with his / her own interpretations." (Marker and Methven, 1991). In the other words students construct their own concepts from their experience, that is why, it is a well established fact that theory is more understood and appreciated by the students

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when subjected to experimental techniques (simpler the better), and visual presentation is preferred to abstract lectures and mere statement of facts.

The main part of course namely plan map was commonly offered in two components, with lecture typically once per week and practical work two times a week. The practical or fieldwork needs a complex device called theodolite. The theodolite is expensive and the schools can have just a few of them. As a result, learning experiences in practical work may have minimal impact on helping students construct understanding of plan maps' concepts, content, or relationships.

As a result, practical work is now emphasized in school science. Hodson (1996), identified three justifications of practical work for learning of science:

(1) To help students learn science
(2) To help students learn about science and to
(3) Enable students to do science.

Also, Woohnough and Allsop (1985) have argued that practical work can be viewed as providing experiences, exercises, and investigation Laboratory-based experiments are not necessarily needed for practical work. Out school activities can provide opportunities to learn and to do science as well. In this regard, Griffin (1998) pointed out the importance of informal settings of learning processes, and showed how carefully planned museum-based experience could provide a vehicle to achieve some goals of practical work in school science. Lock (1998), realized that "the limited available empirical research findings suggest that field work may be more effective than equivalent teaching carried out in laboratory." He further concluded "field work can make significant contributions to all three [objectives of practical work in science]". It is inevitable that science, vocational education, and practical work should be changed over time and be geared toward fieldwork. The work can be done in the schoolyard or in the wider environment.

It is known that textbooks are used as an alternative to practical work (Lock, 1997). Even though practical work can include the design of experiments, and when the work goes according to the textbook, it may add little to conceptual mastery.

Laboratory and fieldwork need not reasons for emphasizing the use of complex and expensive equipment. One area of Japanese superiority on test achievement and comprehension in school science can be seen on their teachers' emphases in "the experiment done with everyday simple equipments and materials" (Walberg, 1991).

Kirschner and Huisman (1998), in designing non-traditional practices to replace traditional practices suggest that, "the use of simulations is advocated when: (1) the 'real' laboratories are unavailable, too intricate; (2) the experiment to be carried out is dangerous for the experimenter or to the object of experimentation; (3) the techniques which need to be used are too complex for the typical student; and (4) there are severe time constraints."

Based on local reports and experiences in vocational schools, most of the students who take the surveying course, fail at the end of semester, and their achievement in the course is not adequate, particularly in plan map concepts.

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Generally, the framework and the theoretical orientation of this study were based on the following assumptions:

1. Students acquire plan map concepts throughout- school activities
2. Use of simple equipment can reduce the complexity of the concepts.
3. Use of simple equipment can overcome the unavailability of real laboratory and reduce the students' fears of using expensive and limited tools.

Use of simple equipment causes teachers to do activities beyond the textbooks as a complementary plan without time consuming.

Purpose of the Study

The primary purpose of this study was to determine the effectiveness of two different types of instruction on plan map concepts: that involved simple equipment, and implemented traditional methods. More specifically the research sought data to answer the following hypotheses:

1. There is a significant difference in the students' achievement on plan map concepts between the experimental and control groups.
2. There is a significant difference in the students' level of understanding plan map concepts between the experimental and control groups.

Method

Procedure

This study was conducted using students enrolled in a surveying course during the Fall 1998 in vocational schools of the East Azerbaijan Province in Iran. The course content included the main topic of making plan map concepts.
A quasi-experimental design was employed. The subjects in both control and experimental groups received a traditional lecture method and practical work, using theodolite for an entire semester. Additionally during the semester the experimental groups used the simple equipment of plan map-making as an extra activity.
The plan map as the main part of surveying course was, two-credit, 18-week course offered through the vocational high schools. The class met once a week in 50-minute periods and 100-minute practical work. Worthwhile to mention that the same teachers taught both control and experimental groups. However, 50-minute of 100-minute practical work of the experimental group was devoted to use the simple equipment.

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Participants
The sample consisted of public vocational school students in grade 11, ranged in age from 17 to 18, of the East Azerbaijan Province in Iran. Five school districts were randomly selected to represent a variety of students in terms of demographic characteristics. Within the districts, six groups of students were randomly selected, three as experimental and three as control group as multistage cluster sampling (Borg and Gall, 1989). Therefore, the study was based upon 155 students, of which 65 students were in the experimental and 90 in the control groups. This sample was part of a total 534 male students who took the surveying course in vocational schools.

Measures
Forty multiple test items were used as pre-and post-test to measure plan map concepts. Four instructors and two specialists in surveying confirmed the test validity. The reliability of the test was measured by a split-half method, using Spearman Brown formula (r = 0.69). Since the current effort to reform science education emphasizes the importance of understanding for students (National Research Council, 1996), in response to such notion the author examined the subjects' understanding level in the plan map concept. For that reason the forty items were given to the instructors to select as being in a high level of instructional objective. As an aid for classifying the items, a table that is describing the major categories of each domain of taxonomy (Gronlund, 1976) was given to the instructors. The twenty items were selected as being in a high order level such as comprehension, application, analysis, synthesis, and evaluation of cognitive domains. These items were used to compare the understanding level of plan map concepts among subjects.

Materials
The material consisted of the use of equipment such as a protractor, soda straw, measuring tapes and ropes, paper, and pin. With these materials a piece of equipment was made as shown in Figure 1.
Before going into the field, the students of the experimental groups were asked to be divided into teams, keeping in mind that they could sight correctly and use the equipment. Then, the students were asked to use equipment according to instructions given by the teacher.
Each team was asked to indicate the north on their paper and then sight on a distant object of their choice, such as trees or sticks. The following figure is used to illustrate this technique.
Since the students in the control and experimental groups did not match according to their pre-test scores, any differences in these scores was done by assessing the D score (D=posttest-pretest) to obtain a more reliable difference between the two groups.

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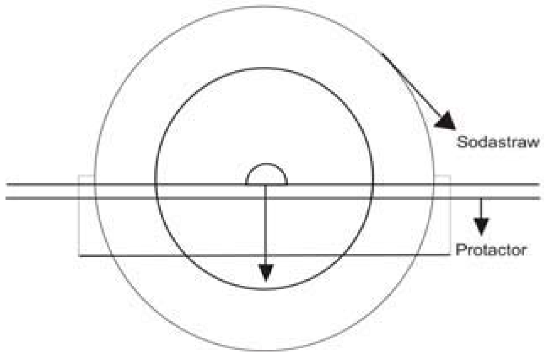

Figure 1. The simple equipment of plan map making

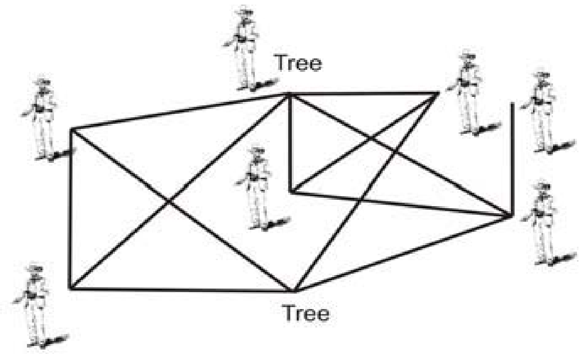

Figure 2. The illustration of sighting

Results

A t-test model was used on the students' achievement scores. There was a significant difference between the D scores of experimental and control groups t(154)=-12.95, p<0.01. Thus, students who used the simple equipment achieved higher that the control group students. One-way analysis of variance (ANOVA) was also conducted to test the difference among groups of the study (Table 1, groups 1, 2, and 3=experimental, and groups 3, 4, and 5=control ones in range of mean scores).

Source of Variance	Sum of Square	df	Mean Square	F	p
Between	146.4437	5	29.2887		
Within	542.8563	149	3.433	8.0390	0.0001
Total	699.3000	154			

Table 1. Analysis of variance among the D scores of the subjects

There was a significant difference between the achievement of the students in the control and experimental groups f(5,149)=8.0390, p<0.01. Thus, the first hypothesis of this study, which was "there is a significant difference in the students' achievement plan map concepts between the experimental and control groups" was confirmed. A post hoc analysis was done by Tukey method to see the differences of the groups with each other. The results are contained in Table 2.

Mean Score	Group	5	4	6	3	1	2
1.0333	5						
1.4667	4						
2.0000	6						
2.3571	3						
3.2308	1	*	*				
4.0278	2	*	*	*			

P<0.01

Table 2. Tukey test between groups achievement

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Thus, it can be concluded that at p<0.01 there was a significant difference of the two experimental groups with the control ones, in regard to the subjects' level of understanding, but there was no significance difference of one experimental group (1) with the others.
An ANOVA was done in regard to the students' higher level of plan map concepts in the groups of the study. The results are shown in Table 3.

Source of Variance	Sum of Square	df	MeanSquare	F	p
Between	86.1660	5	17.2332	23.8785	
Within	107.5337	149	0.7517		0.0001
Total	193.6997	154			

Table 3. Analysis of variance results for high achievement plan map concepts among the subjects

Thus, the second hypothesis of the research "there is a significant difference in the students' understanding plan map concepts among the experimental and control groups" was confirmed.
In order to find out the difference between the groups a Tukey post-hoc analysis was conducted and the results were shown in Table 4.
It should be mentioned that the plan maps made by the subjects, are comparable by the ones that are made by the theodolite. The students used the formula of S=½ab·sinα for calculating the given area. More figures of the plan maps are presented in appendix A and B.

Conclusion

This study provides evidence that students' achievement were enhanced through using the simple equipment as an extra activity of plan map making. During the treatment period, the experimental groups, except one, were able to improve plan map concept and skills. While in comparing to the experimental groups, none of the control group could make an improvement of plan map concepts and skills. The most surprising result of this study is that the statistical analysis indicates a highly significant improvement in the students' achievements for all experimental groups, when those high levels of cognitive skills were measured.

Mean Scores	Groups	6	4	5	1	2	3
1.0467	6						
1.3033	4						
1.4767	5						
2.7500	1	*	*	*			
2.7610	2	*	*	*			
2.7857	3	*	*	*			

p<0.01

Table 4. Tukey post-hoc analysis on the students' high achievement

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The theoretical framework proposed in this study appears to be consistent with the experimental data. The enhancement of the students' performance reveals that the simple equipment reduces the complexity of plan map concepts. This reasoning is in the line of Japanese superiority on test achievement on school science, which emphasized on using simple and everyday materials (Walbeg, 1991). This kind of activity provides opportunities for pupils to learn and acquire the concepts in informal setting (Griffin, 1998) of learning processes. As Lock (1998) identified, fieldwork such as this may be more effective than equivalent laboratory approaches. Finally, using the simple equipment overcomes the costs and time constraints associated with real laboratory experience (Kirschner and Willbord, 1998).

References

[1] Borg W and Gall M, Educational research, Longman: New York, 1989.
[2] Gronlund NE, Measurement and evaluation in teaching, Macmillan Pub.: New York, 1976.
[3] Hodson D, Practical work in school science: Exploring some directions for change, International Journal of Science Education, 18: 755-760, 1996.
[4] Hudes I and Moriber G, Science education for the elementary school teachers, Science Education, 53: 425-426, 1969.
[5] Griffin J, Learning science through practical experiences in museums, International Journal of Science Education, 20: 655-663, 1998.
[6] Kirschner P and Huisman W, Dry laboratories' in science education; computer-based practical work, International Journal of Science Education, 20: 665-682, 1998.
[7] Lock R, Is there life in science 2000?, Journal of Biological Education, 31: 83-85, 1997.
[8] Lock R, Fieldwork in life science, International Journal of Science Education, 20: 633-642, 1998.
[9] Markes EA and Methven SB, Effects of the learning cycle upon student and classroom teacher performance, Journal of Research in Science Teaching, 28: 41-53, 1991.
[10] National Research Council, National science education standards, National Academy Press: Washington, 1991.
[11] Walberg H, Improving school science in advanced and developing countries. Review of Educational Research, 61: 25-69, 1991.
[12] Wollnough B and Allsop T, Practical work in science, Cambridge University Press: Cambridge, 1985.

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Learning Science towards a Sustainable Development

Vila-Chã Baptista RM, Silva P and Costa MFM

Introduction

The learning of sciences can be very stimulating. One cannot say there exists a perfect pedagogical method but our experience proved that actually going through the situations makes it possible for the students to learn the concepts more effectively and efficiently. Concrete experiences help students acquire knowledge with more ease [1].

The objective of the project herein reported is to get the students to learn science and simultaneously awaken to the principles of sustainable development. In the context of the programs of various disciplines, the use of a general and globalizing theme will allow to integrate various areas of knowledge and contribute to better learning.

As collateral objectives, this project also intends to promote the level of literacy of the students and consequently of the society they belong to [2]. The United Nations entitled 2003-2012, the Literacy decade. Scientific literacy is fundamental for the development of our societies and humanity.

The project will be implemented in other schools, located in mountain regions, in different European countries, that will share our experiences and knowledge. A number of exchange visits of groups of teachers and students will be organized in order to enhance the sense of European citizenship among the participants in the project and there schools. Science fairs will be organized where the work developed will be presented to the community.

Characterization of the coordinating school and its region

The village of Vieira do Minho is located in a mountain region, in the foothills of the Cabreira mountain range, a few kilometres away from the Peneda do Gerês National Park in the interior of the northwest Portuguese region of Minho. The whole region has vast natural and patrimonial resources. The region has excellent conditions for production of electrical energy by ecologically safe methods: wind, water and solar. The people live of agriculture, small commerce, services, tourism

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and industries. In general, they have little access to culture and the level of illiteracy is high.
The Vieira do Minho high school is frequented by 715 students, divided into six year levels from 7th to 12th grade. The teaching staff consists of 85 teachers, most of which with a permanent position in the school. Throughout various years several projects, directed toward furnishing the laboratories with the equipment necessary for the teaching of science, have been elaborated in the school successfully. The annual fair has been repeatedly successful and has counted with the participation of school students of the region, especially from primary schools. Special attention is given to the latter because they have limited contact with experimental practice.
One of the major concerns of the board of directors of the school is the fight against failure and dropping out. For this reason certain measures have been taken to promote and value all the competences acquired by the students and introduce methods of diversifying its evaluation.
This project will involve students from the 10th 11th and 12th grades. The disciplines more directly related with this project will be Physics, Chemistry, Biology and Geology. The school curriculum will be covered, always focusing on the principles of sustainable development.

Topics of the project covered in the Physics classes

World energy situation and energy degradation

After an individual study of various sources of informative text, tables and graphics containing technical data and opinions about different energy consumptions in various human activities, the yield of different processes and use of energy sources, the teachers will stimulate the students to make a critical analysis with a scientific foundation about energy problems and the rational use of energy.
The students are invited to analyze the situations of energy consumption on their daily life and suggest solutions for a more rational use of that energy. The growing consumption and daily energy waste will be discussed, especially the energy consumption associated with transportation. Therefore, a comparative research on energy consumption in the transportation sector will be requested. The Superior Technical Institute will be contacted so as to be able to use in our school a driving simulator that they have developed which allows the user to know at the end of each “trip”, and in function of each form of driving, the consumption of fuel and the emission of pollutants.

Energy Conservation

The general law of energy conservation is one of the most important laws of physics. In the particular case of thermodynamic systems the 1st Law of thermodynamics calculate the variation of internal energy through work, heat and/or the absorption/emission of radiation. The most recent formulation of the 1st law of thermodynamics distinguishes heat from electromagnetic radiation and implies a calorimetric definition for heat (energy transfer due to a difference in temperatures).

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For a better understanding of this law and of its implications, our students will be asked to analyze systems well known to them: computers, game consoles, household appliances, mobile phones, etc... By doing so they will identify the transfers of energy that occur in each system in the form of work and heat, always keeping in mind that in each transfer there is energy that is dissipated and consequentially the yield is always less that 100%.
It is important to emphasize the idea that energy is something that is always present in our lives and, when referring to the mountain regions in particular, that are colder in the winter, it is fundamental that the houses are energetically efficient. They should be thermally isolated and the material used in their construction should be chosen in accordance with the characteristics of the area, i.e. solar exposure, relative humidity, etc...

Figure 1. Panoramic view of the Vieira do Minho region

Figure 2. Compostor to be constructed and installed in the school.

Making use of solar energy

In this particular subject various activities will be organized that involve the use of solar energy. The students will learn about the conditions necessary for the use of solar energy for heating or even for the production of electricity.
The students will therefore be led to conclude that the use of solar panels has a positive yield. This way the student will relate the total potential irradiated by a surface with its area and the fourth potential of its absolute temperature (law of Stefan-Boltzmann) and to identify the zone of the electromagnetic spectrum where the potential irradiated by a body is at its maximum.
An educational visit to a school or institution that has these systems installed will take place and the installation of similar systems in our school will be studied. A competition between the participating schools will be held to construct solar collectors. In the end the best work will be rewarded and will be exhibited in all the schools involved in the contest.

Wind energy

The geographic configuration of Portugal, and in concrete of this region, allows the installation of aeolian parks only in high mountainous places. In the plain regions

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the wind has very low average speed and therefore the energy produced is in such a way low that it makes it an economically impracticable project.
A wind generator gets its energy by converting the force of the wind into a binary one that acts on the helices of the rotor. The amount of energy transferred to the rotor by the wind depends on the air density, the area scanned by the rotor, and the speed of the wind.
The kinetic energy of a body in movement is proportional to its mass and to the square of its speed thus, the kinetic energy of the wind depends on the air density. The denser the air, the more energy received by the turbine. The colder the air the denser it is. At great altitudes, such as mountain regions, the air is colder thereby being denser.A typical wind generator of 1.000 kW has a rotor with a diameter of 54m, which implies an area of 2.300 m^2. This determines the amount of wind energy that a wind turbine can capture. Since the area of the rotor increases with the square of the diameter of the rotor, a turbine that is twice as large will receive four times more energy. The speed of the wind is very important for the amount of energy that a wind generator can transform into electricity; the amount of energy that the wind possesses varies with the cube of the average speed of the wind. If the speed of the wind duplicates the amount of energy it contains will be 4 times greater. After a study visit to the Cabreira mountain range wind collector park, the students will learn the concept of kinetic energy and energy transfer with greater ease. Small wind generators will be constructed to test the variation of electrical energy produced in function of the speed of the wind.

Topics of the project covered in the Chemistry classes

The Chemistry program for high school student's deals with certain topics related to this project, thereby integrating itself perfectly.

Atmospheric Pollution

The identification of the atmospheric pollutants is very important because it helps the students to understand that they have many opportunities to avoid erroneous behaviour in favour of the atmosphere. The region in question has, as a common practice, the burning of all types of domestic garbage many times without knowing the harm that is being done. It is not only illegal, but also responsible for the emission of toxic gases to the atmosphere and the cause of many fires.
The students will find the explanations for the reason why some natural agents, as well as some human activities, alter the concentrations of the troposphere constituents that normally exist in trace amounts [3]. Carbon monoxide, one such constituent, results from the combustion of carbohydrates and, in certain conditions, makes the atmosphere toxic and lethal to human beings.

The ozone layer

In a practical activity the students will be invited to observe, using protective eyewear, different light sources: solar light, ultraviolet light, and infrared light.

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Following these observations they can compare the effects of irradiation on different objects (i.e. minerals, white clothes, bank notes, and detergent dust). In this same activity they can observe the protective effect of glass filters, perspex, and solar creams against UV radiation and compare the effect of mechanical filters and chemical filters (the case of ozone) on radiations.
In the process of dealing with the results of this activity, each group will analyze documents relative to the ozone in the atmosphere, systemize information on the consequences of the rarefaction of the ozone in the stratosphere, and interpret international recommendations for its preservation.

The chemical composition of water and pollution

The high-school chemistry program gives special attention to the study and analysis of water and aqueous solutions. Particularly, with respect to acid rains, experimental activities will be carried out that promote the study of the effect of atmospheric pollutants (CO_2, SO_2, etc.) on the pH of the rainwater. River water will also be analyzed. There will be an exchange of the water samples collected between the participating schools.
In the laboratory the students will analyze the pH and the conductivity of the samples:

- pH, translates the acidity of the samples (more or less elevated depending on the amount of acid dissolved in the solution);
- Conductivity is the parameter that indicates the mineralization, this is, the amount of ions and particles dissolved in the water.

Topics of the project covered in the Biology classes.

Biodiversity and protection of species at risk.

Field studies will take place for the identification of the different species, and their characteristic habitats, that belong to the biodiversity of Cabreira mountain range. An exposition panel will be created in order to show photographs of the species in their habitats. After making this inventory, the students will carry out a bibliographical research in order to identify the species that are at risk or in danger of being extinguished, as well as some possible causes for this situation.
Since this region has dams, special attention will be given to fishing. Considering that there exists the Law of the Minimum Sizes for Fishing, an inquiry will be elaborated to determine what kind and amount of fish exist in the region, what sizes when captured, and the evolution of the fishing activity in the past years. After analyzing and processing the data, a brochure will be elaborated with this information that will be distributed to fishing associations, tourism posts, etc...

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To collect, recycle, and reuse

In the present school year a campaign to sensitize students to garbage separation will be elaborated. The first phase will include the display of posters with messages alerting to garbage problems. The posters will be renewed every week and after a month, one day will be dedicated to workshops organized by the students for the students of the school.

Containers for garbage separation will be placed in various locations of the school. These will be constructed by the students under the supervision of the Braval-Evaluation and Treatment of Waist Company, whose participation in the project will be requested.

The decomposition of vegetable or animal matter, that is essential to the fertility of the earth, is a common practice in rural backgrounds. This practice will be implemented in the recycling of the organic garbage produced in the school using a chemical and biological approach. This process can be defined as a controlled aerobic decomposition of organic substrate under conditions that reach temperatures high enough for the growth ofthermophilic micro organisms. The temperature increase appears as a consequence of the release of heat in the microbiological degradation of the substrates. The result of this process is a product called compost that is stable enough to be applied in the ground, with advantages over synthetic fertilizers [4].

The decomposition of residues can also be obtained in the absence of oxygen, being at times incorrectly called of anaerobic decomposition. The resulting product of this process has characteristics very different from those of the compost.

The stabilization of the organic substance is done slowly and the temperature reached is not very high. The residue produced needs to be treated subsequently before being accepted as an organic additive of quality [4].

The students will construct a *compostor* that will be installed in the school. The container chosen must be of wood, containing two spaces, each one with approximately 1 m3. Chemically treated wood (i.e. varnish) not be used.

Geology topics

Geological landmark of the Cabreira mountain range

Earth is a dynamic planet. If the earth’s internal heat had ended, and tectonic forces consequently stopped, the external geodynamic processes, driven by solar energy, would long have levelled the continents and equilibrium would have been achieved [5]. But internal and external forces continue to interact resulting in disarrangement, i.e. dynamic equilibrium.

Volcanic or seismic phenomena are of general knowledge but other less spectacular events, like constant rock transformations, also evidence that dynamism.

The rock cycle shows that each one of the three main rock groups: sedimentary, igneous, and metamorphic rock may be formed at the expense of others under new climatic or physical conditions and as the result of either internal or external forces [5].

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The Cabreira mountain range is a granite massif that shares with others some characteristic landforms, but the most important features of this region are the periglacial landforms, granite pseudo-stratification very well defined, maybe the best on national ground [6].
The top and western hillside of the highest Cabreira Mountain, Talefe, is covered by granite slabs. These slabs originate from endogenous factors (structural and mineralogical characteristics of the granite) and exogenous factors (climatic conditions, particularly the frozen/thawed effects from the würmian glacial and post-glacial period).
The combination of these elements resulted in granite pseudo-stratification (Figure 3), which is still visible in the major massifs (Montesinho or Estrela). The breaking of these blocks covered the Cabreira hillsides with rocks 10 centimetres thick and sometimes a few meters of long [6].
The students will be induced to acknowledge the idea that the top and western hillside of the highest Cabreira Mountain is, in fact part of the local geomorphologic heritage and needs to be protected.

Figure 3. Cabreira granitic pseudo-stratification

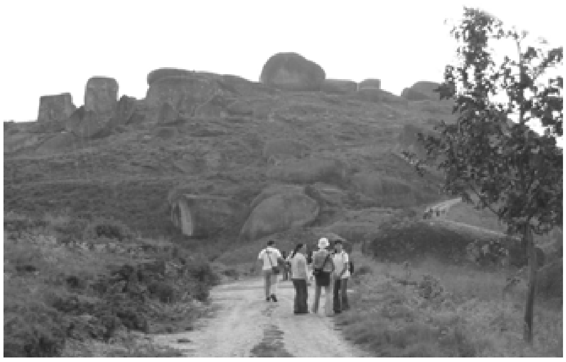

Figure 4. Students on the field trip in the Cabreira Mountain range (Talefe)

Activities

1. Cabreira field trip, that took place during the present year, to observe the referred features and elaboration by students of a field trip guidebook.
2. Geological exchange between the schools with field trips whenever possible, that in Cabreira will be organized by the students. Students will have to collect rock samples covering national ground as well as photographs of local landforms.
3. Granite, from several places marked with pseudo-stratification, comparative study at mineralogical, textural and chemical levels. This study will be made in partnership with Geosciences Department of Minho University.
4. Preparation of one proposal to the European Association for the Conservation of Geologic Heritage to classify Talefe as a geo-monument.

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Conclusion

Many of the questions that affect the future of the society must be approached in the school, making the students want to find out more about various topics such as: the increasing energy necessities, the climatic changes, biodiversity, the scarcity of spaces and resources, Man's interventions in the terrestrial subsystems and its negative impact in our environmental and thus to a sustainable development. It is of utmost importance to change the attitudes of the common citizen and society in general. So that this change of attitudes is verified, solid scientific literacy is imperative so as to assist us in the comprehension of the world we live in, to identify its problems, and to understand the possible solutions. Awareness and critical reflection on these challenges should be promoted. Our students will profit this opportunity of exchange of experiences and knowledge with other fellow students of other cultures. The participation in this project of schools of various European countries will give the project a fundamental European dimension.

Acknowledgement

The authors would like to acknowledge the support of the director of the Vieira do Minho high school, Jose Braga Fernandes, for his support and interest shown in the implementation of this project and the local authorities for their promise to participate in the development of this project, to Arcélio Sampaio for the information he kindly offered and for his work in the graphic arrangement of the presentation, and specially to Alda Ferreira for her support and comprehension. The activities and plans herein reported are inscribed in the frame of activities of the HSci network.

References

[1] Kolb KA, Experimental Learning: Experience is a source of learning and development, Prentice Hall: Upper Saddle River, 1984.
[2] Costa MF, Science Literacy and Development in The European Union, Workshop The Challenges of EU Enlargement, Malta, 20th-22th January 2005.
[3] Ministério da Educação, Departamento do Ensino Secundário, Programa da disciplina de Física e Química A - 10º e 11º Ano.
[4] http://www.escolasverdes.org
[5] Plummer CC, McGeary D and Carlson DH, Physical Geology, International Edition, 9ªEd, McGraw-Hill: New York, pp.: 50, 2003.
[6] Pereira P, Aspectos Geomorfológicos da Vertente Norte do Maciço culminante da Serra da Cabreira, Relatório de Seminário da Licenciatura em Geografia e Planeamento, Universidade do Minho, Guimarães, 2000.

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"Hands-on Science. Science in a changing education",
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Practical Work to Promote Interdisciplinarity between Physical and Natural Sciences: A Teaching Experiment with 7th Grade Portuguese Students

Duarte MC, Sequeira M and Barbosa P

Introduction

Two main ideas are central to the Portuguese curricular reorganization of Basic Education initiated in 2001, including the subjects of Physical and Natural Sciences. The first idea concerns the attempt "to value the experimental learning in different areas and disciplines, [being] compulsory in the case of the teaching of science, to promote the integration of its practical and theoretical dimensions…" [2]. The second concerns the interdisciplinary approach to some topics and contents with the objective of "demonstrating the unifying character of possible themes, emphasizing phenomena that require scientific explanation from different areas of knowledge" [7].

Practical work in the teaching of science

The importance attributed to practical work in the Portuguese Science Curriculum is aligned with the main beliefs shared by experts in science education. Brief reviews of the literature on practical work in Science Education [11, 3, 5, 6, 10], can illustrate its importance. Practical work can motivate learning; develop scientific and analytical skills; enable an improved acquisition and comprehension of concepts; develop a solution-driven pragmatic mindset; develop discussion and critical analytical skills as well as introduce more rigor in Science Research. The issue of motivation is nowadays of particular concern [9], given that a significant portion of the students have little incentives to learn, exiting the schooling system prematurely. Therefore, the teacher should emphasize the emotional sphere and resort to experiments that go beyond simple and mechanistic implementations in order to become more fun and rewarding for the student. This value added in the emotional sphere can also represent a way to obtain better performances by the "least capable" students [9]. Reid and Hodson [9] explain that "this increasingly emotional response causes in itself a feedback movement leading to the

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accumulation of more cognitive abilities that can stimulate learning". The goal is to engage students in interactive teaching methods, so that science can become real and relevant in their eyes. Hence, emphasis should be placed on activities in which students have a high chance of succeeding and in which they can interact and find meaning in their experiments.

The key concept is that of "motivation", which can also take place through the curriculum itself. The latter should include three types of goals, in order of priority:

The first concerns the goals centred in the student such as overall motivation and the development of certain attitudes of self-esteem.

The second refers to the goals centred in society, enabling the framing of the contents through an interaction between science, technology and society (stressing everyday issues, promoting equilibrium between scientific/technological criteria as well as economic, ethical and social considerations).

The third concerns the goals that are centred in science, such as the knowledge and comprehension of scientific concepts and theories (the study and experience of phenomena); the acquisition of cognitive and psychomotor competencies (scientific practices, problem-solving); the development of a scientific attitude [9].

Together with the aforementioned potential for practical work, there are also critical perspectives with relation to how it can be conducted and consequent efficacy in teaching scientific concepts. Some authors [4, 3] consider that practical activities instead of promoting learning can sometimes promote conceptual misperceptions and thus become useless. Others [5] share the thought that in many classrooms practical training is miss-conducted, confusing and unproductive, thus contributing very little to science students' learning. Others still [6] consider that in many situations, practical work is done in an excessively hasty manner, managing the equipment in a very carelessly, so that students fail in the production of the phenomenon they were supposed to observe. Moreover, even if that is not the case, the observed aspects may seem obvious to the teachers and not to the students. Therefore, practical activities can quickly turn into a routine with no objectives for the students. Rendering practical work more efficient requires the need to think carefully about the way it is going to be used as well as the type of activities that will be adopted given the objectives and the students it is aimed at. In fact, this recommendation is explicitly reflected in the Portuguese Basic Education Curricular organization when it mentions: "the experimental activity should be planned with students, deriving from problems intended for analysis, as opposed to the blanket application of a cookie cutter approach. All cycles of schooling must privilege the formulation of hypotheses and prediction of results, as well as their observation and interpretation." [7].

Interdisciplinarity in science education

The definition of the role of Science in the Portuguese Basic Education Curriculum reinforces the idea that Science cannot be applied in a self-contained way, with contents that are detached from the real world. It should instead favour an integral and global perspective on Science [10]. Under this assumption, the curriculum should not be the sum of several parts but an articulated whole corresponding to an

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enriching dialogue between the different sources of knowledge that lie at its core. Herein rests the importance of a horizontal articulation of concepts, themes, contents and skills. In this context, the goal is for students to develop a more global understanding that goes beyond a limiting disciplinary approach. This fact requires information to migrate from other fields of knowledge, and for it to be reinterpreted in light of the problems that cannot be solved purely within the realm of classical disciplines. However, this is not to mean that as stated in the document about "curricular orientations", that disciplinary individualities will not be respected. Instead, it enables teachers to organize their classes, or at least some of the contents, collaboratively. The goal is to expose the unifying content of possible questions, stressing the phenomena that require scientific explanations originating in different areas of knowledge.
Taking these ideas into account we conducted a teaching experiment in Physical and Natural Science, which corresponded to practical work through an inter-disciplinary approach.

The teaching experiment

Taking these suggestions into account, we conducted an experiment in teaching on the topic of "Earth under Transformation", which is shared by Physical and Natural Sciences.
The Basic Education National Curriculum, enacted in Portugal since 2001 defines 10 areas of general competency that should be developed during Basic Education. The first consists in "mobilizing cultural, scientific and technological knowledge in order to better understand reality and to address everyday situations and problems." All competencies foresee a transversal operationalization. As far as the aforementioned competency is concerned, the curriculum suggests an emphasis on: the context and the problem so as to encourage the student's involvement and curiosity; on questioning the observed reality; on identifying and articulating knowledge and information that can enable a better understanding of the situation or the problem at hand; on the application of the necessary procedures to understand reality and solve problems; on the assessment of the adequacy of knowledge and procedures used while adjusting when necessary.
Taking these suggestions into account, we conducted an experiment in teaching on the topic of "Earth under Transformation", which is shared by Physical and Natural Sciences.

Subjects

Thirty 7th grade students, as a class, participated in this experiment.
This is the year in which students start to study the subjects of Natural Sciences as well as Physics and Chemistry, under the Natural and Physical Sciences grouping.

Description of the experiment

During the first phase, the teacher of Natural Sciences approached the students with the topic of "Volcanic Activity: risks and benefits". The study began with a discussion of news of volcanic eruptions, some referring to historical events. Then,

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the teacher proposed that the students build a model of a volcano as practical work to explore the issue of volcanism (Figure 1 and 2).

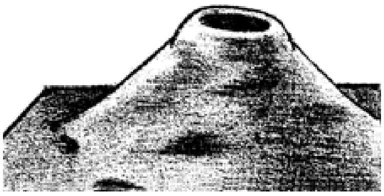

Figure 1. Model of the construction of a volcano

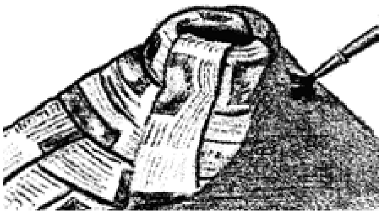

Figure 2. Final model of the volcano

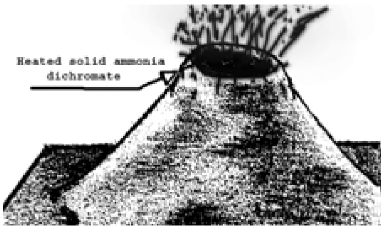

Figure 3. Simulating a volcanic eruption

Simultaneously, the teacher of Physics and Chemistry worked with students on the topic of "Chemical and Physical Transformations." In the realm of chemical transformations the question posed was: "How do some substances transform into others?". To solve this problem several day-to-day situations were analyzed and the practical work was undertaken.
During a second phase, a session of ninety minutes took place with both Natural Sciences and Physics and Chemistry teachers present. Teachers and students discussed the type of volcanic equipment as well as the type of volcanic eruptions and their main causes. They also simulated a volcanic eruption by using heated solid ammonia dichromate (Figure 3), relating it to the study of the topic of chemical transformations and to the particular case of chemical transformations through heat. In this context, both teachers and students used practical work as an opportunity to reflect upon, discuss and integrate knowledge.

Assessing the experiment

The techniques used to assess the teaching experiment corresponded to a direct observation of students while they worked in the classroom and responses to a questionnaire. One of the evaluations reported by a teacher, based on the perception derived from observing students, mentioned the following: "A brief and critical analysis of this experiment reveals very positive results. Firstly, not only for me but for the entire teaching body, the connection established between the programmatic contents of both disciplines was extremely important, due to a dynamic approach to both topics. As far as students were concerned, because they became active agents in the process of learning through the exploration, manipulation and observation of the phenomena, they achieved the objectives of the class and were able to adopt a critical view of the articulation of contents belonging to the different curricular areas".
The learning experience was valued by students and expressed in some of the answers given to the questionnaire. In response to the question: "Did you enjoy this experiment?", students stated that " It was fun because we were able to see - through chemistry - what happens in nature, without too much effort. The entire

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class was interested and that is always very good"; and that "Yes because it was different and we were able to picture moreless how a volcano works while learning Chemistry."

In response to the question – "Do you think that this strategy contributed to a better understanding of the contents of Natural Science and Chemistry?" - we obtained answers such as: "Yes, to some extent it did because it helped us learn chemical transformations much better as well as the "functioning" of volcanoes" and "Yes, because by connecting the disciplines we were able to better understand everyday situations".

Regarding the question – "If you had to compare this strategy to another one in which teachers would teach these contents separately, which one would contribute more towards your understanding of the materials?" - The students replied that "I think the strategy of integrated teaching is better. For instance, to understand Chemistry, we need knowledge of Science and other disciplines"; and that "I think that this strategy is better because it creates incentives for us to be engaged in these activities and understand the subject matter better".

The fourth question asked: "If you could influence your teachers regarding teaching strategies to use in the classroom, what advice would you give them given the experiment with volcanism?". To this students answered that "These activities should be more frequent" and "I would advise them to teach more practical classes and co-teach with other teachers when the topics overlap".

The last question, asked whether "a strong connection between teachers and disciplines was beneficial for students' learning", elicited the following responses: "Yes, because we learn more about a subject if different teachers are teaching it" and "Yes, because students can learn more concepts that can be applied to other disciplines".

All things considered, analyses of students' answers reveal that they have developed a very clear perception of the importance of practical work and of a global approach to phenomena. This is evident when they allude to more practical classes and the need for more cross-disciplinary knowledge.

We strongly believe that this teaching experiment is very simple without requiring sophisticated equipment. It also represents an approach that enables students to investigate real world problems, relate them to their daily lives and better understand the phenomena they are confronted with in the mass media.

References

[1] Cachapuz A, Praia J and Jorge M (Eds.), Ciência, Educação em Ciência e Ensino das Ciências. Ministério da Educação, Lisboa, 2002.

[2] Decreto-Lei 6/2001, art. 3º

[3] Gunstone R and Champanhe A, Promoting Conceptual Change in the Laboratory, in Hegarty-Hazel E (Ed.), The Student Laboratory and the Science Curriculum, London: Routlege, 1990.

[4] Hofstein A and Lunetta V, The Role of the Laboratory in Science Teaching, Review of Educational Research, 52: 201-217, 1982.

ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

[5] Hodson D, Re-thinking Old Ways: Towards a More Critical Approach to Practical Work in School Science, School Science Review, 22: 85-142, 1993.
[6] Millar R and Tiberghien A, Varieties of Labwork: A Way of Profiling Labwork Tasks, in Psillos D and Niedderer H (Eds.), Teaching and Learning in the Science Laboratory, Kluwer Academic Publishers: Dordrecht, pp.: 9-20, 2002.
[7] Ministério da Educação. Currículo Nacional do Ensino Básico – Competências Essenciais. Departamento da Educação Básica, Lisboa, 2001.
[8] Ministério da Educação, editor. Ciências Físicas e Naturais, Orientações Curriculares 3º Ciclo. Lisboa: Departamento da Educação Básica, 2001.
[9] Reid D and Hodson D (Eds.), Ciencia para todos en Secundária. Narcea, Madrid, 1997.
[10] Wellington J (Ed.), Teaching and Learning Secondary Science. Routledge: London, 2000.
[11] Woolnough B and Allsop T (Eds.), Practical Work in Science, Cambridge University Press: Cambridge, 1985.

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The Science Fair as a Means for Developing Children's Graphing Skills in Elementary School

Kyriazi E and Constantinou CP

Introduction

The rising interest expressed by researchers in reforming science teaching proposes to the promotion of a fundamental objective: to prepare students to participate in a scientifically literate and technologically dependent society as informed and insightful citizens. Curriculum designed for this purpose must provide special emphasis on the development of scientific thinking skills in the context of learning science [18].

The ability to construct graphs is important to science and it can be considered as one aspect of an individual's scientific literacy [27, 31, 24, 1]. When arguing in favour of a specific theory, a scientifically literate person needs to manipulate data and refer to relationships as they emerged from evidence represented on graphs or tables. Graphs can summarize very complex information or relationships very effectively. The extensive use of computers, nowadays, has made easier the use of graphs as a way of representing data [29, 1, 26]. This has led to an increase in the visibility of graphical representations in the popular press and other mass communication media.

During the last years, the effective use of graphical representations in mathematics and science education has received special attention [25]. Still, there is considerable evidence to suggest that students perform poorly in tasks related to graphing procedures [24, 1]. We take the perspective that graphing strategies need to be systematically promoted in the context of learning science in elementary school within students´ involvement in broader inquiry - oriented activities that are close to their experiences and interests [10]. Hence, there is a necessity for designing teaching interventions aiming at the development of data graphing skills in elementary school through a combination of different learning styles.

The curriculum designed for the purposes of the present research study combines formal, non-formal and informal educational activities. Students, who participated in the research, were involved in data graphing processes as part of the investigations they implemented for participating in a science fair. In this paper, we discuss the results regarding 10-12 year old children´s performance on data graphing, the difficulties that hamper their attempts to graph data and the necessity for a systematic promotion of this skill through science education.

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Background

Data Graphing

Investigation is a process central to science that involves both reasoning and procedural aspects [7, 5]. The ability to organize and implement an investigation can be analysed into specific investigative skills: the identification of variables, the formulation of questions, the experimental design and control of variables, data graphing, the interpretation of data from tables, graphs and combinations of independent sources and the identification of faults in experimental design are examples of such skills [16].

Graphing skills fall into the procedural part of the investigative procedure. Data emerge from the investigation are organised represented concisely during this stage, which therefore assumes a productive role in sense making. In this context, the production of a graph is a part of a process of problem solving and not an end in itself [1].

Graphs are a flexible medium for displaying data, revealing relationships between variables and communicating the results [27, 31, 29, 24, 1, 26]. Graphs are often preferable to tables for the purpose of displaying data. Firstly, a graph allows the reader to quickly identify trends and relationships between variables and evaluate the strength of the relationships. Moreover, a graph distils a lot of information into a restricted amount of space [27, 31, 24].

The kind of graph chosen for displaying data depends on the type of the variables involved. A histogram is appropriate when the variables involved are categorical and a line graph is preferred when the variables are continuous. Constructing either histograms or line graphs requires some level of abstract reasoning ability. Construction of graphs "involves going from raw data (or abstract function) through the process of selection and labelling of axes, selection of scales, identification of units and plotting" [21]. The complexity in data graphing is identified by researchers [27] who analyzed the skill into other sub skills:

(a) drawing and scaling axes,
(b) assigning manipulated and responding variables to the correct axes,
(c) plotting points, and
(d) using a line of best fit in the case of a line graph or sketching the bars in the case of a histogram.

These subskills can be approached individually in science education as part of the development of data graphing skills [31, 9]. However, we take the approach that graphing skills are better developed in combination with other investigative skills in the context of authentic problem solving situations [19].

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Interpreting information from graphs

The graphing process involves both construction and interpretation [24, 1]. Hence, graphing is sometimes defined as a unique skill that includes two aspects: construction and interpretation of graphical representations.
However, interpretation of information from graphs refers to the ability to read a graph and develop meaning from it. It relies on and requires reaction to a given set of data. This makes it different from the ability to construct graphs, which requires generating new parts that are not given [21].
As a result, the two skills (construction and interpretation of graphs) are approached separately in our educational design. The interpretation of graphs was also analyzed into subskills [27]:

(a) determining the X and Y coordinates of a point
(b) interpolating and extrapolating
(c) stating relationships between variables
(d) interrelating the results of two or more graphs.

Accurate interpretation of evidence relies on good data handling [9]. Hence, the ability to construct graphs would be expected to relate to the ability to interpret information from graphs. The two skills would be expected to interact throughout their development.

Difficulties related to Data Graphing

Several studies, that examined graphing tasks, showed that students encounter various difficulties in their attempt to make their own graphical representations [27, 31, 24]. Approaching graphs as pictures is mentioned by researchers as one of the difficulties students come across [21]. Another difficulty refers to student's ability in drawing the best fit line [27]. The construction of a series of graphs, each representing one aspect of the data, was also identified as a difficulty [24]. Difficulties that are common in both interpreting and constructing graphs strengthen the hypothesis that there is a strong relationship between the two skills through their development.
These difficulties seem to function as obstacles to students' efforts to construct graphs and they often make them feel a general lack of competence in graphing. As a result, they prefer constructing a table than a graph and they often draw conclusions with little or no reference to their graphs [27, 9]. The research literature also declares that many teachers seem to recognize that pupils have difficulties in constructing a graph, but only few teach graphing strategies explicitly [9].

Teaching Approaches

There is comparatively little mentioned in the literature about approaches aiming to systematically promote data graphing in science education. Graphing is often

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considered as a domain only of Mathematics. However, research has shown that many students cannot apply what they have learned about graphs in mathematics to science or other disciplines [23]. Hence, since data graphing is a part of the investigative procedure, it can and should be systematically addressed within science education.

Several research attempts demonstrate that students can improve their graphical techniques through computer-based learning environments, especially the process of interpreting and manipulating graphs [29, 1, 26]. Yet, students firstly have to be encouraged to construct graphs within paper and pencil activities, which is probably more meaningful and understandable for them and then become involved in activities with spreadsheets.

The Science Fair

The Science Fair is a non-formal learning activity in which students implement science projects and exhibit them to the public [30]. Educators internationally use the science fair activity for two main reasons. First, students participating in a science fair are encouraged to become involved in issues related to science and hence, they develop positive attitudes towards science learning. Second, parents have the opportunity to become involved in the learning process [3, 4, 8, 6, 12, 15].

There are relatively few examples of fairs that have clearly specified educational goals and are assessed for their learning outcomes. The very loose connection with the official curriculum is one of the disadvantages of science fairs that are usually acknowledged as the reason for considering them as celebratory school events without much emphasis on the learning outcomes [2, 13, 4].

However, our literature review suggests that when a science fair is used as a learning activity, the students participating:

(a) develop critical thinking skills, problem solving skills and social skills [3, 8]
(b) enhance their opportunities to develop an understanding of the nature of the work of scientists [4, 6, 13, 22].

In our research, the science fair is used as an extended instructional activity that combines formal, non-formal and informal activities and aims at the improvement of investigative skills in elementary school. According to the approach that has been developed, the science fair is the final stage in a long process, where students undertake authentic investigations related to simple questions of their own interest. They work collaboratively to implement an investigation in which they design experiments, collect data, construct graphs and formulate answers. The whole process culminates in a specially organized school event (*the science fair*), during which children display the procedures and results of their investigations and also engage in interactive activities that they have designed in collaboration with their parents in order to teach certain aspects of their investigation to visitors.

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We used this teaching context to investigate the development of children's ability to represent evidence in graphical form. Two examples from the students' efforts to graph data for the purposes of their investigations are presented in Figure 1.

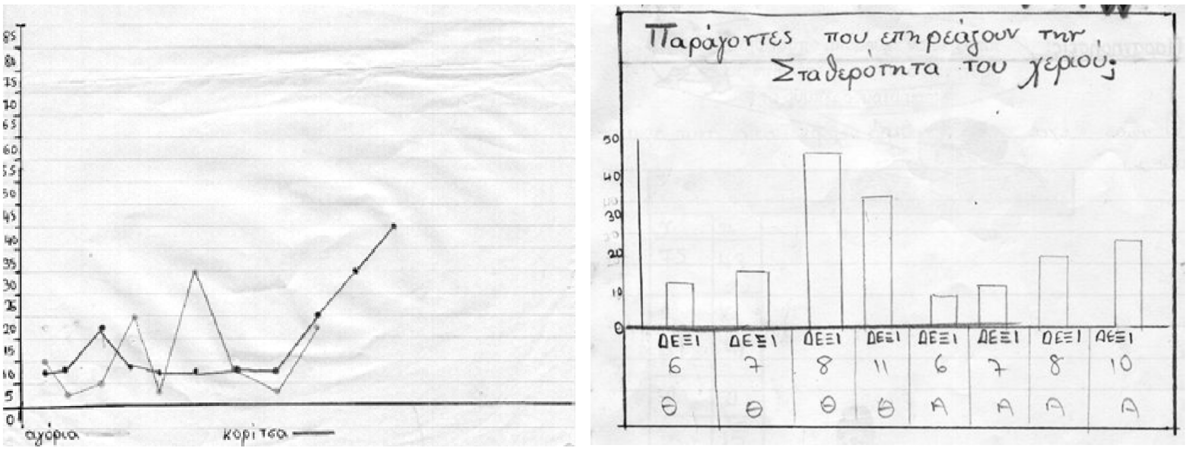

Figure 1. Examples of student's efforts on data graphing

Research study

Participants

Thirty-five 5-graders of a rural primary school in Cyprus participated in this study. The students were engaged in both the formal teaching intervention and the science fair.

The curriculum used in the present study, was designed for the purposes of the research program: *The Science Fair as a means of developing investigative skills, that is* implemented by The Learning in Science Group at the University of Cyprus. The program focuses on the pedagogic exploitation of the science fair as a means for developing investigative skills in elementary school and promoting student inquiry through a sequence of formal and non-formal activities. The teaching and learning materials, involve a handbook for teachers, a student workbook and an investigations' booklet [5]. Part of the material is available online for use by teachers, students and parents [17].

The Intervention Program

The study was divided into three phases, as shown in Figure 2. In the first phase, the students participated in a teaching intervention, which took place in a formal classroom setting. One of the lessons was devoted to data graphing strategies. During the non-formal phase, students implemented their investigation collaboratively and interacted with other students, their teachers and their parents in preparation for their participation in the science fair. The children formulated investigative questions, designed and implemented valid experiments described their procedure in a notebook and created a poster for displaying their methods and

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results. Whenever it was possible, the students constructed graphs to display their data. The actual science fair took place in the third phase of the research.

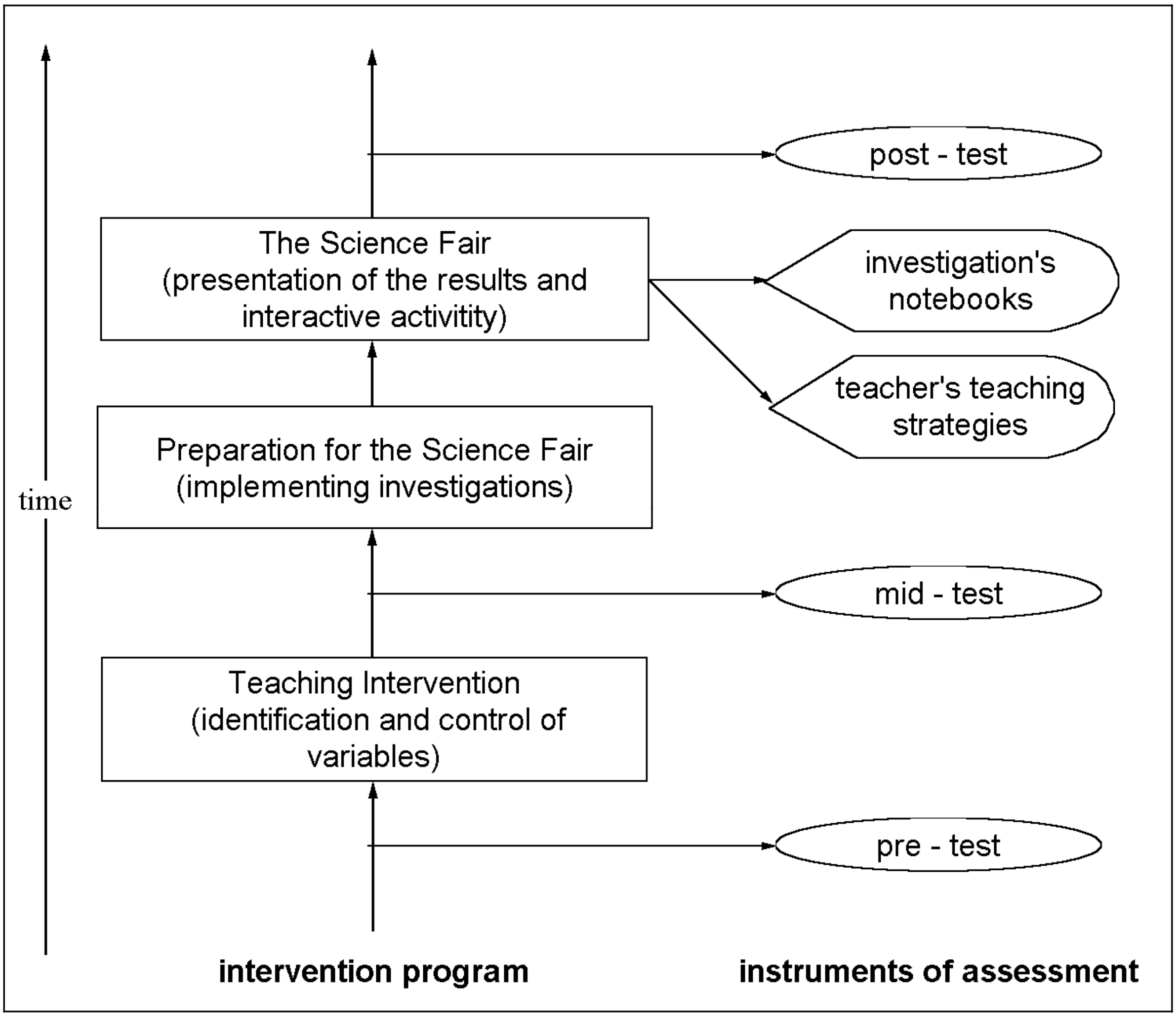

Figure 2. Organization of the research study

Method

For the purposes of the research study, paper and pencil open-ended tasks were administered to the research participants, before and immediately after the formal teaching intervention and after the Science Fair. Totally, four of the tasks aimed at evaluating students' abilities to graph data. Each instrument was administered at least twice during the study. Tasks 1 and 2 were included in the pre and post test. Tasks 3 and 4 were included in the mid and post test.
All assessment tasks presented unfamiliar situations that have not been encountered during the intervention. The context of tasks 1, 2 and 4 was associated with science experiments and the context of task 3 related to everyday situations that were not associated with science by the children. Moreover, in tasks 1 and 4

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students were expected to construct histograms and in tasks 2 and 3 students were expected to construct line graphs. These were stringent criteria that helped us measure real learning as demonstrated by the ability for knowledge transfer.

Task 1

Melina filled up 3 pots with water of different temperatures: pot A with hot water, pot B with lukewarm water and pot C with cold water. He measured the time needed to dissolve sugar in each pot and organized the data in the table below:

Cup	Time for sugar to dissolve
A- hot water	12 sec
B- likewarm water	17 sec
C- Cold water	30 sec

Construct a graph with the data displayed on the table.

Task 2

Simon took two similar plants. He placed plant A in the light and plant B in the shadow. He measured the height of the plants every three days. He organized the data collected in a table as shown below:

Day	1st	3rd	6th	9th	12th	15th	18th
Height of plant A	5cm	6cm	8cm	10cm	12cm	13cm	15cm
Height of plant B	5cm	5cm	6cm	8cm	9cm	11cm	11cm

Construct a graph with the data displayed on the table.

Task 3

Mr Manolis wrote in a table how many costumes and jackets were sold in his shop between April and August.

Month	Costumes	Jackets
April	250	150
May	200	200
June	150	400
July	100	500
August	140	450

Construct a graph in order to compare the number of costumes and jackets sold in each month.

Task 4

Leonidas investigated if the colour affects the extent of transparency of a surface. He used surfaces of four different colours: yellow, red, colourless and blue. He counted the number of surfaces needed to cover completely a specific drawing.

Colour of the surface	Number of surfaces
Yellow	24
Red	15
Non-colour	29
Blue	18

Construct a graph to display these results

Posters constructed by the students for the purposes of the Science Fair and their notebooks were used as additional evidence in the research.

Findings

Qualitative and quantitative data were obtained from the phenomenographic analysis of student's responses to the four tasks.
The results demonstrate:

- Ability levels on data graphing
- Difficulties that hamper students' attempts to graph data
- Significant student differences on graphing achievement on pre-test, mid-test and post-test

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- A significant interaction between the skill of constructing graphs and the skill of interpreting information from graphs

Student's notebooks and posters were mostly used to identify difficulties that students come across in their attempt to construct graphs.

Description of Students' Responses

In tasks 1 and 4, most of the students constructed histograms as they were expected to. Before the intervention (as demonstrated by their responses to task 1), students had chosen the appropriate type of graph. However, most of them either scaled wrongly the axes or did not assign any variables to them. After the teaching intervention (as shown from their responses to task 4), a high percentage of students constructed the suitable type of graph (histogram), they assigned the corresponding variables and they scaled the axes correctly. At the end of the intervention program, in both tasks, almost everybody managed to assign correctly the corresponding variables and to scale the axes correctly in the histograms they created.

In tasks 2 and 3, students were expected to construct line graphs. Before the teaching intervention (as shown from their responses to task 2), most of the students assigned the variables in an inappropriate type of graph (a histogram) and they scaled wrongly the axes or did not scale them at all. The majority of the students did not assign the corresponding variables. Many of them did not offer an answer at all. In task 3, which was administered for the first time after the formal teaching intervention, many students again, did not come up with an appropriate type of graph. Most of them constructed a histogram, without any or wrong scaling and assigning of the variables. In a high percentage of these responses, the axes were scaled correctly, but the variables were not assigned properly. After the science fair, the majority of the students still did not choose the appropriate type of graph to present the data in both tasks and they encountered several difficulties in scaling the axes or assigning the variables. Only a few of them constructed a line graph and assigned the variables and/or scaled the axes correctly.

The responses of the students on each task were analyzed phenomenographically. The groups that emerged were compared and organized in eight general categories, which were ordered hierarchically from the lower level to the higher. Finally, the responses in each task were classified into the levels described below.

Ability Levels on Data Graphing

The eight ability levels on data graphing, which derived from the phenomenographic analysis of student's responses, are:

Level I: S/he does not answer, or s/he does not understand the question or s/he simply reconstructs the given table

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Level II: S/he does not choose an appropriate type of graph, does not assigns the corresponding variables and does not scale the axes
Level III: S/he chooses an appropriate type of graph, without assigning the corresponding variables or scaling the axes
Level IV: S/he does not choose an appropriate type of graph, but s/he

- assigns only the independent or the dependent variable, without or with wrong scaling of the axes
- assigns the independent variable with verbal reference to the dependent variable, without or with wrong scaling of the axes

Level V: S/he does not choose an appropriate type of graph, but s/he

- scales the axes correctly without assigning the corresponding variables, or
- assigns only the independent variable with correct scaling, or
- does not assign the independent variable, but s/he refers to the dependent variable verbally and scales the axes correctly, or
- assigns the independent variable with quantitative reference to the dependent variable, and correct but sometimes double scaling of the axes

Level VI: S/he chooses an appropriate type of graph, but s/he

- assigns the independent variable with quantitative reference, includes only verbal or no reference to the dependent variable and s/he scales the axes wrongly
- does not name the variables, but s/he scales the axes correctly
- assigns only the independent variable and does correct but double scaling of the axes

Level VII: S/he does not choose an appropriate type of graph, but s/he assigns the corresponding variables and s/he scales the axes correctly
Level VIII: S/he chooses an appropriate type of graph. S/he assigns the corresponding variables and s/he scales the axes correctly

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Typical examples from students' responses are presented below:

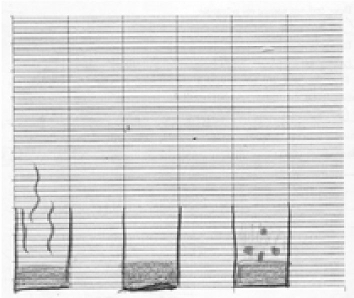

Figure 3. Example from task 1 – level 1

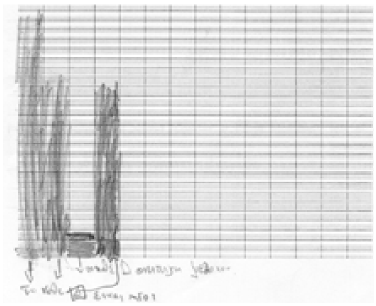

Figure 4. Example from task 4 – level 2

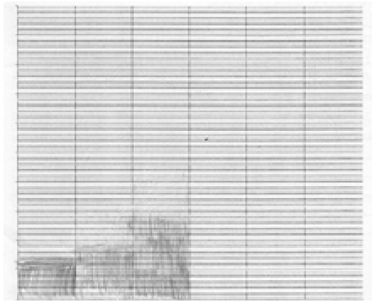

Figure 5. Example from task 1 – level 3

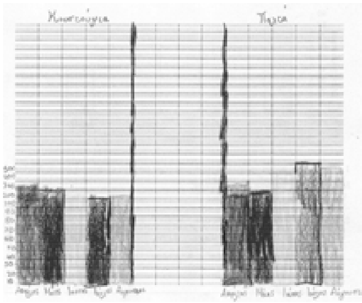

Figure 6. Example from task 3 – level 4

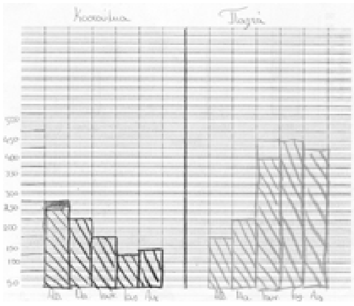

Figure 7. Example from task 3 – level 5

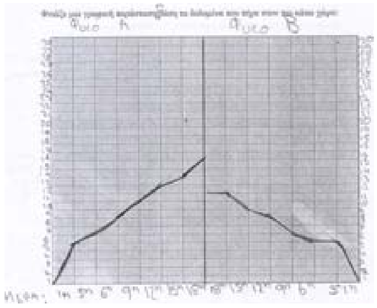

Figure 8. Example from task 2 – level 6

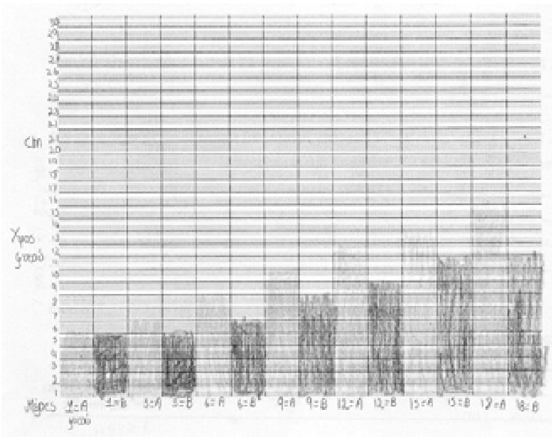

Figure 9. Example from task 2 – level 7

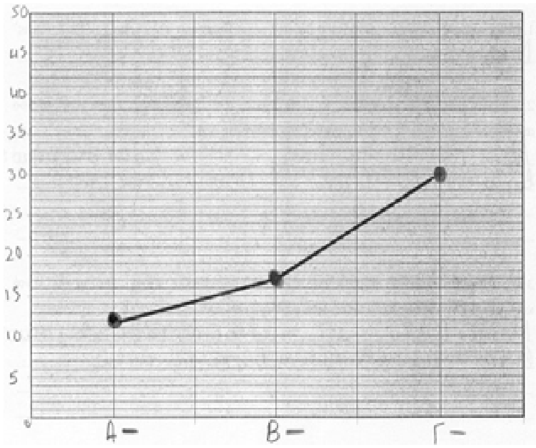

Figure 10. Example from task 1 – level 7

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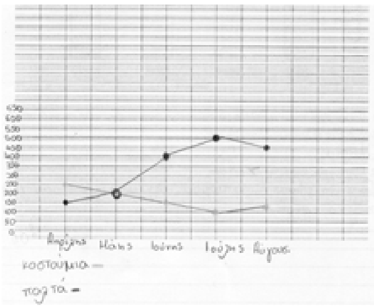

Figure 11. Example from task 3 – level 8

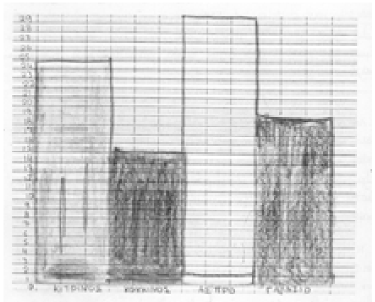

Figure 12. Example from task 4 – level 8

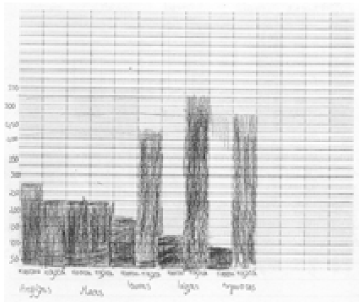

Figure 13. Example from difficulty 1

Student Difficulties with Data Graphing

The students seemed to encounter various difficulties with graphing. Three of them are given below with typical examples:

Difficulty 1: Students tend to construct histograms rather than line graphs, even when the dependent variable is continuous. They understand that they have to display the variation in the values of the corresponding variables, but they prefer a histogram in doing so, as shown in the example below.

Difficulty 2: Students tend to believe that graphs can present only a small number of measurements (a couple of values). They have difficulty in realizing that it is possible to display the continuous variation of these quantities through the same graph, as shown in the example below.

Difficulty 3: Children do not appreciate the importance of scaling the axes correctly, so as to make it possible to compare the quantities. They do not scale the axes in equal intervals, but according to the space they have to construct their graph, as shown in the example below.

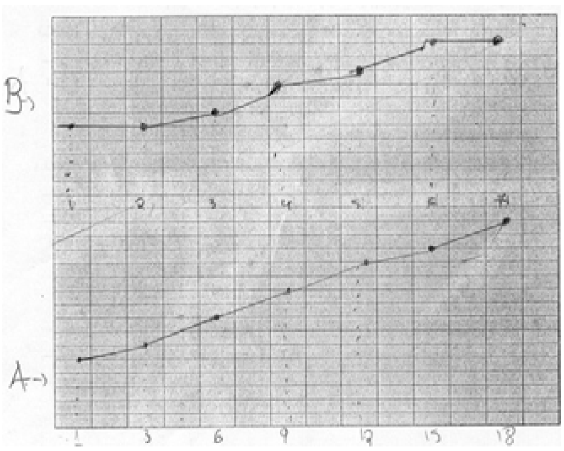

Figure 14. Example from difficulty 2

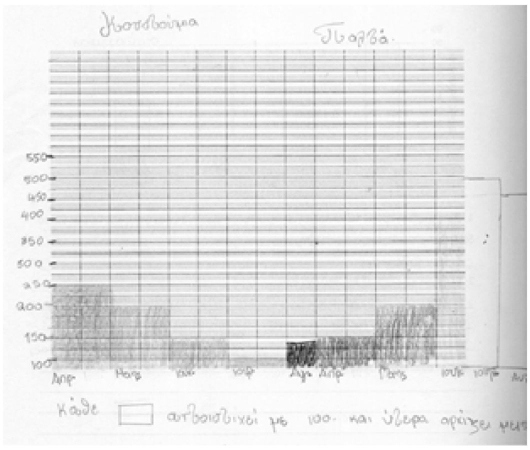

Figure 15. Example from difficulty 3

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Comparing students' graphing achievement on pre-test, mid-test and post-test

Students' responses to all tasks were evaluated and categorized (false answer – score=0, correct answer – score=1). We used the Paired-Samples T-test to compare students' achievement on each task between pre-test, mid-test and post-test.

The mean score on each task and the results of the statistical analysis are presented in Table 1.

Task	mean score			T	df	Sig
	pre-test	mid-test	post-test			
1	0,34		0,66	-2,750	34	,009*
2	0,00		0,06	-1,435	34	,160
3		0,03	0,09	-1,435	34	,160
4		0,63	0,77	-1,406	34	,169

Table 1. Paired-Samples T-Test

Table 1 shows that the mean score of students' achievement in all tasks was higher after the intervention program. However, the difference in students' achievement was statistically significant with $t_{(34)}$= -2,750 and a p-value of 0,009 (<0,05) only in the case of task 1. Students' achievement is also higher on constructing histograms (tasks 1 and 4), as compared to constructing line graphs (tasks 2 and 3).

We also used the Paired-Samples T-test to compare students' achievement between the total mean score on each test (pre-test, mid-test and post-test). A student's achievement on each test was the mean score of the graphing tasks. The results of this analysis are presented in Table 2.

	mean score			t	df	Sig
	pre-test	mid-test	post-test			
Data graphing	,171		,357	-3,404	34	,002*
		,328	,269	-1,871	34	,070

Table 2. Paired-Samples T-Test

Table 2 shows that the difference of students' achievement between pre and post test is statistically significant, with $t_{(34)}$= -3,404 and a p-value of 0,002 (<0,05). There is no statistically significant difference between mid and post test, with $t_{(34)}$= -1,871 and a p-value of 0,070 (>0,05).

Interactions between data graphing and interpreting graphs

In order to identify any interactions between the skills of data graphing and interpreting graphs, we estimated the Pearson Correlation. Table 3 presents the correlation between the two skills on pre, mid and post test.

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skill				Interpreting data from histograms	Interpreting data from line graphs	
Data graphing	Pre-test	Achievement 1	Pearson	-.150	.341*	---
			df	35	35	---
			Sig.	.390	.045	---
	Mid-test	Achievement 2	Pearson	---	---	.390*
			df	---	---	35
			Sig.	---	---	.02
	Post-test	Achievement 3	Pearson	.082	.138	.072
			df	34	35	35
			Sig.	.647	.430	.680
		Achievement 4	Pearson	.195	.371*	.090
			df	34	35	35
			Sig.	.268	.028	.608

Table 3. Pearson Correlations and significance level

Table 3 shows that before the intervention there was a statistically significant correlation between students' achievement on data graphing and interpreting data from line graphs, with $P_{(35)}$=,345 and a p-value=,045 (<,05). This interaction remains statistically significant after the formal teaching intervention, with $P_{(35)}$=,390 and a p-value=,02 (<,05) and after the science fair, with $P_{(34)}$=,195 and a p-value=,268 (<,05). There is no statistically significant correlation between data graphing and interpreting data from histograms. This might reflect the large difference in emphasis given to these two types of graphs in the context of formal education in Cyprus at these age levels.

Discussion

This study refers to a research program in which the Science Fair is used as an instructional activity aiming at the development of investigative skills in elementary school and the promotion of students' inquiry skills through a sequence of formal and non-formal activities.

The results presented in this article show that active participation in a science fair can lead to constructive development of graphing skills. Particularly, in this study we identified eight achievement levels on data graphing and several difficulties that hamper students' efforts to represent data using graphs. However, quantitative results showed that the students who participated in the research scored higher in all the tasks at the end of the intervention program. Their performances were better in tasks referring to the construction of histograms as compared to line graphs. The improvement in their performance was always significant after the whole intervention program. Finally, the results also demonstrate that the skill of constructing data graphs interacts with the skill of interpreting information from line graphs. This study also demonstrates that data graphing skills need to be taught systematically in elementary school in combination with other science investigation skills such as interpreting data.

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References

[1] Ainley J, Pratt D and Nardi E, Normalising: Children's Ability to Construct Meanings for Trend, Educational Studies in Mathematics, 45: 131– 46, 2001.

[2] Bunderson ED and Anderson T, Preservice Elementary Teachers Attitudes Toward Their Past Experience With Science Fairs, School Science and Mathematics, 96: 371-77, 1996.

[3] Burtch B, Who needs the competitive edge?, Science and Children, 20(4): 12–14, 1983.

[4] Carlisle R and Deeter B, A Research Study of Science Fairs, Science and Children, 26(4): 24-26, 1989.

[5] Constantinou CP and Learning in Science Group, The Science Fair as a Means for Developing Investigative Skills (in Greek). Nicosia: Ministry of Education and Culture, Cyprus, 2004.

[6] Czerniak C and Lumpe A, Predictors of Science Fair Participation Using the Theory of Planned Behaviour, School Sci. and Math., 96: 355-61, 1996.

[7] Duggan S and Gott R, The place of investigation in practical work in the UK National Curriculum for Science, Int. J. of Sc. Educ., 17: 137- 47, 1995.

[8] Fort D, Getting a Jump on the Science Fair, Science and Children, 23: 20-23, 1985.

[9] Goldsworthy A, Wood-Robinson V and Watson R, Improving Investigations from the AKSIS Project: Relationships - What's the problem?, Education in Science, 183: 22-23, 1999.

[10] Gott R and Duggan S, Investigative work in the Science Curriculum, Open University Press, 1995.

[11] Gott R and Duggan S, Practical work: its role in the understanding of evidence in science, International Journal of Science Education, 18: 791-806, 1996.

[12] Gowen L and Marek E, Science Fairs: Step by Step, Science Teacher, 60: 37-41, 1993.

[13] Grote MG, Science teacher educators' opinions about science projects and science fairs, Journal of Science Teacher Education, 6: 48–52, 1995.

[14] Hamrick L and Harty H, Science Fairs: A Primer for Parents, Science and Children, 20: 23-25, 1983.

[15] Hansen B, Planning a Fair with a Flair, Science and Children, 20: 9-11, 1983.

[16] Kyriazi E, The Science Fair Sciences, University of Cyprus, 2004.

[17] http://www.ucy.ac.cy/lpg/sciencefair/index.html

[18] Kyriazi E and Constantinou C, The Science Fair as a means for developing investigative skills in the elementary school, in Divjak S (Ed.), Proceedings of the 1st International Conference on Hands on Science, 2004, Jul 5-9, Ljublja, Slovenia, Ljubljana: University of Ljubljana, 2004.

[19] Lawson A, Combining Variables, Controlling Variables, and Proportions: Is There a Psychological Link?, Science Education, 63: 67-72, 1979.

[20] Laguex BJ and Amols HI, Make your Science Fair Fairer, The Science Teacher, 53: 24-28.

[21] Leinhardt G, Zaslavsky O and Stein MK, Functions, graphs, and graphing: Tasks, learning, and teaching. Review of Educational Research, 60: 1-64, 1990.

ISBN 978-989-95336-2-2

[22] Levin K and Levin R, How to judge a Science Fair, The Science Teacher, 58: 43-45, 1991.
[23] McDermott LC, Rosenquist ML and van Zee EH, Student difficulties in connecting graphs and physics: Examples from kinematics, American Journal of Physics, 55: 503-13, 1987.
[24] Mevarech Z and Kramarsky B, From verbal descriptions to graphic representations: Stability and change in students' alternative conceptions, Educational Studies in Mathematics, 32: 229-63, 1997.
[25] NCTM, Principles and standards for school mathematics, Reston VA, 2000.
[26] Nicolaou Ch, Nicolaidou I, Zacharia Z and Constantinou C, Microcomputer-based Laboratories: Interpretation of Graphical representations and Phase Transformations, in Divjak S (Ed.), Proceedings of the 1st International Conference on Hands on Science; 2004, Jul 5-9; Ljubljana, Slovenia. Ljubljana: University of Ljubljana, 2004.
[27] Padilla M, McKenzie D and Shaw E, An Examination of the Line Graphing Ability of Students in Grades Seven Through Twelve, School Science and Mathematics, 86: 20-26, 1986.
[28] Romjue M and Clementson J, An Alternative Science Fair, Science and Children: 30: 22-24, 1992.
[29] Rogers L, The computer as an aid for exploring graphs, School Science Review, 76: 31-39, 1995.
[30] Ward A, Planning, Organizing and Staging a School Science Fair, School Science Review, 75: 41-47, 1994.
[31] Wavering MJ, Logical reasoning necessary to make line graphs, Journal of Research in Science Teaching, 26: 373-79, 1989.

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Experiential Phenomena as Experimental Activities in Science Laboratory based on the Human Body – Four Cases

Sotiropoulos D, Tsagaroulaki K, Svarnas T, Metaxa A and Kalkanis G

Introduction

The main scope of this paper is to elevate an idea of hands on science experimental procedure: the use of the human body as a means for experiential interdisciplinary activities. These activities can easily be placed under the general umbrella of Science Technology Society (STS) teaching. STS education addresses learning of science concepts in the context of real life experiences and with application to real life problems and issues (Lutz, 1996) [1]. The human body and its functions are easy to understand and affects and interests every human being that is the main reason it can be a good vehicle of promoting students to be involved with measurements in a laboratory procedure. Thus we develop four experimental activities: a) counting heart and human respiration rate using a microphone attached to a computer; b) calculating human response time when a ruler falls and the acceleration of a human punch, using a range sensor; c) counting body's temperature in various circumstances: after body exercise and during woman's period using thermometers and temperature probes and d) oral hygiene with the use of a PH sensor.

Methodology

For the whole intervention we propose the scientific /educational method which is a pedagogical approach of the historically recognized scientific research method. That method through which scientist, researcher, man, had research, is researching and will continue to research natural world [2]. In every activity we used software, which developed under the simplest form so that it can be used for any other similar procedure to support it. The software acts supplementary giving in every step of the methodology the necessary elements such as videos and pictures, which are used to activate the students and to give them the appropriate guidance through the experimental procedure. The way the software is used can be altered according to the kind of the laboratory that is chosen each time. The software provides also the

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necessary worksheets that the students used to follow the scientific / educational method. The worksheets were developed under simplicity and directness of executing specific acts.
The first implementation took place with students of the Pedagogical department of the University of Athens. These students are future teachers so they should acquire certain experimental skills and general knowledge about human body and health.
Generally speaking that kind of procedures can be implemented in the two last grades of primary education, to the last grade of high school according to the curriculum mostly in the educational zone which is known as the interdisciplinary activities zone or as introductory lessons to science experimentation. That kind of procedures could familiarize students with sensors, computer software and experimental practice.

Experimentation

Counting heart and human respiration rate using a microphone attached to a computer

In many researches it is clear that most of the students confuse the cardiac rate with the breath. Although both functions are interdependent the rate of the breath is not identical with the rate of heartbeat. In order to establish this kind of difference we used a simple way of measure the heartbeat and the rate of the breath (without using expensive measuring tools). Using a microphone that is attached in a certain point on the neck, we measured, through a program of processing sounds (e.g the shareware software Goldwave) the heartbeat. An image taken from this software is given in Figure 1.
If the sound is not clear enough using the previous mentioned software (or any similar to that) it can be cleared so that the sound is heard loud and clear (experiential). From this graph students can measure the cardiac rate (measurement/calculation). After that students put the microphone near the nose and an image like Figure 2 will print to the screen.

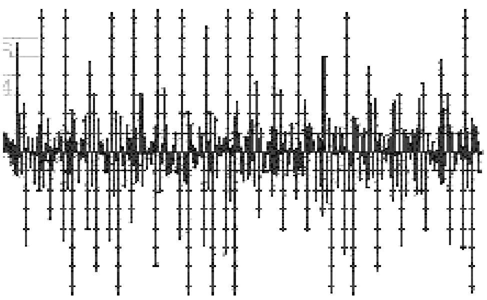

Figure 1. Heartbeat of a student

Figure 2. Rate of the breath of a student

This kind of software depends on timeline so it is easy to estimate the heart and breath rate from these graphs. In addition using the microphone we can measure the rate of the breath before, during and after certain activities, in order to correlate

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them with the heartbeat. We can also use people who are smokers or people who don't exercise regularly in order to underline the bad affects to our health in these circumstances. The kind of the activities that finally are adopted depends on our didactic approach and the school level.

Calculating human response time when a ruler falls and acceleration of a human punch, using a range sensor

Furthermore an activity we suggest is that one which uses a range sensor that measure the distance of a moving body. In this activity we use a ruler that falls and we have placed the sensor in order to measure the change of the height of the lower part of the ruler. The time-height graph that the sensor's software is producing is the one of Figure 3.

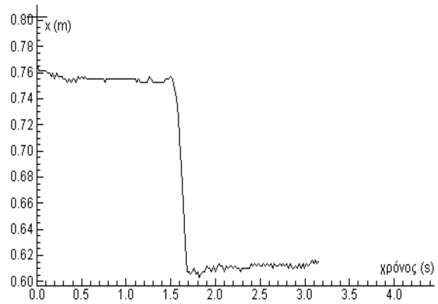

Figure 3. Catching a fallen ruler…

The experimental process is carried out by two people. The first person holds the ruler in a certain height above the sensor and the second person is ready to catch the ruler when it falls (the activation is given with a sound). In that way we measure the time one person takes to react so we can discuss a lot for the way the human brain works.

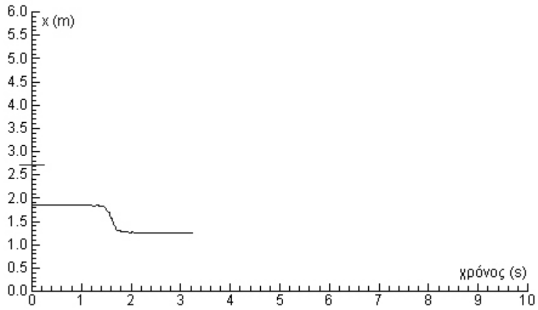

Figure 4. Graph of a human punch

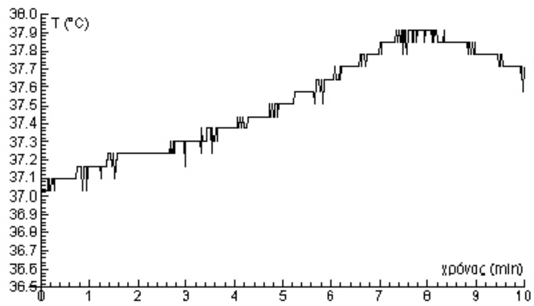

Figure 5. Body temperature

To enrich the reports concerning the human brain but also to deal with experimental procedures relevant to the velocity and the acceleration, using the same sensor we

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propose the measurement of the velocity and the acceleration of the human punch. One graph measuring distance and time has the formulation of that in Figure 4. Furthermore we can compare two graphs from two students with very different body shapes and expand the possible results in specific Biology and Physics lessons.

Counting body's temperature in various circumstances: after body exercise and during woman's period using thermometers and temperature probes.

In this activity is attempted to measure the human body's temperature in many different situations. The temperature in a laboratory can be measured using sensors or digital home thermometer. Then the measurements are recorded and appear in graphical representations like this one in Figure 5. We can also measure the temperature of a number of people and extract specific conclusions through dialogues about the variation or not of the experimental data.

In the next experiment we propose (in latest grades) that the girls can measure their temperature during their period. This is something that apart the other (science) benefits can help the students, not only girls of course, to socially mature and to stop having taboos about human body through a scientific procedure. Furthermore the measurements, in general, outside laboratory can help students to introduce in everyday life the scientific method and with particular references they could estimate the value of the measurement.

Oral hygiene with the use of a PH sensor

Even though the PH sensor is constructed to measure the PH of chemical solutions, through specific procedures can help students to estimate how acid or basic is their slaver. Generally speaking our slaver has specific PH that remains steady and varies after drinking or eating and there are many factors that can influence the PH in our mouth. In many circumstances the reason for having problems with our teeth is what we drink or what we eat. So it is good to know what affects our oral hygiene. In addition the PH of our mouth indicates more for the whole health of a person. For that, we organize experimental procedures using a PH sensor and appropriate worksheets. Maybe the whole procedure sounds difficult to be made but finally it is less difficult than it sounds and can help the students to understand and interconnect these factors that can give them good health.

Conclusions

The most encouraging element of all the procedure was the huge interest that students showed from the beginning of the experimental procedures. It is also good to be mentioned that students with low expectations of themselves appeared to be more skilful in that kind of experimental practice than we expected. Most of the problems encountered concern the use of the sensor's software but this is something we were expecting as soon as the implementation was limited in time. We can overcome that kind of difficulties with the extensive use of sensors and

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software in introductory laboratory. Nevertheless more conclusions can be extracted if more research take place, but the first elements indicate that this kind of experimental activities can cultivate experimental skills with an easy and pleasant way and help students to become scientific literate members of our society.

References

[1] Su Walter Yu-Jen, Promoting scientific Literacy for Future citizens through developing STS activities, Proceedings of the 1st IOSTE Symposium on Science and Technology Education Preparing Future Citizens, Paralimni, Cyprus, pp.: 182-189, 2001.

[2] Kalkanis G, Which (and How) Science and Technology Education for Future Citizens?, Proceedings of the 1st IOSTE Symposium “Science and Technology Education Preparing Future Citizens”, Paralimni, Cyprus, pp.: 199-214, 2001.

[3] Kalkanis G, Educational technology, University of Athens, 2002.

[4] Kalkanis G, Educational physics, University of Athens, 2002.

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Mechanical and Solar Energy Projects … in Action

Tsagliotis N

Introductory Framework

Thirty five (35) pupils of the 6th grade of primary school have dealt with the “energy” concept within a framework of a series of teaching interventions with experimental investigations (*formal science teaching and learning*), extra-curricular projects with mechanical and solar energy constructions (*non-formal science teaching and learning*) and a final presentation of project work by pupils to fellow pupils, teachers and general public in a science fair activity (*informal approaches in communicating science within a free choice environment*).

It has been reported extensively that the “energy” concept, being abstract in its nature, it is hard to teach and learn in science education (Duit, 1986; Solomon, 1992; Williams and Reeves, 2003; Leggett, 2003). Thus, the difficult task for teachers has always been to find creative ways in which the “energy” concept could characterized with more “concrete” accounts and registers for pupils, to “reify” some of its aspects in a sense, especially for primary school science. This can be combined with an approach of using or creating toys in the teaching and learning of “energy”, within a more familiar framework for child life and culture (cf. Taylor, 1998).

It is claimed that specific project work undertaken by pupils, alongside with experimental investigations and discussions in class, has contributed significantly in the conceptual development of “energy” for the primary school children of this study (cf. Tsagliotis 2004; 2005). The “energy” conceptual framework that provides the basis for the project work, as well as the study in broader terms is “energy change” and “energy degradation”, with foreground hints for “energy conservation”.

Project work on mechanical energy

The pupils worked in pairs and they all constructed in class catamaran boats out of stripes of expanded polystyrene (DOW), which moved with a paddle gripped on a stressed rubber band. The conceptual idea we elaborated on is that the rubber band has “stored dynamic energy” (potential energy), which is changed to “energy

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of motion” (kinetic energy) rotating the puddle and moving the catamaran toy (Figure 1)

Figure 1. The catamaran toy

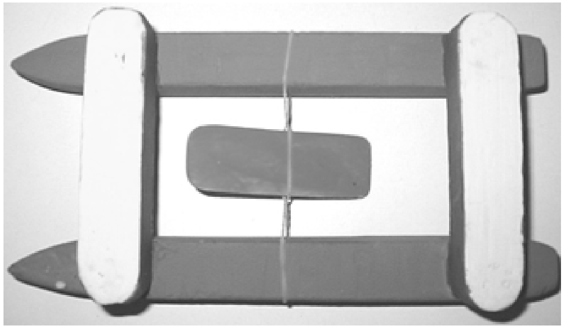

Figure 2. Improved catamaran

We also had to confront with “energy losses” due to friction or “the drag force” of the water as the catamaran moved in it. Thus, we had “energy degradation” due to “energy change into heat” when the toy catamaran with squared, uneven edges moved though the water. We had to deal with this “problem” by constructing more “hydrodynamic catamaran” toys, which moved faster and farther using more of the “available” mechanical energy, with less “energy degradation” to heat due to “friction with the water”. This is of course a qualitative, macroscopic approach of “energy change” and “energy degradation”, but with a reified potential, thinking over “real” objects and their performance (see the improved catamarans we presented in the science fair in the Figure 2).
In a similar context “airplanes” or “boats” that moved with helixes and rubber bands were constructed by pairs of children as project work (Figure 3)

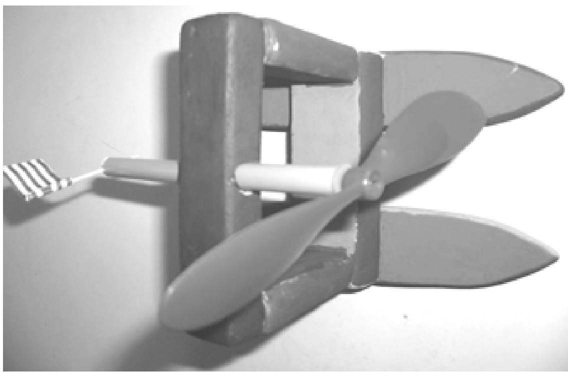

Figure 3. Helixe

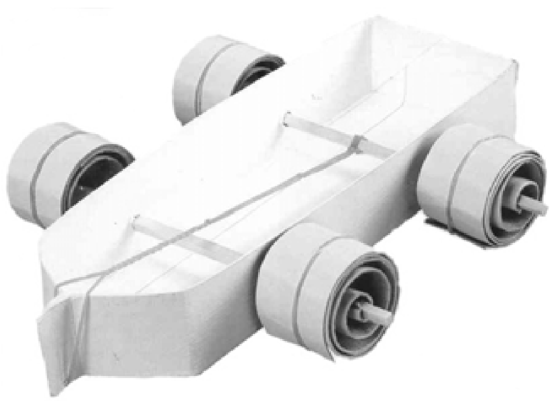

Figure 4. Toy car

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Furthermore, a couple of "toy cars" moving with elastic bands were constructed by a couple of groups of children as an additional project on mechanical energy. Some children liked these toy car projects with elastic bands, but we had no time to make more of this kind and work further on their designs (Figure 4)

Project work on solar energy

The children worked in pairs and developed projects and constructions related to applications of solar energy, which had to be functional and tested; therefore they had to develop certain techniques and deal with particular problems throughout the development of their projects. Children's project work dealt with three groups of projects in the study of solar energy: a) *solar water heaters*, b) *solar cookers* and c) *solar toys*.

There are several designs of *solar water heaters* to choose from. The group of six pairs of children, who worked on these projects, chose to construct the following six solar water heaters:

- a "classic solar water heater" with flexible black tubes in horizontal and vertical arrays (see photo below)
- two "serpentine solar water heaters" with the flexible black tube arranged in an "S" shape
- a "spiral solar water heater" with the flexible black tube arranged in a circular form
- a "plastic bottles solar water heater" with the flexible black tube arranged in an "S" shape, passing through transparent, 1,5 litter soda bottles
- a "model solar water heater" with a spiral arrangement of a small plastic tube, where the water was gathered in a small container and circulated with a small water pump powered by 3 solar cells connected in a series (Figure 5)

There is a variety of designs for *solar cookers* to choose from, within three main categories:

a) *box solar cookers* (Figure 6)
b) *open solar cookers with reflector panels* (Figure 7)
c) parabolic solar cookers (Figure 8)

In the latest school science fair we chose to construct *three box solar cookers* and *three open solar cookers* with reflector panels, whereas we avoided the construction of parabolic solar cookers, which are generally considered more technical and difficult. Nevertheless, a *parabolic solar cooker* will be presented in the Science Fair organized within the *2nd HSci Conference*, which was constructed

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in an earlier school science fair (see in the photos below one example from the three categories of solar cookers respectively).

Figure 5. A model solar water heater

Figure 6. ***box solar cookers***

Figure 7. Open solar cookers with reflector panels

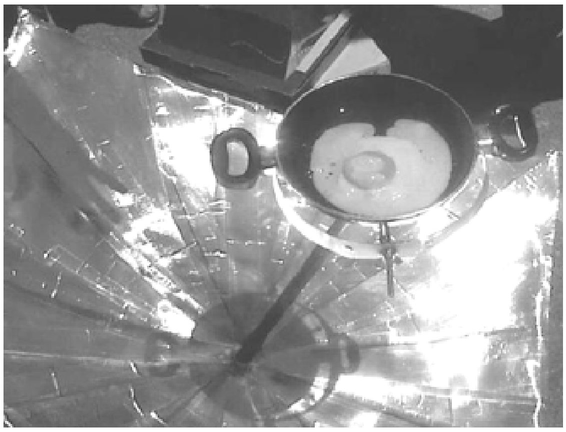

Figure 8. Parabolic solar cookers

The preparation and the experimental construction of *solar toy cars* and *boats* took some time and effort, since quite a few detailed problems had to be resolved and an appropriate combination of materials needed to be arranged and purchased. Furthermore, a suitable kind of solar cells should be used for each construction to be functional. Thus, for example light and powerful photovoltaic cells were needed for the toy cars, whereas they were not necessary for the solar boats, which could move with smaller and heavier photovoltaic cells made out of amorphous silicon.
The children constructed several solar toy cars and boats, more than we had originally planned to construct. This happened because all children, when completing their projects in the groups of solar water heaters and solar cookers, wanted also to build their own solar toys. This is perhaps a good indication that a playful approach of “science in the making” or dealing with “hands-on science activities” for the particular purposes of project work, tends to be more attractive for children, triggering their interest and commitment.

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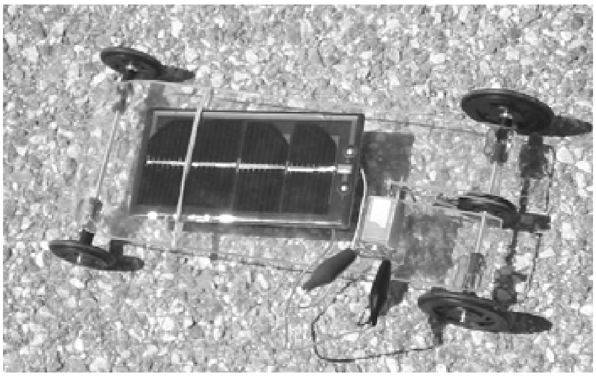

Figure 9. A solar toy car

Figure 10. A solar boat

Being consistent with the conceptual framework of "energy" we briefly described earlier that is "energy change" and "energy degradation", the children have identified solar energy changing into heat warming up the water in the solar water heaters or cooking their food in the solar cookers. They also had to confront with issues of "energy losses", mainly heat "escaping" out of their solar collectors, tubes or water tanks and boxes in their solar box cookers and they had to find out effective solutions, insulating their constructions in better ways.

In the case of solar toys, more "energy changes" have been pointed out, such as solar energy changing into electrical energy and then into kinetic energy and finally "degrading" into heat due to friction in the various parts of the toys, with the surface of the ground or with their movement through the water. Again effective solutions had to be found and applied in order to confront with these "energy problems" to the best possible extent (cf. Tsagliotis 2004).

On the whole, the mechanical and solar energy projects to be presented in the Science Fair of the *2nd International Hands-on Science Conference* at the University of Crete in Rethymno, appear to be of interest for pupils, science teachers and the general public because they highlight, in a rather concrete way, aspects of the "energy" concept, through the goggles of a child centred approach, linking science with daily life activities and with simple, easily accessible and familiar materials, applications and/or constructions.

References

[1] Duit R, In search of an energy concept, in Driver R and Millar R (Eds.), Energy Matters, University of Leeds, pp.: 67-101, 1986.

[2] Leggett M, Lessons that non-scientists can teach us about the concept of energy: a human-centered approach, Physics Education, 38: 130-134, 2003.

[3] Solomon J, Getting to know about energy in school and society, The Falmer Press: London, 1992.

[4] Taylor BAP, Exploring Energy With Toys: Complete Lessons for Grades 4-8, NSF-Learning Triangle Press, 1998.

[5] Tsagliotis N, Hands-on science activities for the teaching and learning of mechanical energy with 6th grade primary school children in Greece, in Proc. of

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the 2nd International Conference on Hands-on Science: Science in a changing education, 13-16 July, Rethymno, University of Crete, 2005.
[6] Tsagliotis N, Conceptual change in the teaching and learning of solar energy with 6th grade primary school children in Greece, in Proc. of the EARLI 4th European Symposium on Conceptual Change: Philosophical, Historical, Psychological and Educational Approaches, Delphi, 2004.
[7] Williams G and Reeves T, Another go at energy, Physics Education, 38: 150-155, 2003.

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“Hands-on Science. Science in a changing education”,
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Hands-on Technology Education for Teachers: The Role of the Technology Fair Project as a Mechanism for Developing Problem-Solving Skills

Alexandros C and Constantinou CP

Introduction

The technology fair is a new idea derived from one interpretation of science fair projects as designed by the Learning in Science Group at the University of Cyprus and now implemented nationally throughout the educational system of Cyprus (Constantinou et al, 2004). Science fair projects have long been used as a mechanism for promoting scientific skills with an emphasis on learning through hands-on activities. Identifying problems, formulating questions, making observations, proposing solutions, and interpreting data are necessary skills for students in school and throughout their lives. The core underlying idea has been to promote a type of education that places emphasis on these skills through hands-on science activities, while simultaneously enhancing understanding of fundamental principles in science (Czerniak and Lumpe, 1997; Duggan and Gott, 1995).

The technology fair was elaborated from the general idea of the science fair, which promotes learning by doing. The main focus of the Technology Fair is on engaging students in the process of design through hands-on activities as an approach to developing methodical solutions to technological problems. Our interest in this area arose from the idea that participation in a technology fair could stimulate students' interest in technology education while simultaneously promoting the development of technological problem solving skills.

Theoretical Background

The approach to learning that includes consciously working towards a solution to a problem is often called "Problem Based Learning". It is an instructional approach that has already been implemented, at least on a trial basis, in elementary and secondary education (Delisle, 1997). Problem-based learning typically begins with a problem for students to solve or learn more about. The problem acts as the stimulus and focus for student activity and learning (Boud and Feletti, 1991). Learning in this way is purposeful and self-sustaining as the student learns while searching for

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solutions to the problems they have formulated themselves. Students are actively involved and learn in the context in which knowledge is to be used.
Problems are designed to be "ill-structured" and to imitate the complexity of real life situations. Often, they are framed around a scenario or case study format. Problem based learning assignments vary widely in scope and sophistication. Our approach uses an inquiry model: students are presented with a problem and they begin by organizing any previous knowledge on the subject, posing any additional questions, and identifying areas on which they need more information (Delisle, 1997). Students devise a plan for gathering more information, then do the necessary research and reconvene to share and summarize their new knowledge (Stepian and Gallagher, 1993).
Most of the technological problems that students are dealing with in design and technology education are ill-defined. Greenwald (2000) characterized an ill-defined problem as being: “unclear and raises questions about what is known, what needs to be known, and how the answer can be found. Because the problem is unclear, there are many ways to solve it, and the solutions are influenced by one’s vantage point and experience” (p. 28). An ill-defined problem can be introduced to students within the context of a larger, realistic scenario. In design and technology education, ill-defined problems become better defined and more contextualized as they are worked on and hence the solving and learning is through doing.
In some approaches to design and technology education problem solving is conceptualized through a dynamic sequence of steps called the *design process*. In Cyprus the national curriculum, operationalizes this process as a sequence of eight steps:

1. Identify a need or a problem
2. Formulate the design brief
3. Write the specifications and limitations that the solution should satisfy
4. Search any relevant information
5. Draw/Sketch possible ideas/solutions for the problem
6. Select the best possible solution
7. Construct a prototype
8. Test and Evaluate the solution (redesign if possible)

These steps can be implemented one after the other but can also be repeated as individual steps or combinations of them at any stage of the process.
The use of design as a means to technological problem solving is the dominant paradigm in technology education in many countries. Additionally, some researchers argue that the application of a design process makes it possible to guide students with little experience in technological problems (Walker, 2000; Moriyama, 2002). The current study is based on the teaching of a design process as part of a pre-service primary education programme. In our programme, we use the design process with non specialist pre-service teachers in order to provide a sense of security, a scaffolding framework and some guidance on how to approach

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technological problem solving. We explicitly avoid implementing the process as a serial sequence of steps and we also integrate into our teaching reflective mechanisms with a view to promote awareness of the different aspects of the design process and their complex inter-relationships.

To develop technological problem solving skills, students must merge design as a problem solving approach with the content of technology and integrate technical skills with problem solving skills. In our context, we have developed the technology fair as an activity that provides opportunities for our students (pre-service teachers) to work with children in order to gain practice in achieving this type of synthesis.

Very often technological problem solving can be very effective through hands-on activities. Hands-on activities are materials-centred activities, manipulative activities, and practical activities (Doran, 1990; Hein, 1987). Elementary school science and technology teachers have long been interested in the use of manipulative to provide concrete learning experiences (Ross & Kurtz, 1993).

Piaget stressed the importance of learning by doing, especially in science and technology. According to Piaget, "a sufficient experimental training was believed to have been provided as long as the student had been introduced to the results of past experiments or had been allowed to watch demonstration experiments conducted by his teacher, as though it were possible to sit in rows on a wharf and learn to swim merely by watching grown-up swimmers in the water. It is true that this form of instruction by lecture and demonstration has often been supplemented by laboratory work by the students, but the repetition of past experiments is still a long way from being the best way of exciting the spirit of invention, and even of training students in the necessity for checking for verification" (Piaget, 1986, p. 705).

Bruner also stressed learning by doing. The school boy learning physics is a physicist, and it is easier for him to learn physics behaving like a physicist than doing something else (Bruner, 1960, p. 14). Bruner states, Of only one thing I am convinced. I have never seen anybody improve in the art and technique of inquiry by any means other than engaging in inquiry (Bruner, 1961, p. 31).

A hands-on approach is also advocated by some people who advocate a constructivist approach to science teaching. "Learning is defined as the construction of knowledge as sensory data are given meaning in terms of prior knowledge. Learning always is an interpretive process and always involves construction of knowledge.... Constructivism implies that students require opportunities to experience what they are to learn in a direct way and time to think and make sense of what they are learning. Laboratory activities appeal as a way of allowing students to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science" (Tobin, 1990, p. 404-405).

The Technology Fair

During the technology fair primary school children, with the assistance of pre-service teachers were responsible for identifying a human need, formulating a technological problem, collecting information and developing an appropriate

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solution. Each pre-service teacher was responsible for collaborating with one child (aged 10-12) on a single technological project.

In this context, technology fair projects provide an opportunity for interaction between pre-service teachers and primary school students so that they can work as a team with shared but different goals: the child aims to solve a technological problem and present both the description of the problem and its solution during the technology fair; the pre-service teacher aims to use the interaction as a process for helping the child develop technological problem-solving skills through a systematic approach (Mettas and Constantinou, 2005).

Figure 1. Typical poster presenting the design process in the technology fair

Once the work of pre-service teachers and pupils reaches a level where specific products are available, the school organizes a public event where each pupil displays a poster describing their designing (figure 1) and the constructed artefact (figure 2). In addition, pre-service teachers and pupils develop interactive activities specifically for the technology fair which are implemented with a view to engage the visitors in the learning process and enhance the educational value of the fair (figure 3). This interactive activity should be of some relevance to the initial problem and their solution (Mettas and Constantinou, 2006). Through this activity they will attract interest and participation from the parent and student visitors to the fair. At this

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phase a whole day school event was organized, called the technology fair, and parents and other school children were invited to participate.
During the fair, each pupil with his pre-service teacher displayed a poster describing the design process (Figure 1)
Pupils and pre-service teachers also presented the artefact they constructed as a solution to the technological problem (Figure 2)

Figure 2. A model designed for a renewable energy house

Figure 3. Children interacting around a specially designed activity during the Technology Fair

Additionally, the children engage the public in a specific aspect of their work through a specially design interactive exhibit (Figure 3).
Prior to the technology fair, the pre-service teachers received formal instruction for a period of 4 weeks on Design and Technology with particular emphasis on using design as a process of solving technological problems. During that period each pre-service teacher became engaged with a single technological problem and worked on developing and evaluating solutions to that problem as a member of a small group. They investigated the problem and designed a solution that satisfied explicit

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specifications to the extent possible. In the next phase, pre-service teachers prepared teaching materials and implemented them with primary education children as part of their technology fair preparation. A period of 4 weeks was needed for the preparation of teaching materials and the meetings with children. Figure 4 shows graphically the phases of the research and how the technology fair was implemented and assessed.

Purpose of the Research

The main purpose of the study was to investigate the effectiveness of the Technology Fair in developing pre-service teachers' problem solving skills and their pedagogical content knowledge about technological problem solving. More specifically, the purpose of the study was:
(i) To examine whether the Technology Fair influences pre-service teachers' involvement and interests in Technology.
(ii) To improve our understanding of the processes used in developing technological problem solving strategies and how the technology fair could contribute in this direction.
(iii) To examine the understandings and strategies that the pre-service teachers develop in their effort to facilitate the development of technological problem solving by primary school children.

Research Design, Methods and Sample

In order to assess pre-service teachers' understandings about the design process, a number of tasks were designed and organized into pre-tests, mid-tests and post-tests. Tests were administered to students before, during and after the preparation of the technology fair, respectively (25/10/2004, 8/11/2004 and 29/11/2004). Pre-tests, mid-tests and post-tests included exactly identical tasks. In addition, each pre-service teacher was asked to keep a detailed reflective diary after every meeting with the child. These diaries formed an additional source of complementary data. In the diary, each pre-service teacher recorded about the difficulties they encountered and how they were able to overcome them. Additionally, teaching methods, emotions and ideas were reported after each meeting with the primary school pupils. Finally, following the completion of the technology fair, 12 pre-service teachers were selected and interviewed about the experiences, problems and difficulties they faced as well as their interests and commitments while working with the child.

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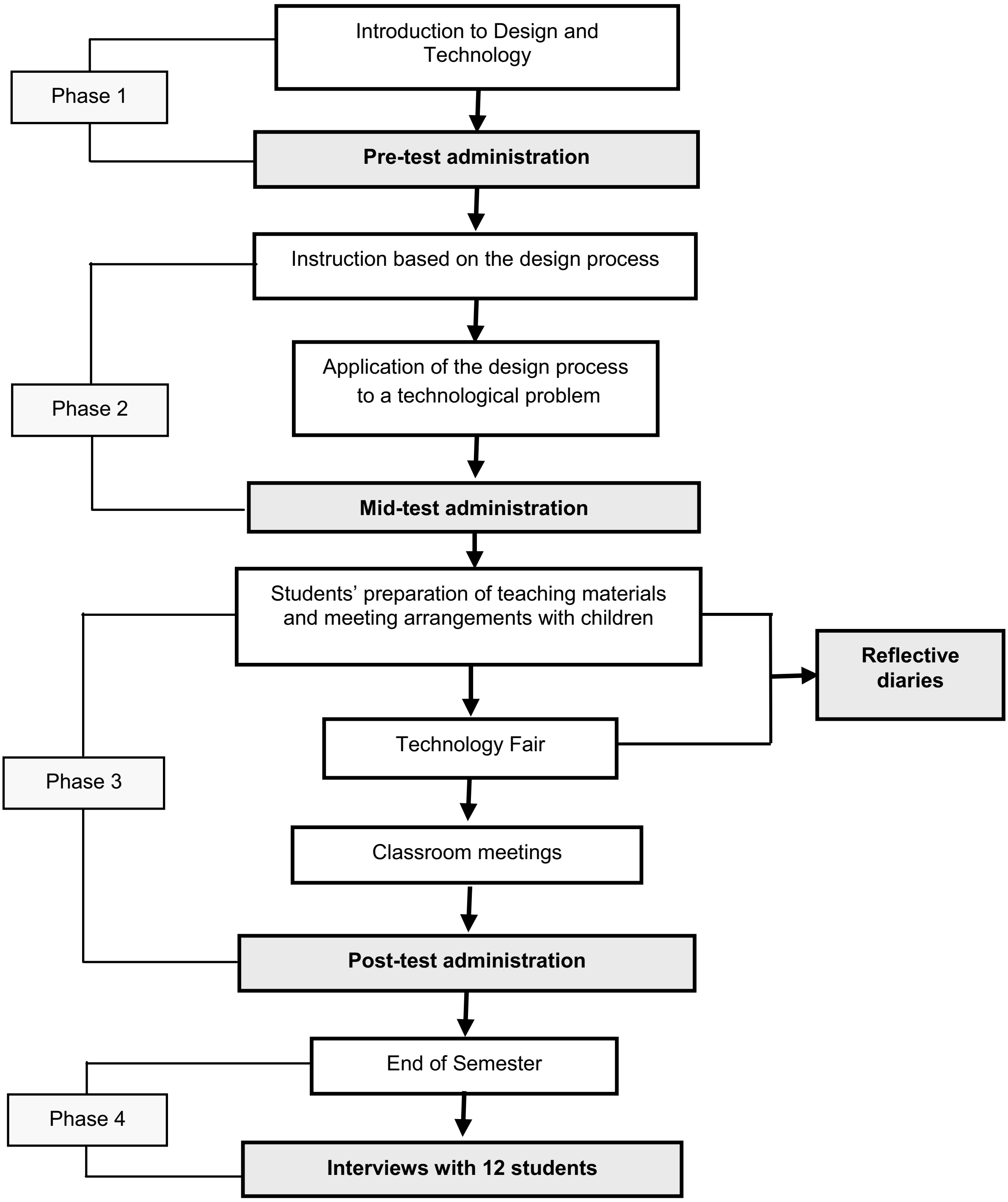

Figure 4. The technology fair course structure

Sample

The sample of the research consisted of 82 pre-service teachers at the Department of Educational Sciences, University of Cyprus. All pre-service teachers were enrolled in a compulsory course on Design and Technology Education. The pre-

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service teachers were studying for the degree of primary education in order to serve as teachers at primary school. All students were in their second year of a four-year course and they were all coming from similar educational backgrounds, having graduated from the Cyprus state high school system. Consent forms were distributed to the whole class and the 82 pre-service teachers that took part in the study returned their completed form within one week.

Purpose of each Task in the Test

Six tasks were designed and organized into pre-tests, mid-tests and post-tests in order to assess the understanding of pre-service teachers in the application of design as a technological problem solving process. All the tests (pre-test, mid-test and post-test) consisted of identical tasks. The tasks were designed to assess specific aspects of design as well as design as a coherent process. The tasks were pilot-tested and improved for 2 semesters prior to this research study. The requirements for each task included in the test are shown below:

- *Task 1-Problem Identification:* Requires pre-service teachers to identify a technological problem (or a need) from the domain of transportation. Specifically the actual task stated: 'Identify a need that could be considered as a technological problem, which you are able to solve, within the time limit and the available materials of the course on Design and Technology'.
- *Task 2-Design Brief:* Requires pre-service teaches to formulate the design brief for the following technological problem: 'Many people travel from city A to city B every day. In-between the two cities there is a large lake that causes difficulties in their transportation, because people need to drive a long distance to reach the other side of the lake'. Therefore a new construction is needed that will be reliable, decrease the existing transportation time and secure easy access from one city to the other.
- *Task 3-Specifications:* Requires pre-service teachers to identify the main specifications and limitations for a given product (Bridge model). For the requirements of that task pre-service teachers had to consider all the factors that could affect the design of a specific artefact, as shown in figure 2.
- *Task 4-Problem Investigation:* Requires pre-service teachers to list a number of issues on which they need to seek information in order to be in a position to develop an appropriate solution for the problem given to them in task 2. Pre-service teachers identified the most important factors and mentioned which information needed to be obtained in order to embark on developing the best possible solution.
- *Task 5- Alternative Solutions:* Requires pre-service teachers to draw/sketch possible ideas/solutions for the problem given in task 2. The pre-service teachers were asked to draw a solution that is possible to be

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constructed by themselves within the course limitations (time limit and materials availability).

- *Task 6-Test and Evaluation:* Requires pre-service teachers to test and evaluate a finished construction (bridge model). Pre-service teachers had to consider the product specifications that they mentioned in task 3 and then decide and describe the appropriate tests needed in order to evaluate the product.

Reflective Diaries and Interviews

Reflective diaries and interviews formed an additional source of data in relation to the pre-service teachers' strategies in applying the design process with the children. In the reflective diary, each pre-service teacher recorded a detailed description after every meeting with the child, as well as information about difficulties and problems they encountered while working with pupils and how they were able to overcome them. They described in detail every step of their design work. Additionally, teaching methods, emotions and ideas were reported after each meeting with the primary school pupil.

The purpose of the interviews with the pre-service teachers was to investigate their understanding of technological problem solving, their appreciation of its educational value and their approach to facilitating the development of relevant skills after their experience with the technology fair. The questions of the interviews were open ended and the pre-service teachers were encouraged to draw explicitly on their experiences while working on the technology fair. During the interviews, pre-service teachers initially responded to tasks of the same context as the tasks included in the test, e.g. to identify a technological problem and formulate the design brief, to consider the main specifications of different products, to describe the kind of research and different information that could possibly inform the design and to evaluate some finished technological products.

Results

Responses to pre-tests, mid-tests, and post-tests were analysed using the phenomenographic approach developed by Marton (1981). Pre-service teachers' responses were organized into categories, which were then arranged hierarchically so that category 1 is the most appropriate category of responses, category 2 is cognitively less adequate than category 1 and better than category 3 etc. We undertook statistical analysis in order to examine the influence of the two parts of the teaching intervention ((a) formal teaching and own constructions, (b) preparing for the technology fair in collaboration with a child) on pre-service teachers understanding of the different aspects of technological problem solving.

The test consisted of 6 tasks that required understanding and implementation of different aspects of design in order to solve a new technological problem. The pre-service teachers' responses to four of the tasks (tasks 2, 3, 4, 6) were on an interval scale and, hence, were analysed using the paired samples t-test. The other two

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tasks (Tasks 1, 5) had responses on an ordinal scale and were analysed using the (non-parametric) Wilcoxon Test.
Tables 1-3 show the results of the paired samples t-test for tasks 2, 3, 4 and 6. Table 1 shows the comparison between pre-test and mid-test, i.e. the period from the introduction to the topic until the teaching and the implementation of the technological problem solving process by the pre-service teachers themselves. Table 2 shows the comparison between mid-test and post-test, i.e. the period during which the pre-service teachers guided a child to solve a technological problem and prepare for the technology fair, including the implementation of the fair itself. Table 3 shows the comparison between pre-test and post-test, i.e. the effect of the overall intervention (both parts) on pre-service teachers' problem solving skills.

Task	Mean Pre-Test	Mean Mid-Test	S.D. Pre –Test	S.D. Mid-Test	T	d.f	p
Task 2. Design Brief	1,13	1,56	1,08	0,92	-3,840	81	,000
Task 3. Specifications	3,09	3,39	1,18	1,23	-1,783	81	,078
Task 4. Information search	2,11	3,01	1,01	1,54	-5,185	81	,000
Task 6. Test – Evaluation	1,21	1,39	0,94	0,78	-1,504	81	,136

Table 1. Paired samples t-test comparing Pre-test and Mid-test assessment data

Task	Mean Mid-Test	Mean Post-Test	S.D. Mid -Test	S.D. Post-Test	T	d.f	p
Task 2. Design Brief	1,56	2,51	0,918	0,633	-9,557	81	,000
Task 3. Specifications	3,39	6,24	1,23	1,10	-17,518	81	,000
Task 4. Information search	3,01	5,24	1,53	1,17	-12,191	81	,000
Task 6. Test – Evaluation	1,39	2,54	0,78	0,70	-10,495	81	,000

Table 2. Paired samples t-test comparing Mid-test and Post-test assessment data

From table 1, we can see that pre-service teachers perform significantly better in mid-test as compared to the pre-test, in task 2 and task 4. The differences are statistically significant for both task 2 and task 4 with $t(81)=-3,84$, $p<0.01$ and $t(81)= -5,18$, $p<0.01$, respectively. There are no statistically significant differences between pre-test and mid-test performance for tasks 3 and 6. From tables 2 and 3, it can be seen that there are statistically significant differences for all the tasks, both from mid-test to post-test and from pre-test to post-test.

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Task	Mean Pre-Test	Mean Post-Test	S.D. Pre -Test	S.D. Post-Test	T	d.f	p
Task 2. Design Brief	1,13	2,51	1,08	0,633	-11,886	81	,000
Task 3. Specifications	3,09	6,24	1,18	1,10	-18,304	81	,000
Task 4. Information search	2,11	5,24	1,01	1,17	-19,503	81	,000
Task 6. Test – Evaluation	1,21	2,54	0,94	0,70	-10,909	81	,000

Table 3. Paired samples t-test comparing Pre-test and Post-test assessment data

Tables 4-6 shows the results of the Wilcoxon test for task 1 and task 5. Table 4 shows the comparison between pre-test and mid-test, table 5 shows the comparison between mid-test and post-test and table 6 shows the comparison between pre-test and post-test.

	Mid Task 1 – Pre Task 1	Mid Task 5 – Pre Task 5
Z	-1,605(a[1])	-1,043(b[2])
Asymp. Sig. (2-tailed)	,109	,297

Table 4: Wilcoxon test comparing Pre-test and Mid-test performance on Tasks 1 and 5

	Post Task 1 – Mid Task 1	Post Task 5– Mid Task 5
Z	-5,244(a)	-5,587(b)
Asymp. Sig. (2-tailed)	,000	,000

Table 5: Wilcoxon test comparing Mid-test and Post-test performance on Tasks 1 and 5

From table 4, we can see that none of the differences between pre-test and mid-test are statistically significant for tasks 1 and 5. On the contrary, table 5 and table 6 indicate that there are statistically significant differences for tasks 1 and 5 from mid-test to post-test (Wilcoxon Z = -5,244, p<0,01 and Wilcoxon Z = -5,587, p<0,01, respectively) and from pre-test to post-test (Wilcoxon Z = -6,140, p<0,01 and Wilcoxon Z = -6,277, p<0,01, respectively).

[1] Based on negative ranks

[2] Wilcoxon Signed Ranks Test

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	Post Task 1 – Pre Task 1	Post Task 5– Pre Task 5
Z	-6,140(a)	-6,277(a)
Asymp. Sig. (2-tailed)	,000	,000

Table 6: Wilcoxon test comparing Pre-test and Post-test performance on Tasks 1 and 5

Indications from Students' Reflective Diaries

Pre-service teachers' records in their reflective diaries were also analysed using a phenomenographic approach. A number of different factors in relation to technological problem solving emerge from the reflective diaries. The main findings are discussed below:

Almost every pre-service teacher (94%) characterized the opportunity to participate in the technology fair as a very important experience for their future teaching practice, e.g. a pre-service teacher stated in her reflective diary: "my cooperation with the primary school pupil was very important for my future studies. I found myself improving my teaching skills because of my interaction with the pupil". Another pre-service teacher stated in his reflective diary: "it was a very valuable experience, working with a primary education pupil. I tried different approaches with the child and I realized that these kinds of activities are important as part of our training as teachers".

A significant number of pre-service teachers express their positive dispositions and values gained through the fair. They also consider themselves to be more effective in identifying technological problems and in a better position to overcome possible obstacles that they might encounter in the process of teaching technological problem solving, e.g. a pre-service teacher stated in her reflective diary: "I realized that simple technological problems could be drawn from everyday activities, for example, where to store my toothbrush, how can I improve the appearance of my bedroom, etc".

A large percentage (86%) of the pre-service teachers noted in their reflective diaries that primary school children worked through the design part of their projects with enthusiasm and positive attitude, e.g. a pre-service teacher stated in her reflective diary: "the pupil worked with enthusiasm during the design and construction of his project". Another student said: "the designing part of the project was great fun. I and the pupil were extremely motivated in our collaboration by the idea of the participation in the technology fair".

Indications from Students' Interviews

During the interviews, pre-service teachers expressed their beliefs about their experiences from their participation in the technology fair. They also responded to tasks in relation to technological problem solving. The main outcomes from the interviews are presented below:

Pre-service teachers expressed the belief that after the technology fair they were more confident in teaching the subject of Design and Technology in primary school,

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e.g. pre-service teachers said during her interview: “After the technology fair I am feeling more confident to teach the subject of design and technology in primary school. It is very important to have this kind of teaching experience as part of our studies”.
The overall process and the presentation of their work in the fair seem to enhance pre-service teachers and pupils’ motivation and interest in the area of technology, e.g. a pre-service teacher said during the interview: “The atmosphere during the technology fair was very stimulating for both pupils and students. My pupil showed an interest in every single project presented in the fair”.

Discussion

The purpose of the study was to examine the influence of the technology fair in developing pre-service teachers’ problem solving skills. The analysis of the results indicates that the technology fair has a significant influence in improving pre-service teachers’ understanding and application of problem solving strategies within the area of design and technology education. The results from the tests, reflective diaries and interviews triangulate and offer substantial support to this conclusion.
From these results it emerges that the technology fair can be considered as an effective teaching approach. The comparison of pre-test and mid-test, i.e., the period from the introduction to the subject of Design and Technology up to implementation of the design process in workshop, indicates that there are statistically significant differences only for two out of the six tasks. The two tasks that demonstrated statistically significant differences were related with the formulation of the design brief and the search for information that can contribute to a successful solution. These are influenced by theoretical strategies and hence the impact of formal instruction is understandable.
In contrast, there are statistically significant differences for all tasks for the comparison between the mid-test and post-test, i.e. the period before and after the technology fair for all tasks included in the tests. This outcome, in connection with the analysis of reflective diaries and interviews demonstrates that the pre-service teachers’ engagement with the organization of the technology fair strongly influences their abilities to research and solve technological problems through processes of design. The effectiveness of problem based learning in education was also identified from other researchers as well (Boud and Feletti,1991; Chard, 1992).
A possible explanation for this outcome is that the responsibility that was undertaken by pre-service teachers to work with a child and present their results in the technology fair, helped them to focus their efforts and work more effectively. Results obtained from previous research (Hoffman and Ritchie, 1997) show that students involved in problem-based learning are more likely to acquire knowledge and become proficient in problem solving and self-directed learning.
During the preparation of the technology fair, pre-service teachers worked harder and sought feedback on their work more frequently than during the formal instruction period in which traditional learning approaches were used (before the technology fair). Throughout the technology fair pre-service teachers indicated an interest both about the designing of a technological project, and for possible

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pedagogical approaches that could be usefully implemented within design and technology education. Project based learning has been shown to be effective in increasing pre-service teachers motivation and in improving their problem-solving skills. Analogous results have been reported by Blumenfeld et al. (1991) who consider project based learning as an effective and stimulating teaching approach.
From the analysis of pre-service teachers' reflective diaries and interviews, it can be seen that the technology fair contributes to the development of positive values and attitudes in design and technology education. Many pre-service teachers express the belief that the atmosphere during the technology fair was very stimulating and technologically rich. Technologically rich environments were also considered by Riel (1994) to be a very important factor that fosters positive values and interest in technology education. Positive values and attitudes that are developed as a result of the technology fair will help pre-service teachers to enhance their interest in technology education in general and in technological problem solving in particular when they come to serve as a teachers.
Important factors that emerge from this study are the enthusiasm and the motivation that this kind of education conveys to pre-service teachers. This outcome is evident both from pre-service teachers' reflective diaries and interviews. Most of the children express the willingness to participate again in a technology fair, while many pre-service teachers stated that they will consider undertaking the organization of a technology fair in their future career as primary education teachers. Children's enthusiasm and motivation for this kind of education was also obvious from observations during the days of the technology fairs.
There are a plethora of benefits that pre-service teachers and primary school children adduce to hands-on learning as part of the technology fair. The evidence from the current study supports that hands-on activities through the technology fair increased learning outcomes, increased motivation to learn, increased enjoyment of learning, increased skill proficiency (including communication skills), increased independent thinking and decision making based on direct evidence and experiences; and increased perception and creativity.

Conclusions

Based on the results of the tests, the reflective diaries, and the interviews, it can be concluded that the technology fair can enhance the development of technological problem solving skills by pre-service teachers. Another important factor that emerged from this study is the enthusiasm and the motivation that this approach to teacher education offers for both children and pre-service teachers.
The technology fair seems to be considered by pre-service teachers as an important educational activity that will help them in their future career. From reflective diaries and interviews, it can be concluded that the technology fair developed positive values to pre-service teachers towards technological design. In addition, during the fair, pre-service teachers expressed positive viewpoints both for their cooperation with children and for the educational value of the technology fair.
This study also identified a number of limitations that could be improved in future designs of the technology fair. Further research is needed in order to extent this

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study with the design and evaluation of teaching materials to support the technology fair activities. The research can also be extended to examine in depth how students address design problems spontaneously. Observations of students and children while working towards the technology fair can provide another source of valuable data in this effort.

References

[1] Blumenfeld PC, Soloway E, Marx RW, Krajcik JS, Guzdial M and Palincsar A, Motivating project-based learning: Sustaining the doing, supporting the learning, Educational Psychologist, 26: 369-398, 1991.
[2] Boud D and Feletti G (Eds.), The challenge of problem-based learning, St. Martin’s Press: New York, 1991.
[3] Bruner JS, The process of education, Harvard University Press: Cambridge, 1980.
[4] Bruner JS, The act of discovery, Harvard Educational Review, 31: 21- 32, 1961.
[5] Chard SC (Ed.), The Project Approach: A Practical Guide for Teachers, University of Alberta Printing Services: Edmonton, 1982.
[6] Constantinou CP (and The Learning in Physics Group), The science fair: a means for developing investigative skills: teachers' guide, Cyprus Ministry of Education and Culture, Nicosia, Cyprus, 2004.
[7] Czerniak M and Lumpe T, Relationship between Teacher Beliefs and Science Education Reform, Journal of Science Teacher Education, 4: 247-266, 1997.
[8] Delisle R (Ed.), How to use problem-based learning in the classroom, Association for Supervision and Curriculum Development, Alexandria, VA, 1997.
[9] Doran RL, What research says about assessment, Science and Children, 27: 26-27, 1990.
[10] Duggan S and Gott R, The place of investigations in practical work in the UK National Curriculum for Science, International Journal of Science Education, 17: 137-148, 1995.
[11] Greenwald NL, Learning from problems, The Science Teacher, 67: 28-32, 2000.
[12] Hein GE, The right test for hands-on learning, Science and Children, 25: 8-12, 1997.
[13] Hoffman B and Ritchie D, Using Multimedia to Overcome the Problems with Problem Based Learning, Instructional Science, 25: 97-115, 1997.
[14] Marton F, Phenomenography - describing conceptions of the world around us, Instructional Science, 10: 177-200, 1981.
[15] Mettas A and Constantinou C, The Technology Fair as means for promoting Primary education students’ problem solving skills and interest in Science and Technology', In Benson C (Ed), 5th International Primary Design and Technology Conference: Excellence through Enjoyment, Birmingham, England, pp.: 79-82, 2005.
[16] Mettas A and Constantinou C, The Technology Fair Project, The Technology Teacher, 65: 19-21, 2006.

ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

[17] Moriyama J, Satou M and Kin C, Problem-Solving Abilities Produced in Project Based Technology Education, Journal of Technology Studies, 28: 154-58, 2002.
[18] Piaget J, Science of education and the psychology of the child, in Gruber HE and Voneche JJ (Eds.), The essential Piaget: An interpretive reference guide, Basic Books: New York, 1986.
[19] Riel M, Educational change in a technology-rich environment, Journal of Research on Computing in Education, 26: 452–474, 1994.
[20] Ross R and Kurtz R, Making manipulative work: A strategy for success, Arithmetic Teacher, 40: 254-57, 1993.
[21] Stepien WJ and Gallagher SA, Problem-based Learning: As Authentic as it Gets, Educational Leadership, 50: 25-8, 1993.
[22] Tobin K, Research on science laboratory activities: In pursuit of better questions and answers to improve learning, School Science and Mathematics, 90: 403-418, 1990.
[23] Walker D, Process over Product. A Critique of the Present State of Problem Solving in Technology Education, Technology Teacher, 59: 10-14, 2000.

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"Hands-on Science. Science in a changing education",
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Hands on Physics and Biology in House of Science

Gumaelius L and Johansson KE

House of Science

Stockholm House of Science in Stockholm is a laboratory for Science, entirely devoted to schools [1, 2]. The House is situated in an academic environment at Albanova University centre. Researchers, university students and teachers develop exciting and interesting experiments that can not normally be performed at school. The aim is to make modern science accessible to teachers, school classes and individual students and increase the students' interest in today's natural science. During its first four years in operation almost 2000 school classes and more than 40 000 students and several thousands of teachers visited the laboratory.

The world of particles

Many of the physics experiments start with a visual inspection of the continuous 40 x 40 cm area cloud chamber (Figure 1).

Figure 1. High school students studying particles in a Wilson cloud chamber

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Several types of otherwise invisible particles can be seen: electrons, muons from the cosmic radiation and alfa particles from the decay of radioactive substances in the surrounding. More detailed studies are performed with particle detectors and ionisation detectors to explore the world of particles, the cosmic radiation and the radiation in our environment.

Electrons and annihilation processes

The classical e/m experiment is a good way to get familiar with the electron, particle acceleration and the effect on charged particles of electric and magnetic fields. Annihilation of the electron and its antiparticle, the positron, was studied using a positron emitting specimen and the apparatus shown in Figure 2. In the annihilation two photons are simultaneously emitted back to back to preserve linear momentum, each with energy of 511 keV corresponding to the rest mass energy of the particles. The particles are registered by detectors coupled in coincidence to eliminate background radiation. With the two sets of detectors, the location of the annihilation source, normally hidden under a cover, is determined. By detecting several such coincidences with a large number of detectors the precise location of the source can be pinpointed. This is the idea of the PET camera (Positron Emission Tomography) used in medicine.
Electron-positron annihilation at the highest energies available were studied using the web based education program Hands on CERN [3, 4] based on real data from the DELPHI experiment [5] at the LEP collider at CERN. At high energies particle annihilations give rise to several types of particles-two photon final states are very rare.

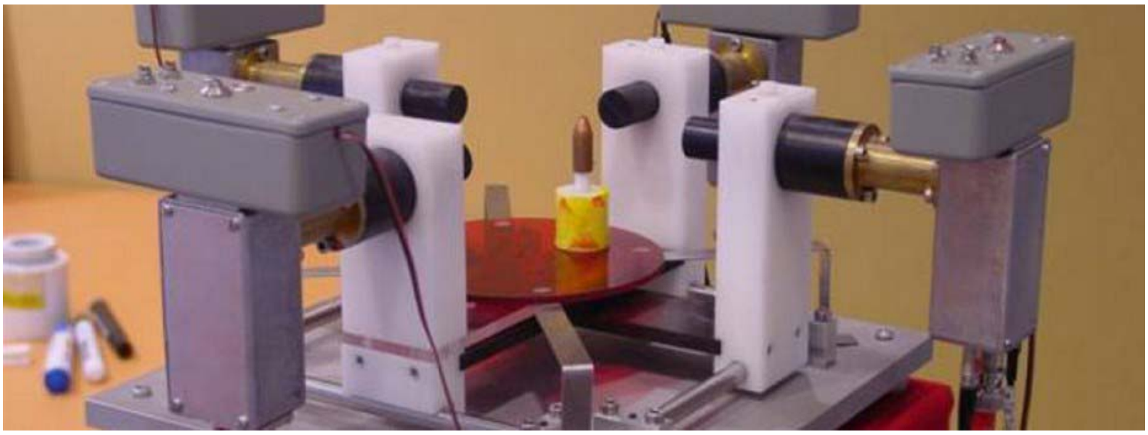

Figure 2. A simple PET camera. Each pair of movable detectors is coupled in coincidence. During the demonstrations the source is covered

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Muons

Muons, seen as diffuse spots in the cloud chamber, are created in the upper atmosphere. According to classical physics it is surprising that muons with a lifetime of around 2 μs, created at altitudes of around 20 km, can make it down to the Earth. Einstein's special relativity and the description of the time dilation explain this as a prolonged muon lifetime with a factor of about 40. Figure 1 shows students studying cosmic muons in the cloud chamber, contemplating mysteries that can be explained by special relativity.

Alpha particles

The highly ionising alpha particles are the most striking particles in the cloud chamber. What are they and where do they come from? This is the starting point of nuclear physics in House of Science. Radioactive substances, changes in the nucleus, the study of exponential decays and the exploration of radon in our surroundings are the main examples of where the observation of alpha particles in the cloud chamber can lead. House of Science is equipped with both stationary and mobile detectors making it possible to determine the radon content in different locations – in schools, cellars or the underground (Figure 3).

Figure 3. Preparing the measurement of Radon under ground

The DNA molecule

The DNA molecule is a fascinating molecule that carries the information of life in almost every little living cell. Today the DNA information is used for many purposes, such as designing medicines or improving crops. However, some people are concerned about the consequences of improper use of gene manipulated organisms. Therefore it is important that students get a good understanding of DNA and its use, and get a chance to discuss the ethical aspects of using personal DNA.

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Pyrosequencing

With a Pyrosequencing machine the DNA code can be established and used for identification of different species or individuals. This method is now used at House of Science to solve a fictive criminal case. The visiting students work as criminal investigators_ resembling very much the investigators in real life or in CSI series on TV. The experiment is set in a crime scene where a hair has been found in the victim's bathroom cabinet. The different suspects are described and the case has to be solved within the next few hours. At the end of the experiment a typical pyrogram received by the students determine the first 10 nucleotides on this sequence. In Figure 4 a diagram is presented where the sequence C, G, C, A, G, T, A, C, A, A, A, T, A, T, G, T, C has been determined. Comparison with sequences from the suspects shows that the analysed hair originates from the old housemaid. Despite that the technique is rather advanced the procedure consists of steps that are easily comprehended by the students [6].

Fruit flies

Fruit flies are excellent for genetic studies as it takes only nine days for a new generation of flies to be produced. The effect of the DNA information is manifested when studying the phenotype for different mutations in fruit flies. Breeding experiments are carried out with fruit flies having different eye colour. After nine days the result can be studied under a microscope and it can be determined by the students that the genes responsible of eye colour is located at the chromosomes of gender.

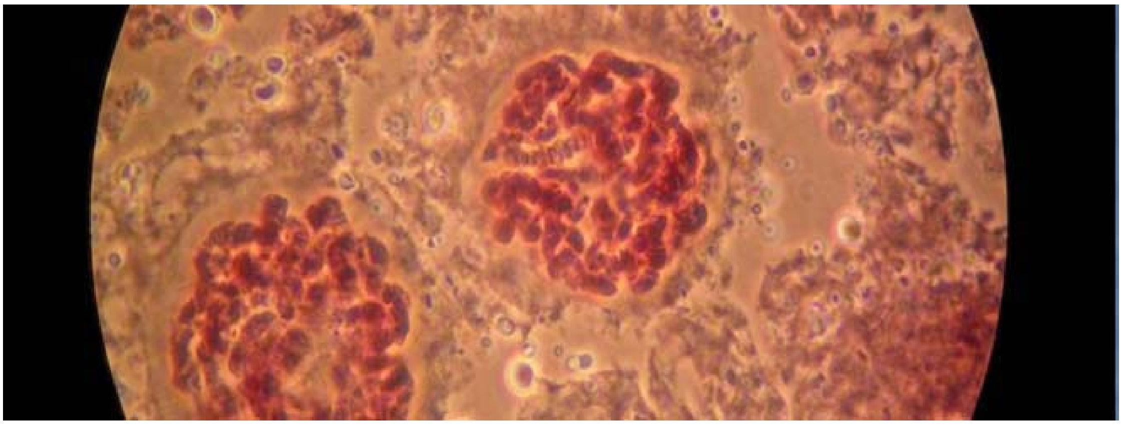

Figure 4. Chromosomes from the salivary gland in a fruit fly

The larvae of the fruit fly are dissected to study the gigantic chromosomes in their salivary glands. As seen in Figure 4 the typical darker bands with packed DNA and lighter bands with less packed DNA can easily be studied under a microscope.

Interdisciplinary projects

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Interdisciplinary projects of biology and physics are implemented for the exploration of living material. Many discoveries of DNA were performed by chemists and physicists at the Cavendish laboratory and elsewhere [6]. In House of Science biology and physics experiments are performed very close to each other, sometimes using the same laboratory.

SEM (Sweeping Electron Microscope)

The development of sophisticated microscopes, and maybe particularly the use of a particle accelerator, is examples of how physics and biology join forces to explore biological structures. In the basement of House of Science an old SEM is used to depict biological structures. This microscope can provide a magnification of up to 50000 times while keeping a large depth of focus. Once loaded with samples the microscope can be operated by the students themselves. A typical experiment for students often starts with a look into the microscopic world and continues with the theory behind the technique of electron microscopy. Figure 5 shows a photo of a nettle leaf.

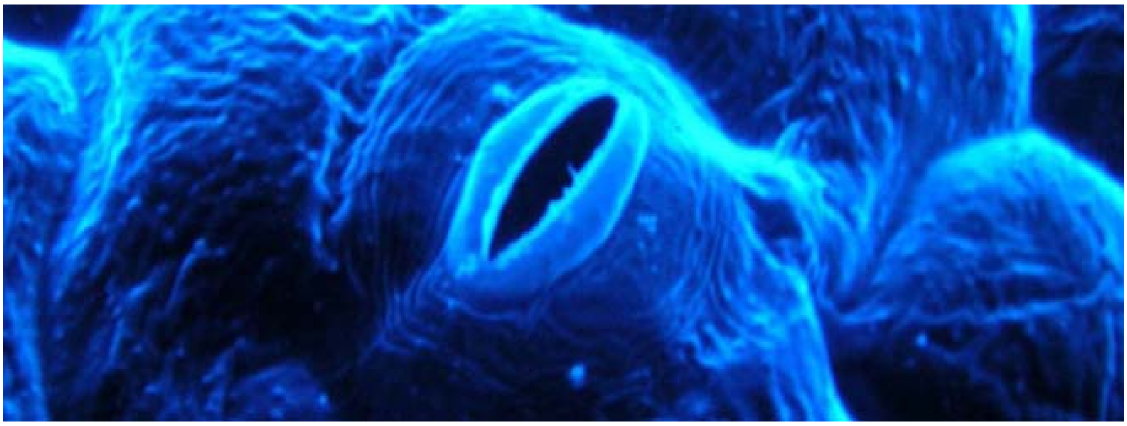

Figure 5. A stoma on the lower epidermis of a nettle leaf

Summary

House of Science is a laboratory close to the university where hands on experiments can be performed by school classes. The experiments complement the basic laboratory experiments performed in school, and give the students a chance to experience the academic environment of a university. Different fields of science, particularly astronomy, biotechnology and physics are demonstrated and several interdisciplinary experiments are being implemented. The laboratory has become very popular in the Stockholm area with the yearly visit of around 700 school class and hundreds of teachers. The House of Science concept can be a model for other universities or academic environments.

References

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[1] Johansson KE, House of Science, a university laboratory for school, Phys. Educ., 34: 342-345, 2004.
[2] http://www.houseofscience.se/
[3] http://hands-on-cern.physto.se/
[4] Johansson KE, Hands on CERN–a well-used physics education project, Phys. Educ., 41: 250-254, 2006.
[5] http://www.cern.ch/Delphi/Welcome.htm
[6] http://www.pyrosequencing.com/pages/technology.html
[7] http://www.phy.cam.ac.uk/

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Gravitropism Hands-on Device

Oikonomidis S, Grigoriou V, Kaponikolos N, Kanavi S and Kalkanis G

Introduction

Gravitropism is simply a plant's response to gravity. When a plant, or part of a plant such as the root, grows with gravity, it is called positive gravitropism. When the shoots grow against gravity, it is referred to as negative gravitropism. Plants are accustoming to the Earth's 1g pull from a very young age, even before the seedling has grown into the light. The research of gravity sensing is very exciting right now because the exact mechanism is not known. To better understand gravity sensing it is important to be aware of some of the components. The specialized cells and tissues for sensing gravity are called statocytes. The receptor receives the signal that was sent from the statocytes and then transduces it into physiological information. Sensing ends here and the signal then moves into the transmission phase.

Materials and method

Our device consists of an electric motor which is connected with a rubber band to a round metal disc. The metal disc rotates with an angular velocity of 1rad/s approximately. A piece of steel pipe 1m long is welded at the centre of the metal disc. As a result, the pipe is rotating at the same speed as the metal disc. At the other end of the steel pipe, we placed vertically a 1.2m long wooden axle (Figure 1). At the ends of the axle we hanged two cotton balls which contained lentils seeds with a short thread. The seeds are making circles 24 hours per day.

More specifically, we used a power supply which could provide variable voltages (10-12V) and it could change the setting of the current, thus the sense of rotation in the electric motor. The electric motor is working with direct current and with maximum input voltage 12V. The maximum rotation speed is 2,400rpm. Because of the small size of the motor axle, we cut and fitted a cd-case. Then we welded a piece of a steel pipe 1m long at the centre of a metal disc. The metal disc was fitted in a base which could be rotated through the electric motor. At the end of the pipe we fitted a horizontal axle where we putted 3 small magnetic balls as counterbalance. We also putted two small cotton balls which contained the seeds.

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Figure 1. Experimental apparatus

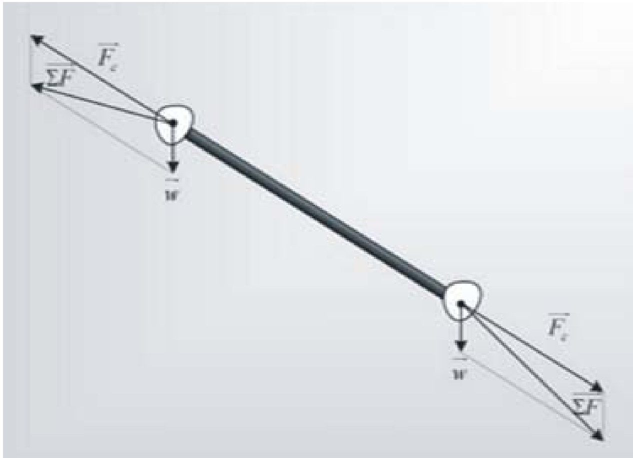

Figure 2. Forces applied at the seeds

Educational proposal

According to our method, the didactical approach that is supported by a worksheet should follow five steps: trigger of interest, express of hypotheses, experimentation, express a theory and generalize. This experiment refers directly to the third part of the following method and it can be used for measuring various natural and mathematical quantities such as period, frequency, angle, time, velocity, length. In order to achieve the accomplishment of the student objectives, it is better for the experiment to consist of two parts: the first one with an experimental setup where the cotton balls with the seeds would be motionless and an experimental setup where the cotton balls with the seeds would be rotated. Thus, it would be feasible to make comparisons between the two different ways of grow. In the fifth step here students are called to generalize their assumptions, we can put some questions in order to direct them. Particularly, we can ask them:

1. What are some general observations of the typical downward growth of a seed?
2. Is there anything that happens that is different from what you expected?
3. Using the data provided, how fast is the seed growing?
4. Why is it important to know how a seed normally grows?
5. What are some sources of error in this experiment?
6. How does the growth rate of this gravistimulated seed compare to the typical downward growth of a plant? Is it hindered or enhanced?
7. Supposed you see a plant's orientation and that no other reason affects plants grow, can you determine the effective gravity?
8. Can you make any hypothesis about the importance of gravity sensation of a plant in the space?

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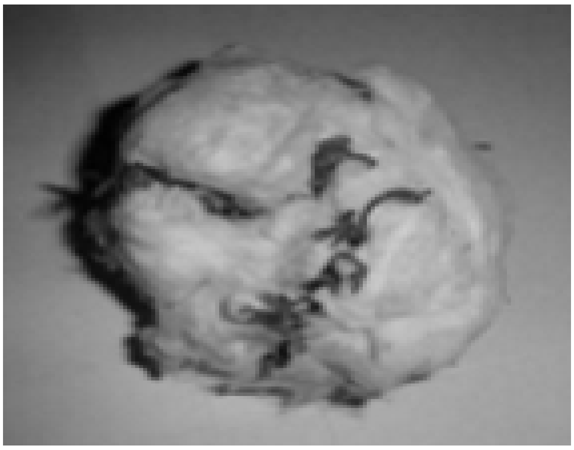

Figure 3. The grown seeds

Figure 4. Proposed apparatus

This exercise may fulfil a large variety of student objectives that can be accordingly applied to the student level. These objectives can be divided into two categories, not only cognitive but also psychomotor.

To be more specific, students (in the cognitive segment) are expected:

- To predict the normal response of a seed when grown down with gravity.
- To predict the response of a seed when it is being rotated.
- To compare the growth patterns of seeds those have been rotated to those that are growing down with gravity.
- To compare the growth and angle of orientation of seeds according to angular velocity of the device.
- To identify why it is important for a plant to have gravity sensing.

And in the psychomotor segment are expected:

- To explain why it is important to have a control for an experiment.
- To measure the growth and change in seed angle over time.
- To interpret data generated in tables and graphs.

Experimental results

Our experimental results didn't comply fully with our expectations, due to the fact that seeds grew in a small rhythm. According to theory, seeds were supposed to grow parallel to the resultant of their weight and the centripetal force. This means that seeds should not grow vertically to the ground but to make an angle (Figure 2).

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That wasn't what we experimentally noticed. The seeds grew so that shoots appeared to form a small angle with the vertical axis to the ground, but that wasn't too obvious (Figure 3).

Suggestions

As a future enhancement, we propose an experiment based at the aforesaid, where students can study various factors that determine seeds' grow such as light and orientation. With this they will have to handle more variables and study the importance of each one at the seed grows. The required changes in the experimental setup are small, as an electric bulb is needed and a mechanism that turns the vertical axis in various angles (Figure 4).

References

[1] Kamada M, Higashitani A and Ishioka N, Proteomic analysis of Arabidopsis root gravitropism, Biol. Sci. in Space. 19: 148-154, 2005.
[2] http://www.spaceday.com/conmgmt/pdf/2005_Activity_2.2_Seed_Germination.pdf
[3] http://www.sciam.com/article.cfm?chanID=sa006&colID=22&articleID=000790A5-749C-1C70-84A9809EC588EF21

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The Process of Digestion as Chemistry. The Horrible Experiment of Dr. William Beaumont

Van Haegenbergh E

Introduction

Occasionally accidents or coincidence may play an important role in the life of many science workers. So it went with the American army doctor William Beaumont in the 19th century. A severe injury caused by an incidental shotgun was enough for the scientist to start experimenting "in vivo" on his patient Alexis St. Martin. Dr. Beaumont worked with great persistence and accuracy and his it was the first comprehensive study of the influence of gastric juices on digestion. There were five or six old theories of stomach digestion: concoction, putrefaction, trituration, fermentation and maceration.
Very much uncertainty existed as to the phenomena occurring during digestion in the stomach, the precise mode of action of the juice, the nature of the juice itself and its action outside the body. On all these points the observations of Beaumont brought clearness and light where there had been previously the greatest obscurity. His somewhat "horrible" experiment can also be regarded as an example of excellent scientific work. Young people are actually very "food sensitive" and in class room practice topics as healthy food, special diets, low energy drinks, anorexia nervosa claim a part of the biology lessons. This issue of digestion is also compulsory in most of the biology programmes of the secondary schools in many countries. That is the reason why I have chosen to work out this historical experiment and put it in a broader and more actual context. It will be on the school website and three groups of pupils of the 6th year will continue the hands on part and present it during a European Science Symposium of the European Schools.

Historical view of digestion

Earlier work had been done by a Flemish scientist Van Helmont. His sophisticated studies have been taken down in his book "Oriatrike or Physical Refined", published in 1662. People thought of digestion as a kind of cooking brought about by the heat of the stomach. Van Helmont knew that the proven acidity of stomach fluids were not enough to explain the digestion of meat and he introduced "ferments" responsible for specific action in the digestion process. This was very near our

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modern concept of an enzyme. From stewing to chymification, fermentation or putrefaction the view of digestion has been very obscure and open to a lot of guessing.
Later experiments by the Italian Spallanzani also tried to find explain the properties of gastric juiced. He forced animals to swallow tubes of food and made them sick so he could study how the food had changed. He even did the same experiments with himself!

The life of Dr. William Beaumont

1785 William Beaumont was born in Lebanon, Connecticut on November 21, 1785.

1811 At age 26, Dr. William Beaumont enlisted as a surgeon's mate in the U.S. Army. He was assigned to the Sixth Infantry Regiment in Plattsburgh, New York. Soldiers lived in quite miserable conditions; hospitals were set up in buildings, barns, or even tents. After the war ended, Beaumont left the Army and in June 1815 he began private practice in Plattsburgh, NY, where he met his future wife, Deborah Green Platt.

1819 He re-entered the Army in December 1819, this time as a post surgeon. He was sent to a place near the Canadian border.

1921 In August Beaumont took a leave and travelled to Plattsburgh, where he and Deborah were married.

1826 Beaumont was assigned to Fort Howard, Green Bay. The medical problems he saw included fevers, diarrhoea, dysentery, and rheumatism.

1828 He went to in Wisconsin and stayed four years at Fort Crawford. The biggest medical problem was malaria, caused by mosquitoes and the area's problem of flooding each spring.

1834 Service at his last Army post near St. Louis, Missouri, where Beaumont participated in the new local medical society, which soon became the state medical society.

1853 Dr. Beaumont slipped on an icy step while exiting a patient's home, hitting his head severely. He died on April 25 and was buried in Bellefontaine Cemetery in St. Louis.

The Alexis St. Martin Experiment

Fort Mackinac, June 22, 1822, in what is now Michigan: A nineteen-year-old French Canadian trapper, Alexis St. Martin, stands on the threshold of history. Actually, he stands in the American Fur Company store. Suddenly, a shotgun goes off by accident. The gun was 2½ feet from St. Martin's chest. Duck shot shredded his ribs, lungs, diaphragm, and stomach. The post surgeon, William Beaumont, came on the double. Beaumont sifted out bone fragments, patches of burned clothing -- shredded tissue. Finally he gave the ruined St. Martin 36 hours to live. But St. Martin rallied. For two years Beaumont tended him. Then he hired him as a handyman. The ghastly wound healed. Well, it almost healed. The breach in St. Martin wouldn't quite close. Skin healed around a patch of exposed stomach wall.

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The torn stomach, in turn, formed a kind of mouth. It healed into a valve that opened when St. Martin ate too much. Beaumont was no backwoods sawbones. He knew the European medical literature. He'd read the heated debate going on about digestion. Doctors couldn't tell if the stomach ground food up, cooked it, or reduced it chemically. One English doctor had finally cried, *Some ... will have it that the stomach is a mill, others that it is a fermenting vat, others again that it is a stew pot.*

In 1825 Beaumont realized he'd been handed a remarkable opportunity. He made a deal with St. Martin and began a series of observations. He peered into St. Martin to see what his stomach was doing after different meals. He subjected samples of gastric juices to chemical analysis. Early in 1826, St. Martin wearied of the game and walked off. A few years later, Beaumont tracked him down in Canada. St. Martin -- now married and the father of two -- knew his value to Beaumont. He dickered for price. Finally, in 1829, Beaumont rehired him, and his family, so he could continue the tests.

Beaumont published a book in 1833: *Experiments and Observations on the Gastric Juice and the Physiology of Digestion.* It was clean, accurate scientific work. Figure 1 (left) shows the wound. Beaumont set the basis for what we know about digestion today. The book had a powerful influence back in the medical centres of Europe.

And St. Martin? Well, he lived to 83. Long after Beaumont died, he was still showing himself at medical schools for pay. So maybe this is a story about opportunism. After all, both Beaumont and St. Martin grasped the occasion in different ways. But Beaumont had the wit to see opportunity -- to use it for the general good. And if you've ever been cured of a stomach problem -- you should be very thankful he did.

The Beaumont papers

In mid-April 1833, Beaumont went to Plattsburgh, New York, where Beaumont was reunited with his family and began work on publishing his observations in a book, *"Experiments and Observations on the Gastric Juice and the Physiology of Digestion."* Dr. William Beaumont's cousin, Dr. Samuel Beaumont, had published a small newspaper prior to becoming a doctor himself (he apprenticed under William), so Samuel was quite helpful to William with the book's initial printing in 1833 (and with its second edition in 1846).Beaumont concluded in his book that digestion is a chemical process and that gastric juice acts as a solvent. His work won wide acceptance and his book became a trusted source for medical students and opened new avenues of research.

Importance of his work

- The accuracy and completeness of description of the gastric juice itself.
- The confirmation of the observation that the important acid of the gastric juice was the hydrochloric.
- The recognition of the fact that the essential elements of the gastric juice and the mucus were separate secretions.
- The establishment by direct observation of the profound influence on the secretion of the gastric juice and on digestion of mental disturbances.

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- A more accurate and fuller comparative study of the digestion in the stomach with digestion outside the body, confirming in a most elaborate series of experiments the older observations of Spallanzani and Stevens.
- The first comprehensive and thorough study of the motions of the stomach, observations on which, indeed, are based the most of our present knowledge.
- A study of the digestibility of different articles of diet in the stomach, which remains today one of the most important contributions ever made to practical dietetics.

Didactical value

An example of good scientific work

There had been other instances of artificial gastric fistula in man which had been made the subject of experimental study, but the case of St. Martin stands out from all others on account of the ability and care with which the experiments were conducted. The value of these experiments consists partly in the admirable opportunities for observation which Beaumont enjoyed, and partly in the candid and truth-seeking spirit in which all his inquiries seem to have been conducted. "It would be difficult to point out any observer who excels him in devotion to truth and freedom from the trammels of theory or prejudice. He tells plainly what he saw and leaves everyone to draw his own inferences, or where he lays down conclusions he does so with a degree of modesty and fairness of which few perhaps in his circumstances would have been capable."

In the science teaching practice, it's necessary to get pupils to learn how to develop a scientific theory, based on hands-on science? Therefore the Beaumont work could be a perfect example.

Hands-on

Experimental Design Sheet

Develop for the pupils work in the lab an experimental design sheet. They should try to include the following sections:

- Title: What do you trying to find out?
- Background research: Collect information about the topic
- Hypothesis: Based on the research, what will happen when you do the experiment
- Materials: List of materials
- Procedures: How will you test your hypothesis?
- Results: Record your data in chart form, graphs, spreadsheet…
- Discussion: Explain the results; did you hypothesis prove correct of false?
- Conclusion: Briefly summarize your findings

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The experiment of Dr. Beaumont could be a starting point to make students find parts of this experimental approach.

Class experiments: Digestion

There is so much material on the internet that a list of URL's might be very useful. The teacher can check the addresses with the pupils and select the experiments that are close to the original of Dr. Beaumont. But since Beaumont neglected the action of other digestive juice like saliva, the project could be broadened to the complete digestive system.

Here are some ideas that can find found on the web, with already student product sheets available:

- Imitate Protein digestion (breaking down hard-boiled egg with enzymes)
- Imitate Carbohydrate digestion (breaking down soda crackers)
- Constructing the complete digestive system with simple materials as class project
- Specific enzymes for the breakdown of nutrients
- Animation and simulation programmes
- Studying the structure of the main digestive organs
- Make a quiz about digestion

Useful websites:

http://samson.kean.edu/~breid/enzyme/enzyme.html
http://www.smv.org/jil/mll/high/MLL9-12dig-LP.pdf
http://www.tvdsb.on.ca/westmin/science/sbi3a1/digest/digest.htm
http://highered.mcgraw_hill.com/sites/0072437316/student_view0/chapter43/animations.html#
http://www.whfoods.com/genpage.php?tname=faq&dbid=16#digestion
http://kitses.com/animation/swfs/digestion.swf
http://www.zerobio.com/target_practice_quiz/target_practice_quiz_digestion.htm
http://highered.mcgraw-hill.com/sites/0072919183/student_view0/chapter37/elearning.html
http://www.mhhe.com/biosci/genbio/maderhuman6/student/olc/vrl_animation-quizzes.html
http://www.bioplek.org/inhoudbovenbouw.html#spijsvertering
http://www.cheminst.ca/ncw/experiments/2001_baking_e.htm
http://www.gastrolab.net/ghe6.htm
http://www.pebblepublishing.com/forgotten_missourians_who_made_history.htm
http://www.james.com/beaumont/dr_life.htm
http://www.umsystem.edu/upress/spring1996/horsman.htm
http://www.fortcrawfordmuseum.com/drbmt.htm

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Figure 1. Related publications

Links with other food programmes: H.E.L.P. project

The basic experiments of Dr. Beaumont resulted in the publication of his book, where the digestion of all kinds of food in different condition has been accurately written down. In our modern scientific environment we have so many data of food analysis at our disposal, that it possible to make a virtual analysis of the food that we daily consume, to calculate the total energy content and to compare the results with a "healthy and balanced" diet.

A few years ago a team of 7 schools presented the H.E.L.P, a Comenius project organised by 7 European schools: **HE**alth, **L**ifestyle and **P**hysical condition of pupils. A part of the H.E.L.P.-project is about food consumption and the energy balance of the body. The programme files are mostly written in excel and food lists are made in Dutch, English, Norwegian, Italian and Spanish.

Description

The eurofood-part is one of the key-programmes in the HELP project. Using the eurofood programme, together with the energy-calculator it should be possible to create a complete "health-report" for an individual student or a class group. The eurofood programme is created from a teacher's point of view: it is an aid to work

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specifically with youngsters in a classroom environment. Pupils don't need to have a prior knowledge of the subject, and working with the programme is as easy as we could possibly make it.

Objectives

A correct assessment of food intake and/or nutritional status is problematical in pupils. This food programme therefore aims to present user-friendly software on eating habits that can be used in a classroom environment. 16-17 year-old pupils can compare their own eating-habits with recommended data, with the data of their classmates and/or with the eating pattern of pupils in the other European countries. This part of the HELP-programme is linked to other parts of the same programme, so that results can be related (e.g. activity). The aim is not to present a scientifically "foolproof" program, but to provide a framework for the teacher through which he/she can discuss eating-habits in the classroom, involving the pupils in a very direct way.

Comparing food pyramids

Pupils can choose three specialized food pyramids to compare, in three different countries for specific age groups. The USDA offers many choices and some very useful links on their website at:

www.usda.gov/cnpp/
www.bal.usda.gov/fnic/etext/000023.html

One can visit, even for fun, the USDA "Inte-ractive Healthy Eating Index" at http://www.usda.gov/cnpp/healthyeating.html to find out how the foods fit into the food pyramid. The website can also be used to look at the nutritional value of the foods you eat.

A book for fun and science

In the book "Blood bones and body bits" science has never been so horrible and funny. Nick Arnold and Tony De Saulles describe many historical biological and chemical experiments in a funny and pleasant way. Even the experiment of Dr. Beaumont has found a place in the book under the title: "The stomach for the job".
http://www.horrible-science.co.uk/magazine.htm

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How to Engage Science Students Using Demonstrations

Cartwright H

Introduction - a warning!

An important aspect of the work of scientists is to write papers and to give talks; these are the primary ways in which the scientific output of an individual becomes more widely known. One might think that there would be little point in preparing a paper for the Proceedings of a Conference, and then telling readers to ignore it. However, that is what I am asking you to do with this paper - ignore it until the talk that it accompanies has been presented. The reason is simple: some of the demonstrations in the talk will have more impact if you have not read about them in advance. So, let us assume that you have either been to the talk to which this paper relates, or have missed it...

Hands-on Science - and when it cannot be used

The teaching of science is becoming increasingly machine-based. The Internet provides access to a wealth of information and it would be foolish not to take advantage of it. When used judiciously, the Internet allows teachers to accomplish more in the same period of contact time, or to teach material which otherwise could not be covered during class. If used in this fashion, the Internet is undoubtedly valuable.

However, there is an area in which the Internet is at present far less relevant, and perhaps even has a negative influence upon the teaching of science; this is the potential loss of Hands-on experience for students, with classroom experiments sometimes being replaced by Internet-based “investigations”.

Science is inherently experimental, even theoreticians must turn to experimentalists to provide the data upon which they work. Science is so strongly grounded in experiment that it is essential that our students have firsthand experience of the way that science is carried out in the laboratory if they are to fully appreciate the subject. Experimental work is a fundamental part of the training of students in science at all levels and most teachers would be extremely reluctant to remove this practical element from science courses.

Where possible, the practical element of science instruction should be Hands-on; indeed, that is very much the focus of this conference. Most students learn more effectively when they can carry out experiments themselves than when they are

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mere spectators. Unfortunately, it is not always feasible to provide Hands-on experiments in the classroom. The experiment that best illustrates some scientific idea may be too dangerous for students to perform; it may require skills that the students do not possess; the chemicals or instruments required may be too expensive for an entire class to tackle the experiment; or the experiment might be a “one-off”, in which no second chance is possible, and the teacher might be reluctant to allow a student to attempt the experiment on behalf of the class for fear of failure.
Whatever the reason, there are times when experiments are best performed, or can only be performed, as a demonstration rather than as a student exercise. What considerations should govern such demonstrations? Should they be treated in the same way as experiments that students themselves might perform, or are there other factors to take into account? It is such questions that this paper seeks to address.

Demonstrations and experiments, investigations and more...

During the talk from which this paper is derived I will illustrate some of the experiments that are discussed below. Further details can be obtained upon request. The purpose of both the talk and this paper is to set out a number of factors that a teacher, especially one with limited experience, might reasonably want to consider before planning class demonstrations. Such demonstrations can be very valuable, but *they must have a rationale*; full use needs to be made of the opportunities that demonstrations provide. We discuss in the following sections several justifications for introducing a demonstration into classroom teaching.

To create excitement and interest

Demonstrations whose role is to excite students are among the most widely used - and misused - of all. Such demonstrations are often of the “flash-bang” variety, designed to excite and impress; for example a sugar-chlorate flare or the explosion of hydrogen-filled balloons. These can be spectacular (though by their nature they may be dangerous if misjudged) and can usually be relied upon to generate a positive reaction from students.
So what is the problem? It is that of an opportunity missed. Any demonstration provides a chance to teach. If a teacher takes a chemistry class into the playground to show a spectacular chemical reaction merely with the aim of enthusing the class, it may create interest, but also be a wasted opportunity. Furthermore, a spectacular or noxious demonstration may create the impression that chemistry is all about bangs or smells, rather than being a fascinating intellectual subject. The demonstration should be the starting for point for discussion, not merely a means to set science apart from the humanities, in which the opportunity for demonstrations is much less.
The aluminium-iodine reaction, for example, is very impressive, producing clouds of purple fumes. One might ask: what are the purple clouds? Why are they formed? Are the purple fumes dangerous? Why? Why is light emitted by the reacting material? Would other chemicals react so vigorously? If not why not? If so, why are

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they not used? The level of the questions of course must depend upon the class, but advantage must be taken of the opportunity that the demonstration affords.

To illustrate the hidden nature of scientific laws

Scientific laws are revealed by experiment, not handed down written on tablets of stone. However, experiment does not reveal the laws themselves, but instead yields data that we may assess to see whether they agree with the predictions of a hypothesis.

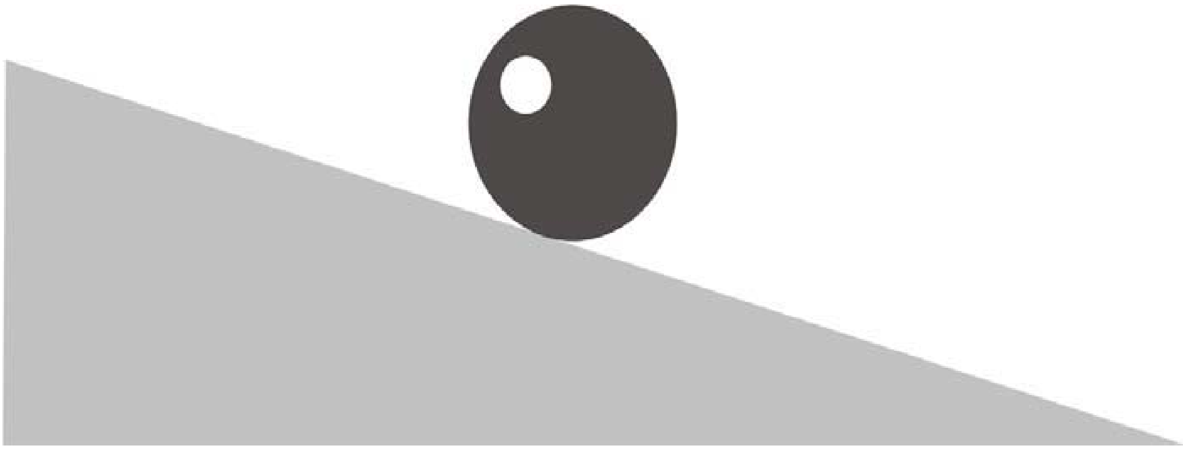

Figure 1. The biscuit tin demonstration.

Students often fail to appreciate this quite subtle point, but it can be exemplified through a simple experiment (Fig 1). A closed round biscuit tin is laid on its side on an incline, and students asked to predict the direction in which it will roll. Suspecting some sort of trick, suspicious students might argue it will roll "uphill", but most will agree it will roll down. However, when released the tin does indeed roll uphill.

What is going on? Clearly there is something unusual about the tin[1], and students can be asked to propose explanations for the observed behaviour. The sophistication of these explanations will depend upon the level of the students, but the presence of a magnet within the tin, and another hidden beneath the ramp to drag the tin upwards, is a common proposal. The teacher could at this stage reveal the explanation, but it is more constructive not to do so. Instead, she could remove the lid from the tin and show what is inside to just one or two students, and then engage in a discussion with the class as a whole.

What sort of theories for the behaviour of the tin can they propose? What tests might they do to establish the validity of competing theories? If we can never actually "see into the tin" can we ever be sure that a theory is "right"? Will

[1]The tin has a small but heavy metal weight attached to one side of the interior. When placed with this weight suitably positioned, the tin rotates to bring this weight to the bottom, even if this means that the tin itself travels up the incline.

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performing multiple experiments help? If every experiment that is performed is in accord with the theory, does that prove that the explanation is correct even though the contents of the tin cannot be inspected?

To show that not all is as it seems

Xylene cyanol is dichromic (literally "two-colour"), indicating that its solutions display two colours at the same time. In neutral solution dilute and concentrated solutions are only slightly different in colour; however in acid solution the difference is very marked. A solution of the indicator in moderately strong acid[2] is dark red, while a dilute solution is leaf green.

When students see two solutions of different concentration in two separate beakers, this difference in colour provokes little interest; when they see that a *single* solution can be two colours simultaneously they are fascinated and perplexed. If a white light is viewed through a thick layer of an acidic solution of xylene cyanol, the solution appears deep red; if the liquid is shaken thin layers appear deep green.

This extraordinary solution is two colours simultaneously. This raises several questions? How can one material be both red and green? Why does (red + green) not make brown, as it would in a paint pot? And most importantly, what is the explanation of this phenomenon?[3]

To show the unexpected in science

In science things tend to change gradually or, by contrast, almost instantly. The growth of plants and explosions are examples of these two extremes. It is natural for our students to gradually develop a feel for "the way things are" as they encounter more and more examples of the behaviour of the natural world. Indeed, this exposure to natural phenomena helps to develop what one might call scientific intuition, according to which students begin to know "how science works". However, intuition is not always a guide to reality, and clock reactions provide a fascinating example of this.

---

[2]Only a little experimentation is required to create a solution with the right characteristics. The pH of the solution can be within the range 1-3, and any common mineral acid can be used. The amount of xylene cyanol must be such that a source of white light appears red when viewed through the solution, but thin layers of solution, when shaken, appear green. It is not difficult to create a suitable solution.

[3]Further details are available from the author, but in essence the explanation is as follows: The solution absorbs blue light strongly and green light slightly but does not absorb red light. When white light is passed through a thin layer of solution all the blue light is removed, but most of the green light remains, as does all the red. The eye is far more sensitive to red than green, so the light appears green. When white light is passed through a thick layer of solution, both blue and green light are removed; red however passes through, so the solution appears red. Because the eye is not very sensitive to this region of the spectrum, the solution appears dark red, rather than bright red.

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In a clock reaction two or more liquids are mixed with no visible change. Then a change of colour occurs abruptly. One clock reaction stands out as being widely used in schools, the iodine clock. This is easy to prepare, relatively safe and can be used not just to intrigue but also to teach science (for example, by studying the effect of the temperature on the time taken for the colour change).
More exotic clock reactions are generally more expensive, more dangerous, trickier to prepare, or all three. However, the oscillating clock reaction[4] is such an intriguing reaction that it deserves a spot in the chemist's list of demonstrations, provided that one has the necessary knowledge to prepare it safely. In the oscillating clock, three colourless liquids are mixed to give a solution which is itself initially colourless. After a few seconds the solution changes to a gold colour, then abruptly to dark purple[5]. This colour fades to give a colourless solution, which then becomes gold before the dark blue suddenly reappears. This cycle may continue for fifteen minutes or more.
The reaction provides a route into a discussion of science at many levels. What is necessary for oscillations in a chemical system? (Answer: an autocatalytic system; clearly an advanced topic) Where are oscillating reactions vital for us? (Answer: in the pacemaker than runs the heart). Will the oscillations in the oscillating clock continue indefinitely? (Answer: No; chemicals are being consumed, so it must eventually stop). Why, then, does our heart pacemaker continue working almost indefinitely? (Answer: because fresh chemicals are being supplied to it constantly). And so on.
Once again, the experimental "hook" that a demonstration such as this provides must be used to introduce topics that relate to it, so that advantage can be taken of the science that underlies the demonstration.

To bring into focus concepts which are difficult to visualise

Dry ice (solid carbon dioxide) and liquid nitrogen are easy to obtain, and sufficiently cheap that their occasional purchase is within the budget of most schools. Dry ice (when added to water) can be used to provide a boiling cauldron for any witches to gather round in the school play, and too often this is the way that dry ice is used in science lessons also - just to entertain.
However, the existence of a temperature below which it is impossible to go, Absolute Zero[6], is an important thermodynamic concept. This is implicit in the ideal gas equation, is important for our understanding of thermodynamics functions such as entropy, is important in statistical thermodynamical calculations and so on.

[4]The oscillating clock requires some potentially hazards chemicals, most notably concentrated perchloric acid (solid chlorates are explosive) and moderately concentrated hydrogen peroxide. It is not a reaction that should be attempted by non-chemists. Details, for those with suitable training, are obtainable from the author.

[5]This colour is due to iodine in the presence of starch, and will be familiar to those who use the iodine test in biology as a test for the presence of starch, and also to those who do the standard "one change" iodine clock reaction in which the same purple colour is produced as in the oscillating clock described above.

[6]-273 C.

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The idea of an absolute minimum for the temperature scale is an easy one to explain, but is far more difficult for students to accept. It cannot be made conceptually simpler by demonstrations that rely on dry ice or liquid nitrogen, but nevertheless by using these materials we can try to give students some feel for how far it is possible to approach that figure. Dry ice sublimes at a temperature of -78.5 C, which is about the coldest temperature ever experienced by a human. Liquid nitrogen boils at a temperature of -195.8 C, which is around 70% of the way down from the freezing point of water to Absolute Zero.
Markers such as these allow students to get a slightly better feel for what the zero of temperature means, and how cold it really is. One can also use demonstrations using liquid nitrogen to introduce a discussion of current ethical issues in science, such as In Vitro Fertilisation and the storage of eggs and sperm (and, indeed, entire bodies) in liquid nitrogen.

The small matter of involvement

Teaching is challenging at the best of times, and especially difficult if one's class is not really involved in the material being presented. When minds are on life after class, they will absorb little. Demonstrations often provide a way in which that involvement can be stimulated.
A simple example is burning a banknote. In chemistry shows I generally burn a small rag soaked in a flammable mixture[7]. With care, the liquid burns in a satisfying fashion but the rag is left untouched. The demonstration relies upon the presence of water, with its high heat capacity, in the rag. This may be sufficient to keep the rag cool long enough that the rag itself will not ignite before the alcohol has all burnt.
In this simple demonstration the rag can easily be replaced by a banknote[8]. If this note belongs to the teacher, or has been borrowed from another teacher or parent, students' desire to see the experiment go wrong, and for the banknote to be destroyed, is always strong. With such a vested interest in the outcome of the experiment, the class is then far more open to a discussion of the science behind the demonstration - what has been done by the teacher to avoid disaster?

The element of fear

It will be clear that I feel student involvement in demonstrations - even if it does not amount to actually performing them - is vital. This involvement makes them far more receptive to a discussion of the science that underlies the experiments.
Just as, in section 6, students usually have a “stake” in the outcome of the experiment (longing for the teacher to make a mistake and destroy the banknote), it is also possible for students to be similarly involved because of an element of

[7]A 50:50 mixture of ethanol and water is ideally suited to this purpose. However, the mixture is very flammable, and care must be taken to ensure that there is no possibility of accidentally igniting the stored liquid.

[8]Practice first! The author of this paper takes no responsibility for your mistakes!

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concern, even fear. Many teachers will explode a hydrogen balloon during class, and this can be done in such as way as to heighten students' anticipation.
One can even introduce the element of fear - is this balloon going to give an even bigger bang than the previous one? This balloon contains hydrogen, but the last one was only helium - how will the bangs compare? This involvement with the demonstration again provides an opportunity for the teacher to teach some real science - why does helium not burn? Why does the hydrogen balloon burn much faster when oxygen is present? And so on.
One must, of course, exercise some caution here. The object of a science lesson is to impart understanding, not develop a fear of chemistry in one's students; if the result of performing an experiment is to leave students in tears the teacher will have done far more to turn students off science than to encourage them to enjoy it.

To show how easy it is to be mislead

Indigo carmine is an indicator. It can be used in a very simple, but most intriguing reaction which can be presented by a teacher in a way that suggested a solution can do mathematics.
Neutral solutions of indigo carmine are blue, but strongly basic solutions of the indicator are green. Unlike most common indicators, which are used to show acidity, the colour of indigo carmine depends upon the amount of oxygen in solution. Therefore, if it is possible to change the amount of dissolved oxygen, the colour of the solution changes.
In the indigo carmine air oxidation reaction[9], the oxygen dissolved in an aqueous solution is consumed over a period of a few minutes by a reaction within the solution, and the solution therefore changes colour. The green colour changes to dark brown, then to red and finally to gold. If oxygen is added to the solution (which can be done simply by pouring the liquid from one beaker to another) the colour changes reverse.
This is most effectively illustrated by pouring about half of the liquid from one beaker into a second and then holding up the two beakers side-by-side; the colours of the two liquids should be perceptibly different. One can then suggest that this is a solution which appears to be able to do mathematics - it can at least divide by two.
If the audience is sceptical, continue pouring the liquid into the second beaker, then announce the solution is still capable of dividing by two, and pour half the liquid back into the first beaker and hold the two liquids side-by-side once more; again the colour change should be clear.
Few students will realise at first that the change has been brought about by mixing air into the liquids. The demonstration, which is easy to perform, provides an effective way of introducing hypotheses and ideas, especially if reference is made

[9]Two aqueous solutions are required: (a) 16g glucose + a small amount of indigo carmine; (b) 7.5 g sodium hydroxide, each dissolved in roughly 400 ml water. The exact concentrations are not important. An immediate colour change occurs when the solutions are mixed for the first time. Upon standing the sequence of changes outlined above occurs over a period of several minutes.

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back to the dichromic solution, which often leads students to conclude that the same explanation might apply in this case also.

Safety

With all demonstrations and experiments, whether conducted in school or University, safety is absolutely vital. Some of the demonstrations outlined here and discussed in the talk are potentially hazardous. For example, perchloric acid, used in the oscillating clock, is a strong inorganic acid which can give rise to serious burns and can generate explosive solids. Both sodium hydroxide and hydrogen peroxide can cause very serious damage if splashed into the eye. If you are contemplating doing any demonstration mentioned in this paper or the talk from which it is derived, contact the author if you are in doubt about any aspect of safety.

Further information

Further information about the demonstrations discussed in this paper, or shown during the talk from which it is derived, can be obtained by emailing Hugh.Cartwright@chem.ox.ac.uk

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The Role of Physics Knowledge in Learning IT. An Educator's View

Berezovska I and Berchenko M

Introduction

The origin and increasingly growing progress of information technology as a science with many applications was the product of multiple forces operating during decades prior to 1980s, when a wide use of PCs indicated the beginning of the IT era. These included many discoveries and accomplishments in physics, extensive research in material sciences, the innovative impact of the quantum theory, and the confidence produced by the success of transistor technology and semiconductor microelectronics at large. By virtue of this experience, IT became a prime example of quick application of new physical ideas, a circumstance which augured of its success.

Evaluation of students' physical background

The lack of the fundamental physical knowledge significantly limits effective learning IT and IT literacy in particular. Students depend on relevant physics information to be successful in mastering IT skills. To clarify a "physical bottleneck" in students' educational background we conducted the survey which sought (1) to learn the comprehension level regarding the knowledge of fundamental physics phenomena that students retained after a school physics course and (2) to explore students' ability to understand how physics phenomena are "transformed" into IT hardware solutions.

Two groups of 1st and 4th year students were recruited for the survey in Ternopil State Technical University. The 1st year students were asked to answer 5 questions concerning electricity and magnetism:

1. What is a ferromagnetic?
2. Coulomb's Law.
3. Electromagnetic induction law.
4. What is a condenser capacity?
5. What are differences between metals, semiconductors and dielectrics?

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Obviously, the questions were selected to reflect the phenomena applied in CPUs (transistors), memory and storage devices. 30 questionnaires were completed. Most students reproduced the formula of Coulomb's Law (70%), many wrote formulas of the electromagnetic induction law (37%) and the condenser capacity (43%). Only 33% students were able to answer the 1st question. About 60% students provided a simple conductivity-based explanation about the difference between metals, semiconductors and dielectrics. No interpretation was given to the formulas they wrote and no comments were made on possible application of the phenomena mentioned.
The 4th year questionnaire dealt with the topics which are addressed in the current Web-based course titled "IT Hardware" [1] and, similar to the previous questionnaire, focused on the physical basis:

1. Which physical phenomena are used in data storage devices?
2. Why optic buses are generally faster than electric ones?
3. What is a physical law applied in an optic fiber?
4. Indicate devices the operation of which is based on the phase transformation from an amorphous state to a crystal one and vice versa.
5. What physical factors can restrict the Moore's Law?

Questionnaires were completed by 18 students. 92% students easily explained the principles of data storage, but only 42% students were able to reason about optic versus electric buses using their knowledge of electricity, magnetism and optics which was found rather insufficient as shown through an additional survey with the 1st year student questionnaire. Many students (67%) successfully explained how an optic fiber and optic storage devices work. 67% students saw the link between the structure of semiconductor materials used in microelectronics and the current trends in this field described by the Moore's Law.
For comparison, the 4th year students were additionally offered to complete the 1st year questionnaire initially intended for the 1st year students. In contrast to 1st year students, the 4th year ones provided descriptive answers to questions #2 (62%), #3 (64%), and #4 (67%). Only one student of 92% students who properly answered the question #5 reasoned in terms of charge carriers, while others, similar to 1st year students, mentioned only different conductivity.
The survey results are summarized in Table 1. We may suggest that as soon as we have made a special emphasize on what physical phenomena are used in IT hardware while teaching the "IT Hardware" course, the 4th year students demonstrate overall better vision of this link.
According to our survey, widespread problems with physics can be summarized as poor knowledge of fundamental electric, magnetic and optic phenomena that makes many students feeling a wide gap between physics and IT. This is not a criticism of current educational practice but merely an observation.

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Question #	1st students	4th year students: 1st year questionnaire	4th year students: 4th year questionnaire
1	33%	42%	92%
2	70%	62%	42%
3	37%	64%	67%
4	43%	67%	67%
5	60%	92%	67%

Table 1. Percentage of proper responses

Physics in the IT context

Physics creates a strong foundation for IT literacy. The portion of the physical knowledge involved in teaching IT can only increase in the near term, which raises a question concerning how teachers can provide efficient access to the relevant information *within* IT courses.

Reasons to learn physics better

Knowledge of relevant physics information is important to students for a variety of reasons:

- it makes the link between the theory and the practice meaningful for students;
- it reinforces comprehension of how IT hardware work;
- it enables students to understand current trends in IT and see the principal limits of those trends;
- it provides support for decision making regarding the proper selection and use of IT hardware;
- it allows seeing new ways in future IT.

The access to physics educational materials within IT courses

Different strategies can be implemented in the science curriculum to address problems of IT literacy by improving instruction in physics and better coordination between subject-specific curricula.

It is the authors' contention that a great deal can be done throughout the modern educational system. Traditional physics courses provide a good primary basis, but a stronger accent on the potential of many physical phenomena, effects and concepts in IT would be useful.

Few efforts can be made to refresh the physical knowledge in students' memory. When faced with forgotten facts, students will often bypass their old textbooks and seek rapid access to easier understandable information.

One way is to make this information accessible through inserting special sections in the IT courseware. But we believe that access, not necessarily duplicating materials

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on particular physical matters, might be the most appropriate recommendation in this case.
Web-based instruction model [1] with its deep linking strategy that links students directly to the structured components of online courseware provides a potential roadmap to a solution. Therefore another way to view the situation at hand is from the perspective of the science teaching profession as a whole. The two examples are given below to illustrate the idea.
Entropy is a cornerstone concept in information theory defined by Shannon in the context of a probabilistic model for a data source. However students are likely having heard this word and have learned the entropy concept while were studying physics and thermodynamics in particular. Indeed, both concepts of entropy, information and thermodynamics, have deep links with each other. Then the sensible approach is to provide a link from IT courseware to a relevant physics resource, for example “Introduction to thermodynamics” developed at the Physics Department, Murcia University [2], and benefit from its opportunities including simulation. This facilitates achieving more pragmatic teaching goals, e.g. explaining what the amount of information is, why one binary element contains a unit of information named a bit, when lossless data compression is possible etc.
There is no doubt that graphics is a students’ favourite. But do they always know which image format is more effective, i.e. yields a smaller file size, and why? Colour models will be a good starting point to show how image data can be compressed using different formats. For example, “Make a splash with colour” [3] may nicely complement a technical description of image formats.
Each way mentioned above has its own strengths and weaknesses, and it may take a combination of strategies to address the complexities of IT literacy effectively.

Potential of the gray literature

Much useful information in science education is generated through academic and non-profit organizations in the form of project reports or deliverables, conference proceedings, newsletters, lecture notes, assignments, topic presentations, and other formats. These materials typically do not find their way into established commercial outlets for publication and, as a consequence, are not consistently indexed in EBSCO and other bibliographic tools or databases for locating science teaching information. As a result, educational documents often fall into the category of “fugitive” or gray literature, i.e. literature that is difficult to locate because it is not available through traditional commercial pathways.
Gray literature is important to science teachers because:

- it enables them to learn from and build on the activities of other professionals working in the field;
- it provides them examples of successful practices.

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The proliferation of such non-indexed, potentially valuable information has stirred interest among those involved in the development of, use of, collection of and access to this body of science educational literature [4].
Improving access to this literature faces a number of considerable problems. The sheer volume, diversity, and non-traditional formats make gray literature difficult to locate. Although gray literature documents have become increasingly available on the Internet, collocation, cross-linking of materials across sites is small.
Additionally, the two established models for systematic access to literature are limited solutions to the access problem for the gray literature in science education. The model of controlled vocabulary indexing by human experts has difficulty scaling up to accommodate the quantity and variety of gray literature documents. Although search engine technology is effective in locating some relevant documents, it is restricted in its coverage by problems of collocation across keyword texts and the absence or choice of descriptive information about the documents such as title, creators and topic. Thus, a teacher who is looking for information about a particular science topic faces a formidable challenge in finding pertinent gray literature in the education domain.
Recently experts in science education have made significant efforts to ensure a more systematic way of organizing the gray literature of science education [5-6]. A notable collection of educational resources has been developed within the Hands-on Science project [5], but it represents a small portion of potentially useful gray literature. Thus further research should be made to improve the collections which exist and develop a relevant approach to the access problem in science education gray literature.

Conclusions

Current teaching models for science subjects have reached a high state of collaboration. In this regard, establishing the content of and providing the access to cross-subject courseware components should be a profession-wide undertaking. However, such an undertaking would necessarily require profession-wide discussion on the scale of current practices in science teaching.
Finally, in such a fluid environment as the science and the Internet, successful support for teaching requires flexibility and creativity that may be an iterative process. New technologies may enhance courseware but also introduce problems because much in education remains more of an art than a science. Better technologies will certainly help us, but very often we will continue to rely on the expert opinion of our professional colleagues who know the science and, most important of all, know the needs of students we teach.

References

[1] Berezovska I and Berchenko N, Web-based Instruction in IT Hardware, Proc. of the 2nd International Conference on Hands-on Science, HSci 2005, Michaelidis P (Ed.). Rethimno-Crete, pp.: 83-86, 2005.

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[2] http://colos1.fri.unilj.si/%7Ecolos/COLOS/TUTORIALS/JAVA/THERMODYNAMICS/THERMO_UK/HTML/Entropy.html
[3] Make a splash with colour, http://www.thetech.org/exhibits/online/color/intro/
[4] Berchenko N and Berezovska I, When less is more: a practical approach to selecting Internet-based resources for teaching IT hardware, System-based Vision for Strategy and Creative Design, Bontempi F (Ed.). Swets & Zeitlinger, Lisse, pp.: 2119-2122, 2003.
[5] Hand-on Science (H-Sci), http://www.hsci.info/
[6] CoLoS, Conceptual Learning of Science, http://www.colos.org/

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From Simple to Complex but What is Simple and for Whom?

Härtel H

Point mass, rigid body and elasticity

When preparing learning material for newcomers it should be sequenced in such a way that progression from simple to more complex topics is facilitated. This is one of those rather rare principles on which most educators will agree.

However, what is simple? Here the problem starts. Is Newton‘s point mechanics simpler than the treatment of elastic bodies with internal vibrations? It certainly is simpler mathematically, and this was definitely the case when no computers were available. Conceptually, Newton’s point mechanics may also be simple if we replace the mathematically defined mass point, which by definition has no size or zero dimension, with a little volume, filled with matter, which, however, is so small and compact that internal vibrations can be neglected.

The next step in increasing complexity is the rigid body. This model too is simple, in a mathematical sense, because it can be reduced to Newton’s point mechanics by referring to the concept of centre of mass. Conceptually, however, the rigid body is simple only if this reduction is taken for granted and no deeper questions are raised. The model of a rigid body implies some kind of "magic" concept relating to the transmission of force. Whenever a force is applied to a rigid body, the same force is present at all parts of this body at the same moment in time (infinite transmission velocity) and this happens without any change in its internal structure.

Such a process is conceptually rather difficult to understand; we physics teachers would have a difficult time if our students insisted on an explanation. However, the model of the rigid body coincides perfectly with our everyday understanding of how objects move. In physics the movement of an extended object is explained by the movement of its parts. In daily life this concept is exactly reversed: movement of the parts is explained by movement of the whole [7].

A sentient being starts moving because it decides to do so. And if it moves as a whole, all parts must do the same. A car starts moving because the motor starts to apply a force. Again all parts must do the same and no further explanation is needed.

This coincidence of an everyday concept (based on some kind of "magic", unreflected mechanism) and the model of the rigid body (based on force transmission with infinite velocity) makes teaching easy. Students see no problem

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and the laws of physics, for instance those about the simple mechanical machines and the so-called golden rule of mechanics can easily be covered. However, a chance is missed to point to problematic aspects of daily life concepts and to argue for a more careful analysis of transmission processes in space and time.
Following the treatment of rigid bodies, elasticity can be introduced. However, this topic implies a major increase in mathematical complexity if closed solutions of the underlying differential equations are of interest. The treatment of elasticity is therefore restricted to advanced studies with special interests in this field.

Didactical consequences

This sequence from simple to more complex has some clear advantages, if the focus is on the mathematical methods and on closed form solutions of the underlying differential equations. Some didactical problems have already been described in relation to the rigid body. However, there is a more general didactical problem. From the perspective of the learner this sequence has advantages in introducing an unknown field and hopefully leads to early learning success. There is, however, a price to pay. The topics to be learned become more and more difficult and the chances increase that the final experience, which may well be decisive in motivating future learning, may be one of failure.
A second more general aspect is related to the fact that the learner has no choice in the direction of learning, but relies completely on input from the teacher. No aspects of the rigid body are visible when Newton's point mechanics is treated and no elastic behaviour comes to mind when the focus is on rigid bodies.
Ausuebel proclaims the importance of advanced organisers for learning [1] and Wagenschein has focussed on the concept of the exemplary in teaching and learning [8]. The ideas of these authors can be interpreted as an attempt to start with some kind of seed, which already contains some important ingredients of the new and as yet unknown learning field. This seed needs to be unfolded during the learning sessions that follow. The advantage is that during the learning process nothing essentially new need be introduced but any new aspect will be experienced as something which follows logically from what is already known.
The important didactical question is if such a seed can be found which is complex enough to cover a reasonable amount of a learning field and simple enough to be acceptable for newcomers. In the light of modern computers, a new question can be posed: can modern media help to develop such seeds and can it facilitate the learning process?

Further Examples

Before such questions will be considered with possible answers, some more examples from the physics curriculum will be given, where the sequence "from simple to complex" seems to be dominated more by mathematical than by didactical arguments. In electricity, the topics "dc-current", "Ohm's law" and "Kirchhoff's laws" are covered before ac-currents and high frequency phenomena are introduced. This relates to the increasing complexity of the related mathematics, moving from simple algebraic equations to trigonometric functions and then to wave equations.

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When teaching dc-current and the so-called simple electric circuit, the elements of "current", "resistance" and "voltage" are treated in sequence before any system aspect is considered [2].

In electrostatics we first introduce charge and the Coulomb force as acting at a distance. Later the field is introduced, sometimes by claiming that the latter is caused or produced by the charge. Since a charge without a field does not exist, this sequence in not only questionable didactically but also in terms of correct physics.

If vector terms like velocity, acceleration or force are treated they are discussed first as scalars and later, if at all, as vectors. Elementary particles like electrons are first introduced as particles, later as waves and finally as "wavicles" in the light of the particle/wave dualism. When covering the topic "oscillation and waves" the simple harmonic oscillator is treated first, then the coupling between two oscillators is introduced, which is then expanded to a system of coupled oscillators to describe the phenomena of waves.

When waves in one dimension are studied, sinusoidal solutions of the wave equation are taken as basic building blocks, and only via Fourier analysis and Fourier integrals, do other forms of waves and pulses come into reach.

In each case the order of presentation is determined mainly by the underlying mathematics, moving from simpler methods to more complex ones.

This link between the structure of the discipline and the structure of learning has its drawbacks, principally because it limits activity on the part of the learner. New knowledge can hardly ever be developed independently by the learner, who instead relies on external input.

Further, it is questionable whether simple mathematical objects, such as point masses, really are simple to understand, and whether mathematical derivations, when applied to physics, have much explanatory power.

With computers available the definition of mathematical simplicity must be completely revised. A new mathematical "language" is provided by computer displays and this opens up a new dimension for explanation and understanding.

Computer supported solutions

Interactive simulations

This new language has been used to develop a new approach for all the examples mentioned above. In nearly every case the traditional sequence is changed, starting from a more complex construct, similar to a seed. It contains in elementary form the major aspects of the topic to be covered and should be unfolded during the learning cycle.

The simulation program xyZET

In our simulation program xyZET [3] we represent all objects in 3d and whenever feasible we start from there. Two and one dimensional movements can be introduced later.

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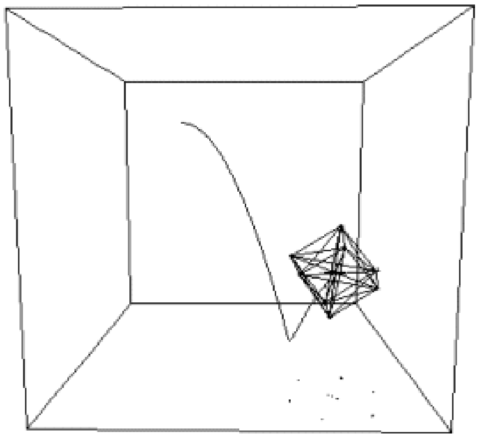

Figure 1: Elastic object dropping to the ground with a trace of it centre of mass

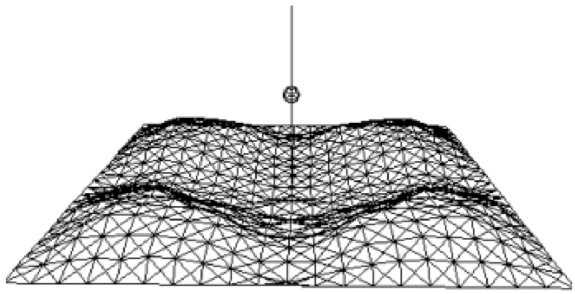

Figure 2. Vibrating elastic plane

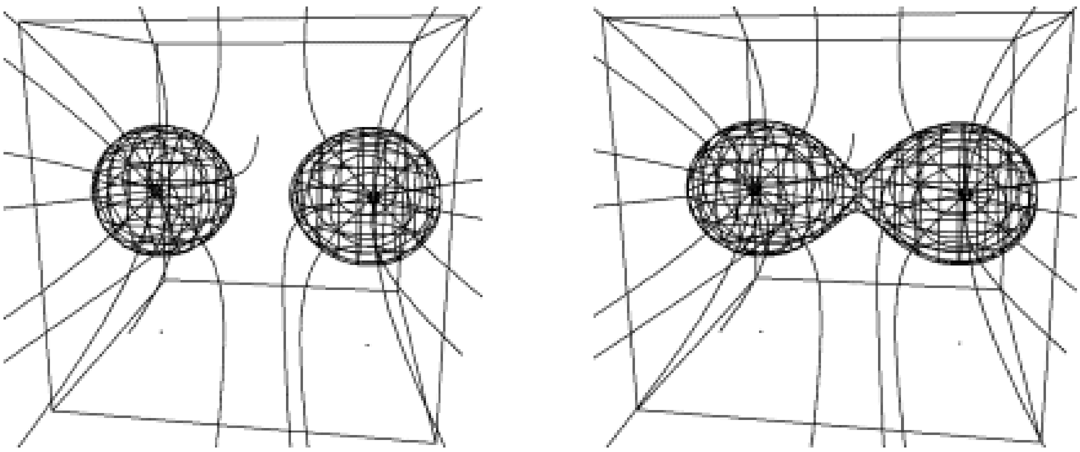

Figure 3: Dynamic arrangement of charge carriers with field lines and equipotential surfaces

All connections between mass points are elastic and the behaviour of elastic objects can easily be shown. The rigid body has to be introduced as a simple but unrealistic model. Charge and field can be shown from the very beginning as two sides of the same phenomenon. For any arrangement of charge carriers, field lines and an equipotential surface can be shown in animation.

Microcosm

In our program Microcosm we can visualize atomic particle in different forms and even with dynamic features.

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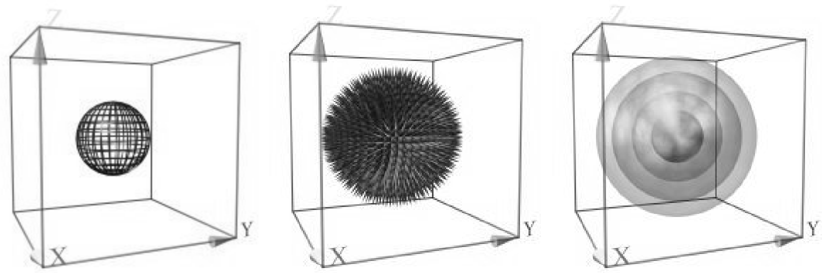

Figure 4: Atomic particles with forms to be discussed

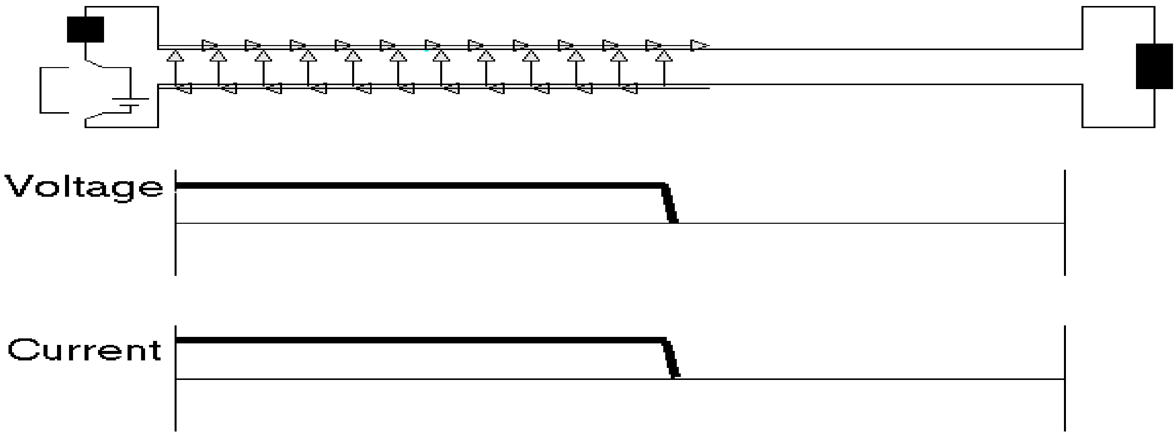

Figure 5: A pulse along a transmission line

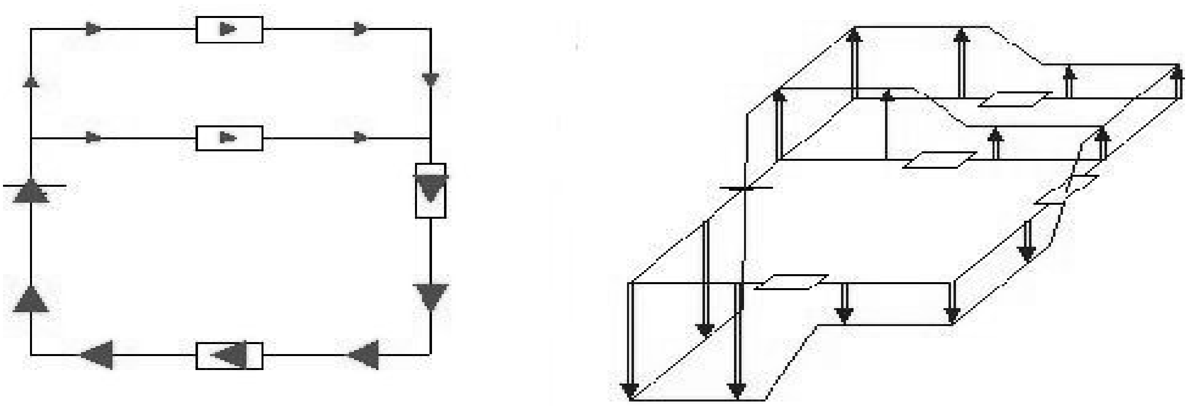

Figure 6: Current and potential along simple electric circuits

Transmission Line

In our simulation program "Transmission Line" [4] - the transmission process of single pulses can be studied in detail, including reflection, change of impedance

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and losses. Ohm's law follows as the equilibrium state, after all reflections have died out.

TICS – Transport in Circular Systems
In our simulation program TICS - Transport in Circular Systems [5] - we can edit any kind of simple circuit and visualize how current and voltage is reaching equilibrium. The potential is visualised as a quantity in the dimension perpendicular to the circuit.

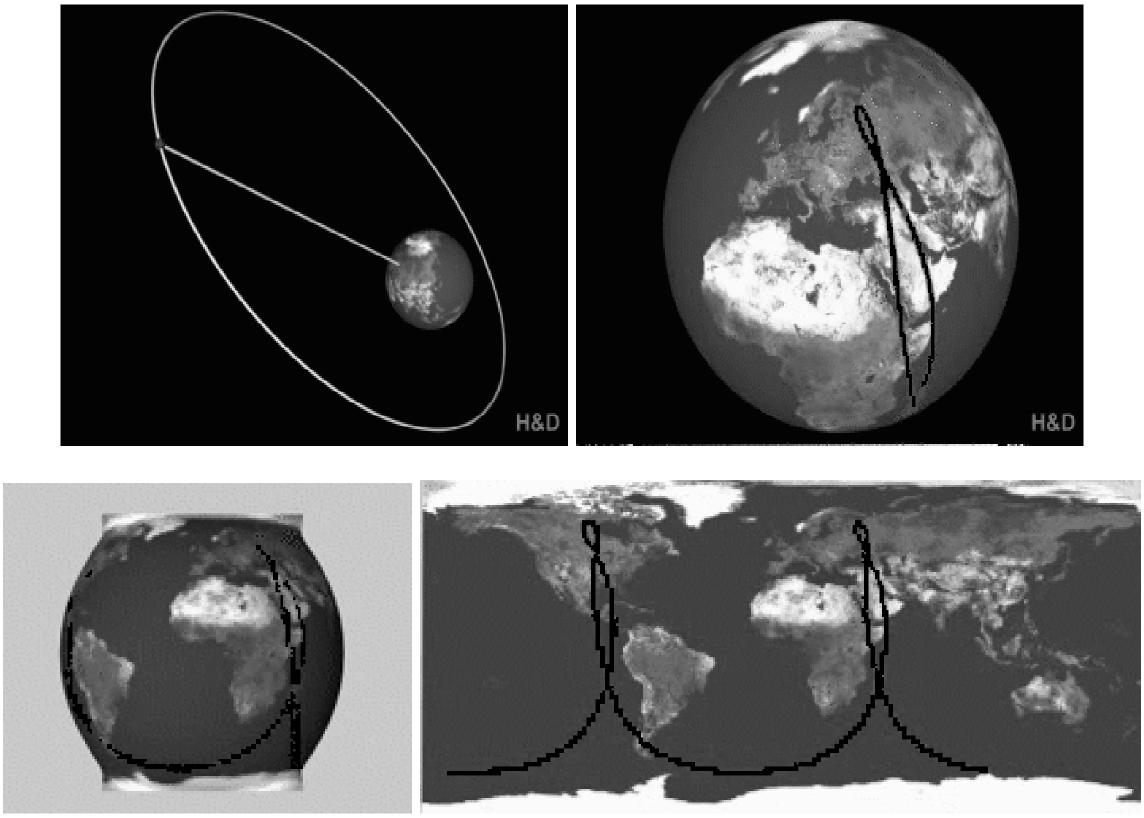

Figure 7: Orbit of a Molnya satellite in 3D and 2D

Computer generated animations
To use advanced organizers may imply a higher complexity of the concepts and topics to be introduced to the learners. Such a higher complexity may be reduced by using the flexibility of computer graphics in form of continuous transitions, virtual trips and motivating visualizations. This allows bringing together as close a possible the different levels or aspect of the principles or concepts to be learned. From a series of about 30 videos [6] a few examples are given to demonstrate the underlying idea.

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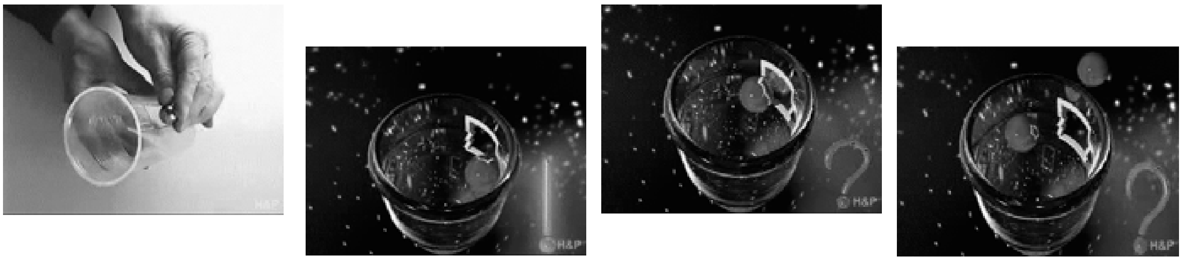

Figure 8: A combination of a real experiment and an animation to enhance attention and motivation

Orbit of a Molnya satellite
On the upper northern hemisphere the normal geo-stationary satellites are not visible. The video shows how the orbits of the so-called Molnya satellites have been selected to serve over part of their orbit as nearly gestational.

Centripetal or centrifugal force
At the beginning an experiment is shown where a sphere spins upward in a beaker. Shifting over to a computer generated animation the focus is set on the question of the direction of the centripetal force.

Electric motor in real and as animation
In combination with a real electric motor the animation visualizes the magnet field lines and helps to understand, when and why the direction of the current is changed to cause a continuous rotation.

Visualisation of potential along electric circuits
For different circuits – serial, parallel, mixed, flip-flop – the potential is visualized along the 3rd dimension.

Research program

In all these programs an attempt has been made to use the flexibility of computer displays to visualize some basic features of the topic under study to serve as guide line or advanced organiser for the unfolding learning process.
The price to pay is higher complexity initially, which may act as a barrier and which the newcomers have to overcome. Research will be needed to determine if this approach favours only strong learners and those who have acquired some pre-knowledge, or if the interactivity and flexibility of computer displays as the new language can help to improve learning and understanding for a broader spectrum of students.

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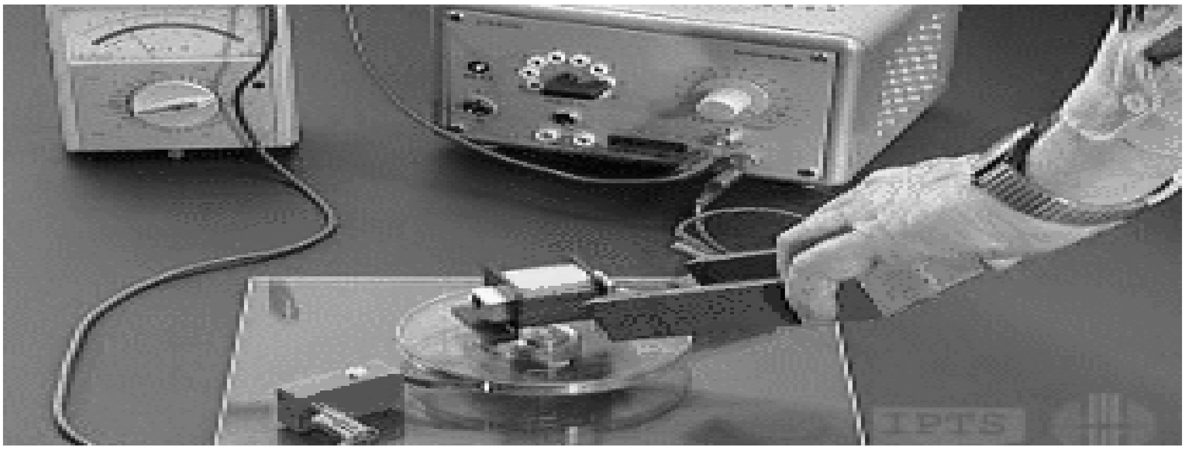

Figure 9a: A real electric motor

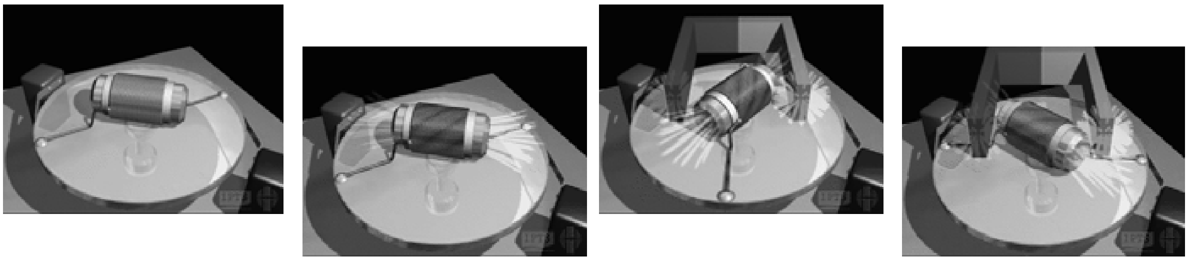

Fig 9b: A computer generated animation

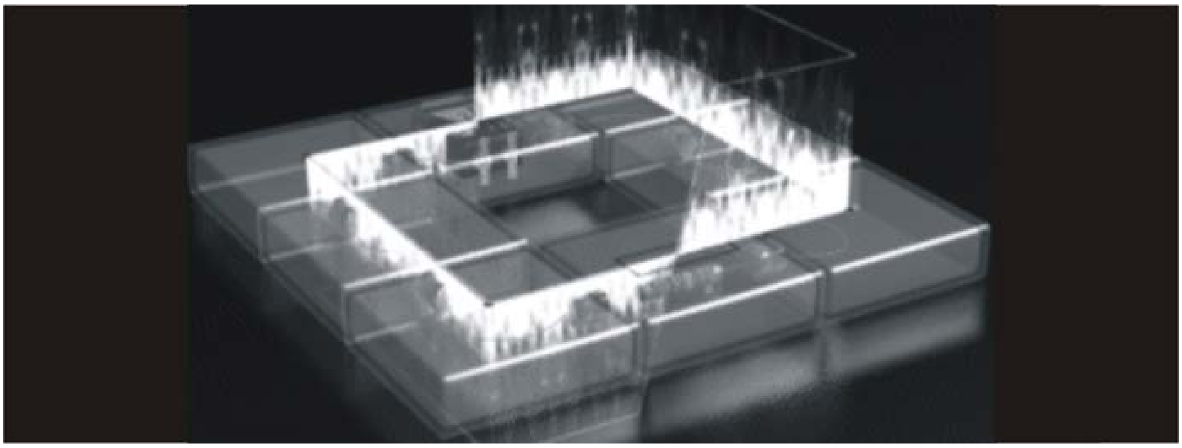

Figure 10: Potential along a simple electric circuit

References

[1] Ausubel D, The use of advance organizers in the learning and retention of meaningful verbal material, Journal of Educational Psychology, 51: 267-272, 1960.

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[2] Härtel H, The Electric Circuit as a System: A New Approach, European Journal of Science Education, 4: 45-55, 1982.
[3] Härtel H and Lüdke M, 3D Simulations of interacting particles, Computing in Science and Engineering, 4: 87-90, 2000.
[4] Härtel H and Martin E. New path for teaching electricity, Proceedings of the International Conference on Computer Based Learning-CBLIS 93, Wien, pp.: 275–284, 2003.
[5] Härtel H, TICS-Transport in Cirkularen Systemen, IPN-Materialien, IPN, 1994.
[6] http://www.astrophysik.uni-kiel.de/~hhaertel
[7] Ogborn J, Newton and common sense, Physics Education, 321, 1987.
[8] Wagenschein M, Verstehen lehren, Weinheim und Basel, 1989.

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Electromagnetic Shoot

Gabriel Rocha J S and Sena Esteves J

Introduction

The *Electromagnetic Shoot*, described in this paper, is a device built for science fair events. It was used for the first time in *Robótica 2006* festival (Figure 1).

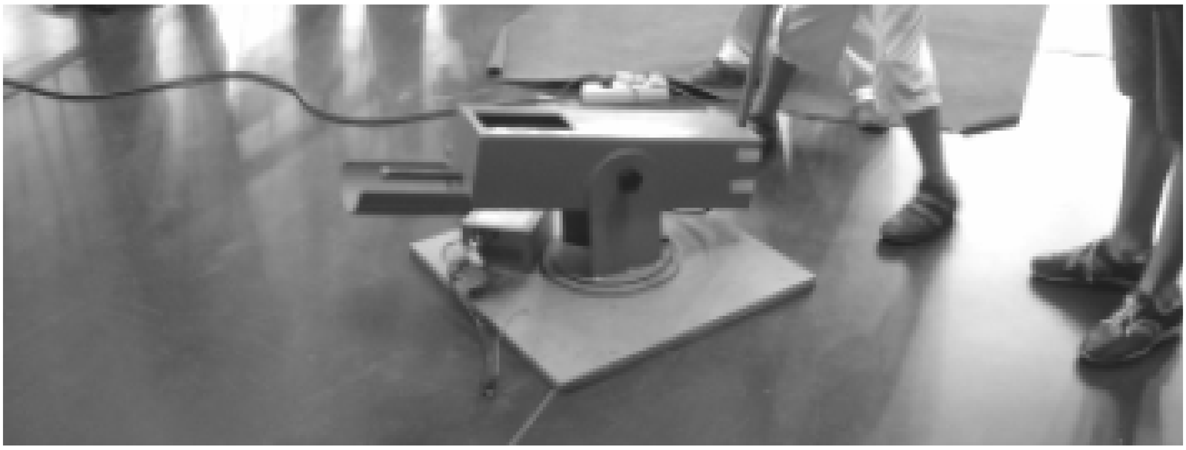

Figure 1. Electromagnetic Shoot at Robótica 2006 festival

The device was a success, in part because it is related with football, which attracts specially the younger ones. A ball is placed in a ball holder. When a button is pressed, the device shoots the ball at a distance of several meters.

The shooting mechanism, shown in Figure 2, was originally developed by João Sena Esteves for *Minho Team* soccer robots and it has been successfully used for several years.

Materials used

The *Electromagnetic Shoot* uses the following materials: Diode bridge; capacitor; button; coil (solenoid); two-piece rod made of iron and nylon (Figure 3); contactor with timer.

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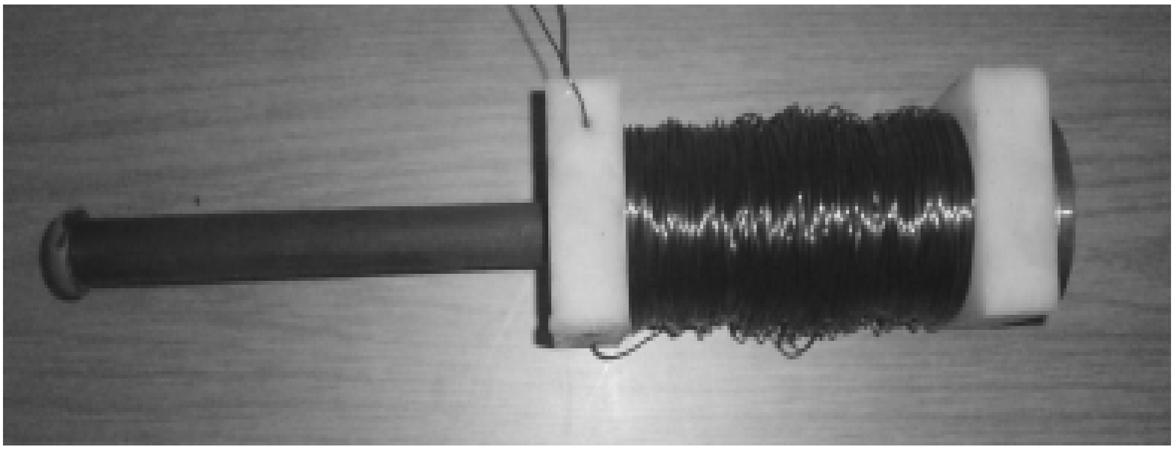

Figure 2. Shooting mechanism

Figure 3. Two-piece rod made of iron and nylon

Device operation

This device operation is based on Electromagnetism laws. When a button is pressed, a current passes through a coil, creating a magnetic field whose direction is given by the right hand rule (Figure 4). The field attracts the iron part of a two-piece rod made of iron and nylon, whose displacement causes the shooting of the ball (Figure 5). The circuit used to produce a current on the coil is shown on Figure 6. The 220V/50Hz mains voltage (Figure 7) is rectified (Figure 8) in order to produce a stronger current and, therefore, a stronger shooting force. A diode bridge is used to rectify the mains voltage. At its output, the voltage is not constant, yet. To accomplish this, a capacitor is added to the circuit. The described circuit is switched on when a button (not shown in Figure 6) is pressed.

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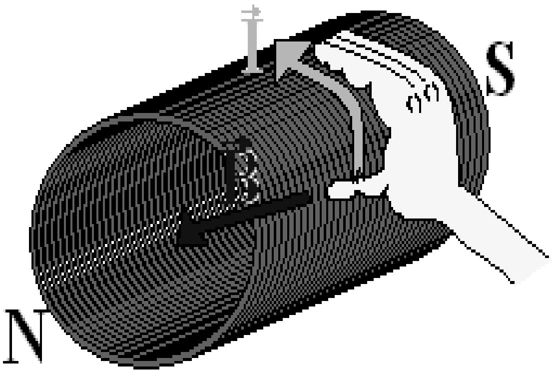

Figure 4. Solenoid

A coil (solenoid) is made of a large number of series-connected wire loops. When a current flows in a coil, it generates a magnetic field whose direction is given by the right hand rule. With your right hand, extend the thumb and curl the other fingers around the coil, in the direction of the current. The thumb points to the north of the magnetic field [1, 2].

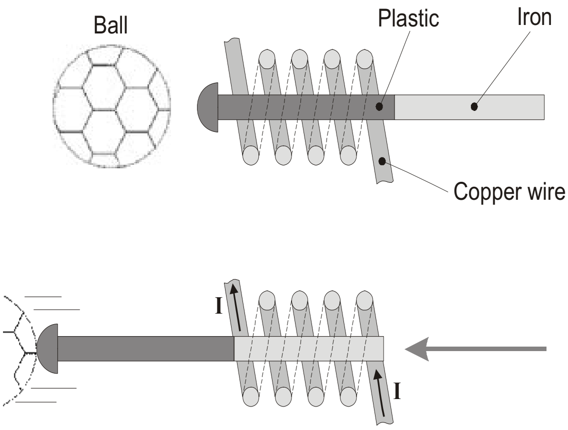

Figure 5. Shooting mechanism operation

Iron has orbital electrons that are organized in small groups called domains. The domains are randomly positioned. When an electrical current flows in the coil it produces a field, which will order the magnetic dipoles of the iron. This alignment of the orbital electrons will push the iron part of the rod into the centre of the coil, making the nylon part shoot the ball.

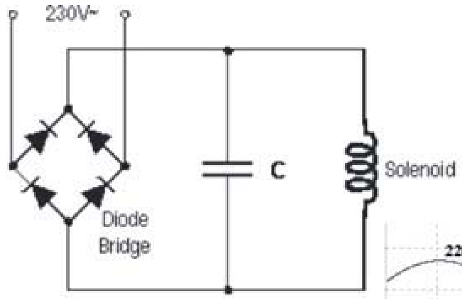

Figure 6. Electric circuit

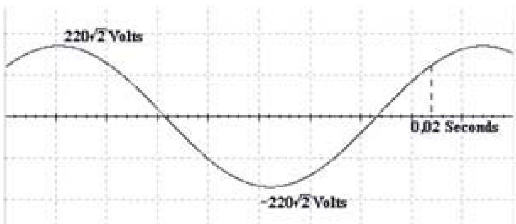

Figure 7. Mains voltage waveform

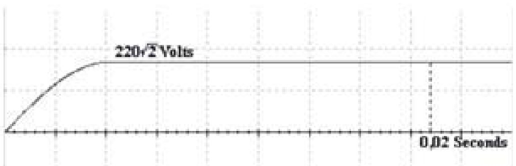

Figure 8. Rectified wave

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A temporized contactor was added to the circuit. This contactor prevents overheating of the coil, since it switches power off automatically – after a predetermined time – even if the power button is kept pressed. The shooting mechanism was fastened inside an iron case mounted on a turning base (Figure 9), which was developed to allow shooting the ball in any direction within a 90º angle.

Conclusions

An electromagnetic shooting mechanism, originally developed for soccer robots and capable of shooting a miniature soccer ball at a distance of several meters, has been presented in a science fair version. The device includes a slewing iron case and overheat protections.

The *Electromagnetic Shoot* is a fun experiment because it's related with sports, more precisely with soccer. But it also is educational, since it illustrates Electromagnetism laws. Its operation principle is the same used in other electromagnetic devices like relays and contactors.

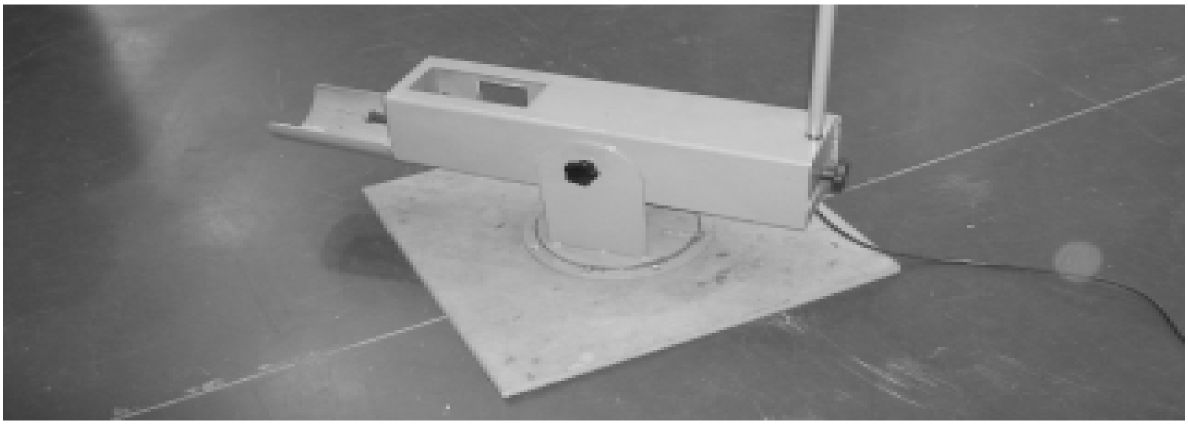

Figure 9. The Electromagnetic Shoot has an iron case mounted on a turning base

The device has been a success as a science fair attraction. Building it was exciting. It was an opportunity to learn a lot and gain experience, too.

References

[1] Plonus MA, Applied Electromagnetics, McGraw-Hill, 1986.

[2] Mendiratta SK, Introdução ao Electromagnetismo. Fundação Calouste Gulbenkian, 1984.

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Induction Ring Launcher

Matos V, Silva L and Sena Esteves J

Introduction

The apparatus described in this paper was invented by the American engineer and inventor Elihu Thomson (1853–1937) [1] to demonstrate his pioneering research in alternating current and high frequency. It is capable of launching metal rings using Electromagnetism laws formulated by Biot-Savart, Ampère and Faraday-Lenz [2, 3]. Further explanations will be merely qualitative. Thomson's ring launcher is a great experiment to demonstrate Electromagnetism laws in science fairs and hands-on classes. The ring launcher is composed by a coil, winded around an extremity of a ferromagnetic core, leaving about two thirds protruding (Figure 1). The projectiles are conducting non-ferromagnetic rings. The coil is driven by an alternating current for a short period of time, until the ring leaves the core. The device (Figure 2, 3 and 4), built for *Oficinas de Electricidade* (Electricity Workshops) – integrating part of *Robótica 2006* festival[10] – was made with an iron pipe with 600mm length and 60mm diameter, as core. Around 200mm of the length of the core, about 800 turns of 0.90mm insulated copper were winded. Several aluminium, copper and brass rings were made to fit around the core.

For safety reasons, core and coil were fit in a structure that prevents aiming upward, in a direction perpendicular to the ground. A fixed angle of 30º with horizontal direction was imposed, making rings jump forward.

The structure can rotate, so the operator can choose the horizontal direction. This way, the device can easily be used as a *'shoot the target'* science fair game, with variable direction and multiple projectiles with different shooting ranges.

How it works

The ring launcher works on the principles of electromagnetic induction and repulsion [4]. When it is fired, an alternating current flows through the coil creating an alternating magnetic field. The field magnetizes the iron, which induces a circumferential alternating current in the ring. This current is repelled by the

[10] *Robótica 2006 – Festival Nacional de Robótica* (National Robotics Festival), Guimarães, Portugal, April 28 – May 1, 2006.

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magnetic field, making the ring jump from the core at a distance of a few meters. The faster the magnetic flux changes, the greater are the induced currents in the ring, resulting in a stronger force.

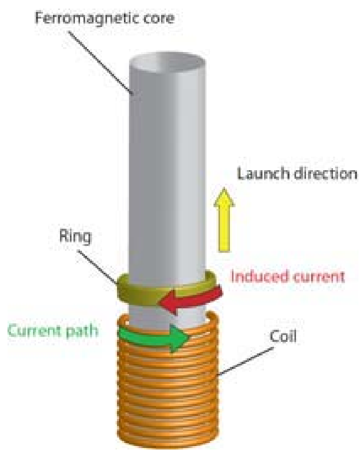

Figure 1. Schematic of the ring launcher

Figure 2. Ring launcher at *Oficinas de Electricidade* (Electricity Workshops)

Figure 3. Trying to launch a brass ring…

Figure 4. A brass ring successfully launched

Step 1 – Creating a magnetic field

As described in the previous chapter, the device is driven by an alternating current, which flows through the coil creating a magnetic field around it (Biot-Savart's Law). When the current flows in a circular direction (Figure 5), the resulting magnetic field is similar to the one from a magnet. The field is not strong enough to magnetize the core unless strong currents are used. In order to reduce the currents maintaining the field value, it is required to add more turns to the coil. This way, the field generated by each turn will add up, resulting in a stronger magnetic field.

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Figure 6 and Figure 7 depict the magnetic field lines generated by a coil with an air core. Using a core protruding from the coil will change this magnetic distribution, resulting in a slightly different magnetic field (Figure 8).

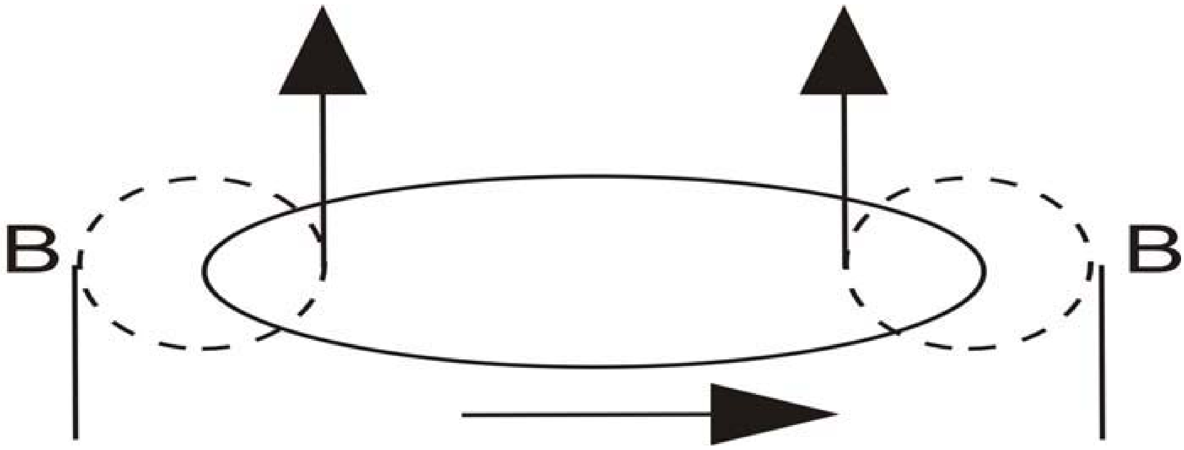

Figure 5. Magnetic field generated by a circumferential current

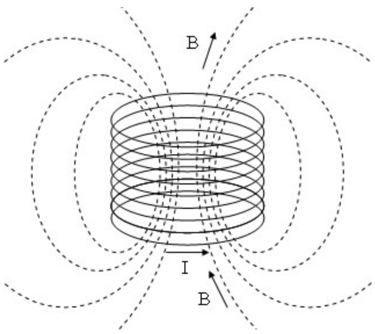

Figure 6. Magnetic field generated by several turns

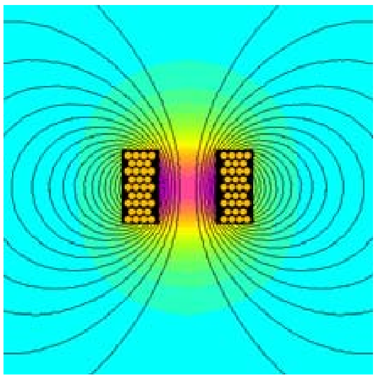

Figure 7. Magnetic field generated by a coil (simulation)

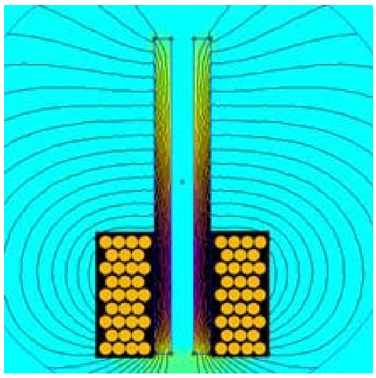

Figure 8. Magnetic field generated by a coil with core (simulation)

Step 2 – Inducing a current in the projectile

Because the current in the coil is alternating, so is the magnetic field generated by the coil and the magnetic flux through a section of the core. This alternating flux induces a voltage in the ring (Faraday-Lenz's law) (Figure 9). Since the ring is a closed circuit with low resistance, the induced voltage generates a circumferential current in it. The faster the magnetic flux changes, the greater is the induced current. From this point on, every time the induced current is referred, it should be understood as the current resulting from the voltage induced in the ring.

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Step 3 – Magnetic repulsion

A current flowing in a magnetic field suffers an action of a force (an equation to determine this force was a result from the experimental work of Ampère and Biot-Savart [2]). Two conductors with currents flowing in the same direction are attracted to each other and two conductors with currents flowing in opposite direction are repelled from each other (Figure 10). The same applies to two parallel conductors with the shape of a ring. Rings with currents flowing in the same direction attract each other. Rings with currents flowing in opposite directions repeal each other (Figure 11). This is the repulsion principle of the apparatus: the ring and the coil repeal each other when their currents flow in opposite directions (Figure 12).

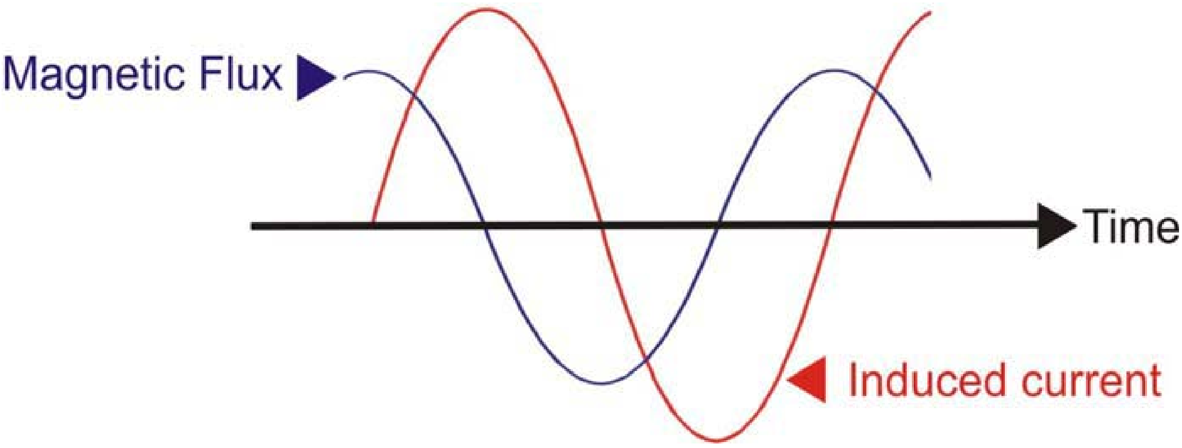

Figure 9. Magnetic flux through a section of the core and voltage induced in the ring

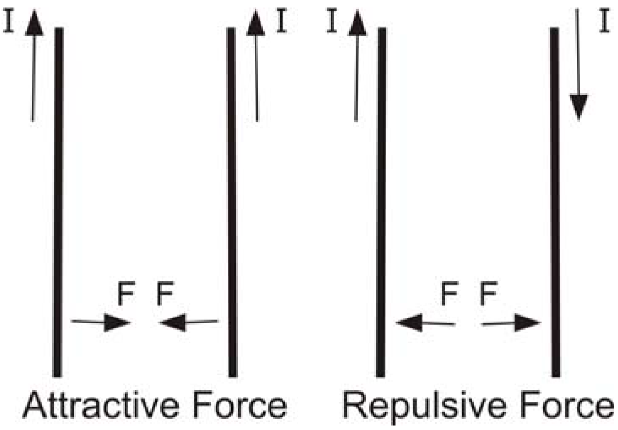

Figure 10. Forces between two parallel conductors

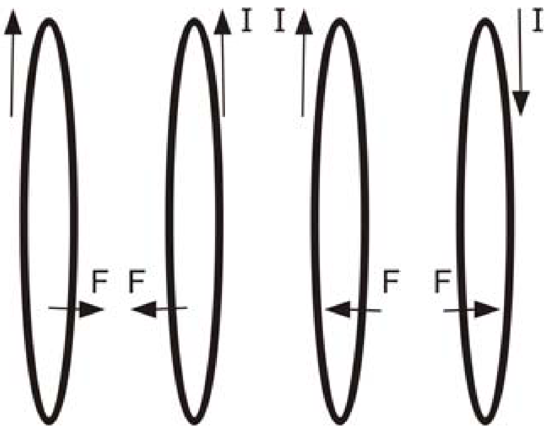

Figure 11. Resulting forces between two rings of the coil

But is the current in the coil always opposite to the induced current? The alternating current applied to the coil generates, through a section of the core, an alternating magnetic flux that is directly proportional to the coil current and induces an

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alternating current, with the same frequency, in the ring. With a purely resistive ring, the induced current would be delayed by T/4 with respect to the source current (T is the period of both currents) [5]. Then, the force between the coil and the ring would be repulsive in half a period and attractive in the other half (Figure 13). If repulsive and attractive forces were of the same magnitude, the ring would remain motionless, or oscillate around a point, due to the balanced resulting effect. A more careful analysis shows that this does not take place.
The ring is actually launched, so the resulting effect cannot be a balanced one. In fact, the repulsive forces are stronger that the attractive ones, creating an overall repulsive force. This is due to the ring self-induction [5]. The ring self-induction delays its current, resulting in a bigger time slice for the repulsive force (Figure 14). The result is an overall repulsive force capable of launching the ring.

Other experiments

Many other experiments could be performed with this apparatus. For instance, making someone hold the projectile and applying an alternating current to the coil. The person holding the projectile will immediately drop it, as it heats up due the induced currents. This experiment illustrates the principle of operation of induction ovens.
Directing the device upward, applying an alternating current to the coil and only then inserting a projectile on it will make the ring levitate. This results from a balance between the force of the magnetic field and gravity force.

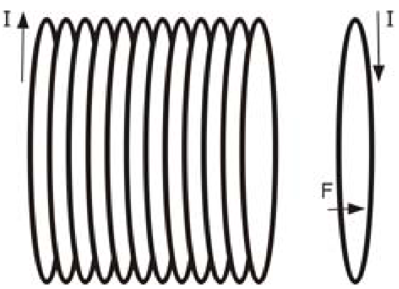

Figure 12. The current in the coil and the current in the ring flow in opposite directions, originating a repulsive force between them

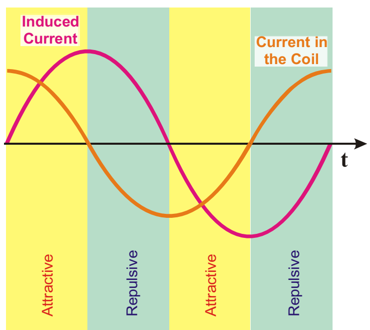

Figure 13. Sense of the forces between the coil and the ring over one period of the currents, for a purely resistive ring

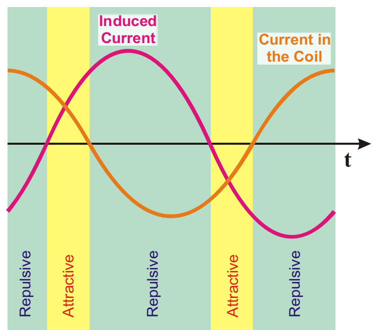

Figure 14. Actual sense of the forces between the coil and the ring over one period of the currents

Conclusions

A device capable of launching metal rings at a distance of a few meters has been presented. The physical principles that rule its operation were briefly introduced. Also, some construction details have been given. The experiment is very appropriate to demonstrate Electromagnetism laws in science fairs and hands-on classes.

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References

[1] http://chem.ch.huji.ac.il/~eugeniik/history/electrochemists.htm

[2] Plonus MA, Applied Electromagnetics, New York: McGraw-Hill, 1986.

[3] Mendiratta SK, Introdução ao Electromagnetismo, Fundação Calouste Gulbenkian, 1984.

[4] Coilgun Systems. www.coilgun.eclipse.co.uk

[5] Silveira FL and Axt R, Explicação Qualitativa do Anel de Thomson. Como Ocorre a Levitação Magnética?, Revista Brasileira de Ensino de Física, 25, 2003.

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“Hands-on Science. Science Education and Sustainable Development”,
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The Odyssey of a Plastic Bottle in the School Laboratory

Tzianoudakis L, Siskakis Y and Papagiannaki S

Introduction

During the latest years an attempt has initiated in Greece in order to update the school science laboratories of secondary education, an attempt which is under development. Nevertheless, the use of simple materials in laboratory activities during science lessons is more or less a familiar practice and in many cases a one-way route for the teachers.

The reasons are many. Indicatively we mention the insufficient laboratory facilities, the familiarity of students with simple everyday materials, the more successful way of connecting theory and practice in this mode, the low cost of the materials and the greater safety of the students.

The Laboratorial Science Centre of Rethymno (EKFE) has started an attempt to record and videotape decades of experiments which can be conducted with simple and worthless (low cost) materials and has already published 2 CDs and 2 DVDs in the teaching units of fluids and heat.

The whole approach in the use of simple experimental devices starts with the choice of the necessary materials, which can also be assigned to students as a team work project. The materials will later constitute the contents of a small suitcase, which will be useful and easy to move around. (Reference to the materials).

How the Worthless Can Become Useful

It is rather impressive how the same object can be used in multiple experiments. Indicatively we mention the plastic water bottle, which can be the basic medium for more than 10 different experiments. An empty aluminium can be used in experiments from different teaching units such as static electricity, hydrostatics, heat, atmospheric pressure, energy and various chemical reactions. In a great number of experiments a lot of simple materials can be used such as a balloon, a coin, a mirror, etc. (Demonstrations, references to particular experiments).

The experiments with simple materials are resourceful for qualitative observation and verification of natural laws and they usually have the advantage of simplicity, they are completed in a short time, they can also be used in a front faced laboratory and they may demonstrate with clarity the teacher's objectives. They have

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disadvantages in the field of quantitative measurements and in the approach of natural laws through mathematical logic.
The experiment with simple materials must function in a complementary way and not substitute the measurement experiment or the experiment, which uses the modern laboratory facilities. It should be also used in the appropriate situation in a way that its “coefficient of teaching performance” should … tend to one!
Last years an effort of modernising Greek School Laboratories has begun and is still in process. The state, even after the usual delay, appears convinced about the necessity of experimental teaching in Physical Sciences. The “laboratorial state’’ of Greek Lyceum has changed dramatically and the lack of material and technical infrastructure cannot provide an alibi anymore for the unwilling teacher to make experiments. Unfortunately the equipment of Laboratories in primary education and in High school, has not reached a good point. Insufficient equipment, in spatial rooms used as Laboratories, or –even worse – wardrobes which take their place, compose a picture that is not flattering for a European country which is called to face the challenges of the 21st century in the sector of education. Taking into consideration this vague and contradictory situation, the instructive method of "experiment" depends-once more on the consciousness of the teacher, the “basic ring in the educational chain”. Under these circumstances, the use of simple materials by the schoolteacher in order to make experiments in the class constitutes a common instructive practice even in secondary school, and, sometimes, the only possible method of teaching. It is worth reminding the opinion of Piaget that ‘’knowledge is not the transmission of a picture, but always consists an energetic process that leads to a transformation of what is real’’. Consequently Knowledge is inevitably connected with acting over objects that are with experimental instructive practice. With regard to the integration of simple materials of everyday life in experimental activities, a lot of questions and objections are rationally claimed. Does the systematic use of this type of activities "downgrade" the quality of experimental teaching and make the students disregard Physical Sciences? Are there cases when the teacher would be asked to make experiments with simple materials? In conclusion, which are the advantages and disadvantages of the experiment with simple materials of everyday life, and the one realised with typical laboratorial appliances?
It is doubtful, that in case that the School has insufficient laboratorial infrastructure, the experiment with simple means is a good choice. If the School Laboratory does not dispose of an appliance of connected containers, the latter principle can be understood by the students with a transparent flexible pipe, or with two glasses that communicate via this pipe, (Phot. 1, 2), or even through the application of this principle in artesian fountains. (Phot. 3)
A second reason, for which this instructive practice is proposed, is the gradual familiarization of students with materials of great utility of everyday life. Only a few Laboratories dispose of a generator of air. All the students, however, know a hair dryer, and they can understand via a spectacular experiment, that the flow of a fluid creates decreased pressure (Phot. 4). An ecological benefit of this teaching method is also that students will realise the multiple usefulness of various objects and that, finally, ‘’nothing is lost’’ in our lives.

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Photo 1

Photo 2

Photo 3

The low cost of these materials, constitutes a factor that will be particularly appreciated, especially from …School Headmasters, who do not affront with eagerness teachers’ demands for laboratorial equipment. The Archimedes principle and the principle of pressure transmission in liquids can be approached experimentally with a lot of ways, one of which is the diachronic "Cartesian diver", which leads to a spectacular result with the minimum cost. (Phot.5, 6)
The experiments with simple materials contribute considerably in a more successful connection between instructive theory and practise. With the experiment of reversed bottle from which the water is not poured (Phot.7), we will have the occasion to stress, that it is in this way that the automatic watering cans of birds and animals function. In this case the experiment functions as a marvellous way in order to "whisper" to the student: "You will need what you learn somewhere".
Furthermore, another advantage of experiments with simple materials is that as a rule they are harmless and in combination with their low cost they can be successfully used in ‘’frontal laboratory’’ (=the one where every student has his personal seat to make an experiment on his own, in front of him, cont. to ‘’demonstrative laboratory’’ where the teacher is the only one to make the experiments and the students simply watch). It is easy to create, for laboratorial exercise, 8 boxes of materials necessary for the experiment that will serve to 8 teams of students (Phot. 7). In this point it is time we stressed that ‘’frontal laboratory’’ undeniably surpasses any other laboratorial method, because it gives a space of initiative to the student, the lack of which "kills" his creativity.
Finally, in the advantages of experiments with materials of utility, belong their simplicity and their brevity. Either as experiments of demonstration, or in frontal laboratory, they are set up and completed in a few minutes. The experiment for the creation of static electricity with the empty refreshment tin and the electrified plastic rule is completed in 10 seconds with minimum cost. (Phot.8). It is impressive that the same object can be used in different experiments. For example, a plastic bottle of mineral water can constitute the basic auxiliary means for more than 10 different experiments. An empty box of aluminium can be used in experiments of different units, as, in the one of static electricity, hydrostatics, heat, atmospheric pressure,

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energy and in various chemical reactions. In a great number of experiments materials like a balloon, a currency, a mirror etc can be used.


Photo 4


Photo 5

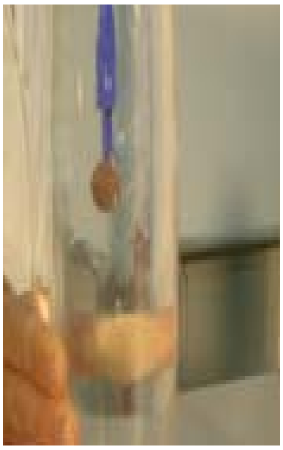
Photo 6


Photo 7

However, the experiment with simple materials is at a disadvantage in the field of quantitative measurement and the approach of natural laws through mathematic logic. The verification of a Natural law is based on size measurement, on the exploitation of mathematic relations and on the report of experimental faults. But here are the chronometer, the tape measure, the electronic scales, the electronic oscillograph etc. The taking and evaluation of measurements is a very important part of experimental work and the teacher should not underestimate it. The demonstration of straight movement and the measurement of speed can be done in a simple way, with a rule and a chronometer and the movement of a bubble into a glass pipe that has been placed with a small bent on a headlight of transparencies (overhead) (Phot.9). Nevertheless, for the study of movements we should resort to the use of an electric chronometer, or air-path, and the sketching of graphics. It is obvious that even if the use of simple materials for experiments can be inserted in any level of education, their frequency of use should be decreased as we go up the educational ranks. In primary education the experiment with simple materials of everyday life should be the rule, while in secondary education it should constitute the exception. With regard to the methodology and the better instructive exploitation of experiments with simple materials, the teacher should bare in mind the following points:
The whole approach in the instructive practice of the use of simple auxiliary means of teaching begins with the choice of the necessary materials. It would be a good idea if the process of collection was assigned as homework to teams of students. The materials will constitute the content of a small suitcase, which will be functional and handy (Phot. 10, 11). If the teacher is prompted to organise frontal laboratory, then he is supposed to create 8 – 10 similar collections in cartons. (ANNEX)

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Photo 8

Photo 9

Photo 10

Photo 11

In experiments with simple materials it is preferable to set only one target, evident and easy to be presented, and to guide all our efforts to it. The experiment of the "Cartesian diver" for example, is one where a lot of laws and concepts of physics can be met, as the Archimedes principle, the distribution of pressures in liquids, the compressibility of gases, the difference of density between liquid and gas etc. The Teacher will set the target and let the experiment "speak" in his part. In the experiment that is presented in Photo 12, the main objective is to show that the hydrostatic pressure exercised in a certain part of a liquid is proportional with the depth of this part, and other parameters as the effect of atmospheric pressure in the flow of liquid are left aside. On the contrary, the experiment with the leaking bottle by which the water is not poured, shows very clearly the existence of exterior pressure (atmospheric) bigger than the hydrostatics pressure, which prevents the water to be poured from the holes of the bottle (Phot.13).
The experiments with simple materials are usually attractive, impressive and have- to a large extent- a character of "game". The teacher should exploit these elements in order to attract the attention of the students, but without stressing them

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excessively. In every case, the student should leave with the impression that he makes experiments in order to interpret natural phenomena or to verify natural laws and that he does not play. The schoolteacher of Physics should be aware of the "thin red line" that separates the "enjoyment of" the course from the "amusement".

Photo 12

Photo 13

The EKFE Rethimno has begun an effort of recording and videotaping the dozens of experiments that can be realised with simple materials. In the scope of this effort, it has already published two CDs and 2 DVDs with experiments concerning the units of fluid and heat that are already distributed to the teachers of Rethimno.
Finally, we consider that the experiment with simple materials constitutes a useful pedagogic practice, as far as it is used as a ‘’treatment’’. The moment when it should be prescribed and in its suitable doses. It should function additionally and not substitute the experiment of measurement, or the experiment that develops the modern laboratorial infrastructure. The object of the "schoolteacher of" physics should be that, through a rational use, the factor of his instructive output … approaches one!

References

[1] Arons AB, Driver of teaching of Physics, Athens: Trohalia, 1990.
[2] Cleaves VJ, Physics for children, Athens: Pnevmatikos, 1995.
[3] Kalkanis G and Kostopoulos D. The laboratory of Physical Sciences for the Schoolteacher, Athens, 1994.
[4] Kasetas A, The game "Experiment" has its rules, Athens: Pnevmatikos, 1993.
[5] Kokotas P, Teaching of Natural Sciences, Athens: Grigoris, 1998.
[6] Koumaras P, Driver on the Experimental teaching of Physics, Thessaloniki: Hristodoulidis, 2003.
[7] Kouremenos K, The teaching of Physical Courses in the High school and Lyceum, Athens: Grigoris, 1993.

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[8] Mitsiadis S, The auxiliary means of teaching in Greece and the organisation of Laboratory of Physical Sciences, Athens: Pnevmatikos, 1993.
[9] Moore A, Scientific experiments for children, Athens: Anastasiadis, 1997.
[10] Papastamatiou N, The experimental teaching of Physical courses in the High school, Athens Pnevmatikos, 1993.
[11] Papazisis K, The intelligent experiments, Athens: Savvalas, 1996.
[12] Tsaparlis G, Subjects of instructive Physics and Chemistry in the secondary education, Athens: Grigoris, 1991.
[13] Vris L, The books of experiments, Athens: Kastaniotis, 1987.
[14] Zavlanos M, Teaching of Physical Sciences, 66, Athens: ION, 1987.

ANNEX

Content of box of experiments with simple materials

3 small plastic bottles of water 0,5 L, a cut plastic bottle of refreshment 1,5 L, a small bottle of wine or beer, 2 small boxes of refreshment from aluminium, 2 cylindrical metal boxes, a small basin or plastic bowl preferable transparent, 2 glasses, a cup of coffee, a small ceramic dish, a sheet of waterproof paper or cardboard 3-4 pieces, 4-5 wooden rule from thin timber, plasticine, plastic straws, wooden straws, toothpicks, matches, 2 suckers with hooks, balloons (circular and cylindrical), glue tape, glue, thread, line and thicker thread, cotton, rubbers relatively fat, rubber of buckrams, handkerchief, napkins, black cloth of wool, a piece of rubber for hydraulic insulations, a lighter, cigarettes, 2-3 small candles with base from aluminium, 3 small mirrors, a small piece of glass, magnifying lens, crystal prism, coloured gelatines, 2 small balls of ping-pong, pencil, pen (BIC), ink or colour dissoluble in water, salt, vinegar, alcohol, baking soda, baking-powder, aspirin, HCl, sugar, flour, sulphur, lime, liquid soap, transparent plastic rubber, dropper, digital clock or calculator, small round magnets, 2 stick like magnets, metal strainer of tea, bullets, small springs, small lamp, small lamp LED, electric lens, fat wire of aluminium, thinner wires, two cylindrical pieces of iron, tinfoil, laminas from metal Zn or aluminium, laminas from copper, dust of iron, nails, pins, fasteners and screws, metal currencies of 0,5 euro, wooden pincers, plastic teaspoon, corks, ruler of plastic, protractor, transparent lid of box, comb, newspaper, hairdryer, battery of 4,5 V, small engine, cables, pliers, screwdriver, sandpaper, a small knife, a pair of scissors.

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Historic Experiments on Internet. Trying to Find New Answers to Old Questions

Kyriaki E, Papatsimpa L and Dimitriadis P

Introduction

We started three years ago developing educational material about some Historic Experiments. The idea was to publish it on the Internet, so everybody has a free access to it; it is intended to serve a secondary level science class in its every day work.
Its main characteristics:

- Simple structure; the options of the main menu are in the form of direct questions. The text in each option is short, clear, written in plain English, so it is easily understood. There are links to detailed description and further explanation.
- The Historic Experiments are visualized through static pictures and animations.
- There are videos of experiments trying to reproduce the historic ones, using modern technology (e.g. sensors). There is information about the material used in the experiments and instructions how to build them up.
- There are lesson plans, questionnaires and worksheets to encourage the students study the material carefully and test their skills.

We tried to build up an easy to follow site; we also tried to give enough information around the Historic Experiments and the way they were carried out. We present, in short, the previous theories the droughts, the difficulties and the breakthrough for each one of them.
Following the exemplary line of reasoning followed by the scientists who introduced the Historic Experiments, we believe that we contribute to the better understanding of the physics' laws.

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What are the Historic Experiments?

Scientists who tried to test a hypothesis have introduced experiments. Some of them contributed to the establishment of revolutionary theories; in this way they have influenced the evolution of ideas in science and the society. Those are the Historic Experiments.

Historic Experiments to be are conducted as we speak, somewhere in the world. A collection of Historic Experiments should include modern experiments as well. It would be interesting to start up a discussion of which modern experiments will be considered as Historic Experiments 500 years from now.

Why to teach about Historic Experiments?

The idea of teaching in class elements from the History of Science and reproducing a number of simple Historic Experiments is a way to help students learn about the nature of scientific inquiry and to encourage school teams in working as "researchers" and discover the way of discovering (AAAS, Historical perspectives: 1993),.. More specifically:

- Pupils get familiar with real problems and with the way the pioneer researchers solved them.
- The pupils get an idea of all the difficulties and contradictions around a revolutionary theory At a later stage the students will find out that the scientists often don't follow in their research the standard step of the scientific method as we teach them at the secondary level; their work includes the collection of phenomena of relevant evidence which in combination to logical assumptions and the intuition of the researcher lead to the scientific hypothesis.
- Dealing with real problems, the students learn the concept of controlled variables; if two or more parameters vary in an experiment then you cannot have clear results from the experimental data. It is difficult, in this case, to correlate specific changes to the relevant magnitudes. One should be careful in designing an experiment and selecting the devices, to avoid such complications (AAAS, The nature of science: 1993).
- The students get aware that the results of a research might be different than the expected ones. New ideas are often the product of such situations and they lead to new research (*T. Kuhn, 1962)*.
- Students develop an understanding of modern science's historical roots in a way that emphasizes the hard work involved. We believe that young people are inspired by the pioneer experimentalists. Great scientists in the past believed in and promoted the study of the early theories…

  "…Schrödinger clearly believes that there is more to the study of ancient history than mere factual curiosity and a concern with the origins of present - day thinking… He is primarily concerned with the very nature of physical reality, the humanity's place in relation to this "reality" and with the historical question of how great thinkers of the past have come to terms

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with these issues. (Roger Penrose; Foreword at the book "Nature and the Greeks" and "Science and Humanism" Erwin Schrödinger)

Why to present some Historic Experiments on Internet?

Presenting Historic Experiments on the Internet has certain advantages:

- In a web site, detailed instructions can be given to school teams that want to reproduce a historic experiment, accompanied by simulations.
- It is possible to exchange ideas and present the work of teams who perform their version of the Historic Experiment
- It serves the Science teacher by providing him/her with material tailored to the needs of the Science lesson. Each presentation can be given in both a short form and a detailed one, which cannot be done in a book. Most science teachers will limit themselves to examining the short option. For someone who is more deeply interested in a certain part (e.g. the historical events, or the detailed description of the experimental data) there is the possibility to find out more about it by using the appropriate hyperlinks.

The authoring environment

We developed the educational material in HTML and Macromedia's Flash MX files; we believe that these tools can provide web pages of sufficient quality. In the Macromedia environment we used the Action Script to support the simulation models presented.
Some of the animated pictures are built by using an environment providing tools for image manipulation; in the program Animation Shop 3, we combined static pictures – frames, created under the program Paint Shop Pro 8, to get effects and animation.
The outcomes is available to schools that have access to the WWW; they can view and study the information presented; we hope in a later stage that educators and students will be enabled to actively participate in the process of exchanging ideas and providing additional information.

The authoring environment

A "complete" selection of Historic Experiments should involve about 50-60 experiments, from different historical periods. We should make it clear that the term "Historic Experiments" does not exclude modern experiments of our time. On the contrary, at a later stage we hope to have a process of on line "evaluation" and selection of experiments that are developed today in different countries.
The criteria for selecting some of the most important experiments of all times are:

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- The experiment should be simple enough to be understood by pupils of the secondary level.
- The experiment should be included at the most European curricula. It should refer to concepts that are taught at the secondary level.
- The experiment should cover different topics in Science.
- The experiment should be possible to be reproduced in a school laboratory.

We could not avoid starting with the experiments that we like for some reason. They are simple and fascinating; they have made an influence to us since our school years.
At the moment four experiments are included in our small collection. Those are:

MECHANICS
Galileo Free Fall Experiments

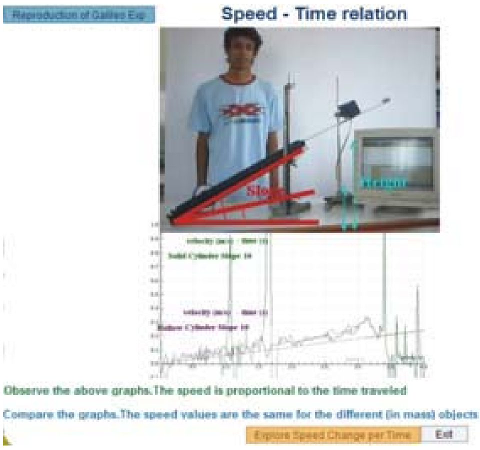

Figure 1. Galileo Free Fall Experiment

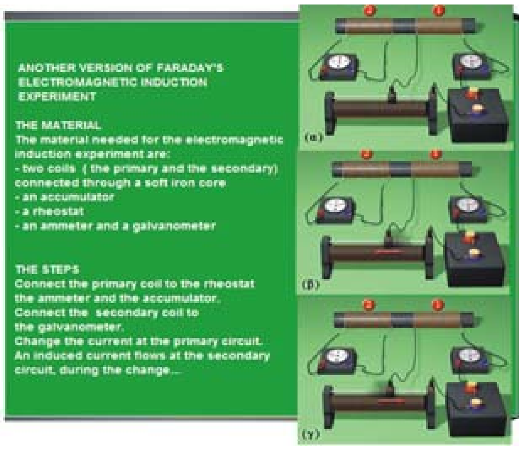

Figure 2. Faraday-Henry Experiment

ELECTROMAGNETISM
Faraday-Henry Electromagnetic Induction Experiments

WAVE-PARTICLES
De Broglie – Davisson/Germer Experiment

BIOLOGY
Beaumont – Digestion as Chemistry Experiment

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The reason why the collection is yet small is:

- We try still to find our way of how to build up properly the educational site. We wish the material published to be used in class. For that reason we decided to proceed slowly.
- We are a small team of full time teachers; we hope to have some more support from other colleagues in the future

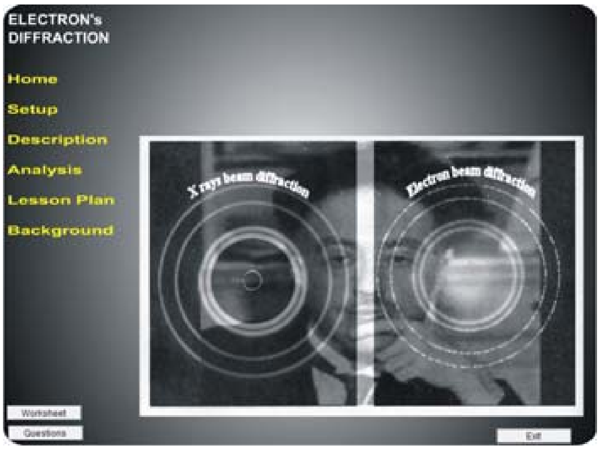

Figure 3. De Broglie Davisson/Germer Electron Diffraction

Figure 4. Beaumont Digestion as Chemistry Experiment

The topics – the structure

The structure of the menus for the experiments is similar. The options are referring to:
When, Where, by Whom and How a historic experiment was developed; it also refers briefly to the *Impact* of the experiment (and the relevant theory) to the evolution of ideas in Science.
More specifically:

For the Galileo Free Fall Experiments the menu options are:

- The Importance (of the Experiment)
- The Personality (Galileo's personality)
- The Determination (of Galileo)
- Aristotle's Theory (the previous theory)
- Doubts… (about Aristotle's theory)
- Galileo's Doubts (about Aristotle's theory)
- The Hypothesis

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- The Experiment

The submenu “The Experiment” includes the options:

- The Breakthrough
- The Steps
- The Formulae
- Simulation Models
- Modern Experiments

For the Faraday Electromagnetic Induction Experiments the menu options are:

- The Importance (of the Experiment)
- The Personality (Faraday’s personality)
- The Determination
- Previous Theories
- The Inspiration (Oersted’s Experiment)
- Faraday's Efforts (expectations)
- The Hypothesis
- The Experiment

The submenu “The Experiment” includes the options:

- The Breakthrough
- Conduct Exp1
- Conduct Exp1
- The Formulae
- Your Experiments

For the De Broglie – Davisson/Germer Experiment the menu options are:

- Home (introduction)
- Setup (of the experiment)
- Description (of the experiment)
- Analysis (expectations – results)
- Lesson Plan
- Background

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The submenu “Background” includes the options:

- Wave – Particle theory
- Peak Condition
- Historic Experiments
- Experimentalists

For the Beaumont – Digestion as Chemistry Experiment the menu options are:

- The Importance
- The Personality (of Beaumont)
- Hippocrates' Theory
- Other Theories
- First Contact
- Second Contact
- Third Contact
- Alexis Martin (the patient)

We tried to describe the Historic Experiments Step by Step. That is: A description of the experiment; the declaration of the variables, the collection of the experimental data, the variable dependence in the mathematical model (P. Dimitriadis 2002).
The menu options guide the user in following the standard steps of the Scientific Method. Moreover, it allows the teacher and the student to find easily what he/she is interested in.
The text is divided in small parts; it is simple and clear. In each page there are static pictures, animation or simulation, with some degree of interactivity.
There is enough information about the problems and the difficulties the pioneer scientists faced in carrying out the experiment.
The simulations are quite simple. They serve as tools to compare the previous and the new models; for the same reason we used also static pictures.
The reproductions of the Historic Experiments are presented in videos. We figured out that this is the best way to capture the interest of the student; from our experience in class we know that the students pay more attention to videos, which is “real”, than to simulation, which many consider a game.
Ms Papatsiba designed a variation of the Historic Experiment of Electromagnetic induction in a Microcomputer based labs environment (including position, magnetic field and voltage sensors): a magnet is sliding down a gentle slope and induces Electromagnetic Induction to a coil at the bottom of the slope; in this way the acceleration of the magnet is relatively small, so the magnet can be traced by the position sensor.
The students can reproduce the experiments following the instructions and the pictures. They are encouraged to try to redesign the experiment under their

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teacher's supervision using probably modern measuring devices like sensors. We tried to encourage the users throughout the site, to try the experiment themselves in real life, because this is the best way to learn.
The results from the measurements of the reproduction of the Historic Experiments are compared to the conclusions of the initial hypothesis and of the accepted theory, today. The students are encouraged to observe the outcome graphs from the sensors, comment on the shape of the graph and read the values. Then, they work by inserting the values in Excel spreadsheets on line. We hope that this way the students get a better understanding in the relevant theory.

Students' participation

A team of 3 students of the 5th grade (15 years old) of the Greek Gymnasium Lyceum of Brussels studied Galileo experiments from the site and worked on reproducing one of the Free Fall Galileo experiments. The purpose was to compare the velocities of falling objects of different mass. They used gentle slopes and let a solid and a hollow cylinder roll down; the slope was placed at the edge of a table 0.80 cm above ground. After the cylinder reaches the bottom of the slope falls in a parabolic orbit. By measuring ONLY the horizontal range of the orbit for the two cylinders, the students reached the same conclusion as Galileo did ones: that the velocities of the cylinders at the bottom of the slope are practically the same. The student work includes videos, calculations and text; it is now a part of the site about the Historic Experiments. The project was submitted and took part at the competition of "Ideas for science fairs".

The plan further

We wait for a detailed external evaluation of the educational material. Based on it, as well as on the remarks from teachers and students, we hope to be able to improve the content and the style of the site.
At the home page of the site about the Historic Experiments, there is a global map; on top of the map the Historic Experiments are marked with different colours, depending on the historical period. The same idea could apply to a popular virtual globe program, a 3D global map representation of the earth, the Google Earth. A collection of points that represent Historic Experiments in different historical periods, could give in a glance a picture of the distribution of important experiments in place and time.
The collection of the Historic Experiments should be extended. It should include more of the most important experiments, based on the same structure and style.
At a later stage we hope to have a process of on line "evaluation" and selection of modern experiments. As it is already mentioned, it would be interesting to have a debate of which modern experiments will be considered as Historic Experiments 500 years from now.

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The site

http://home.tiscali.be/gr.school/galileo/

References

[1] Adb-El-Khalick F and Lederman N, Improving science teachers' conceptions of the nature of science: a critical review of the literature, International Journal of Science Education, 22: 665-702, 2000.
[2] Akerson VL, Abd-El-Khalick F and Lederman NG, Influence of a reflective explicit activity-based approach on elementary teacher' conceptions of nature of science, Journal of Research in Science Teaching, 37: 295-317, 2000.
[3] American Association for the Advancement of Science (AAAS), Project 2061: Science for all Americans, AAAS, Washington, DC. 1989.
[4] American Association for the Advancement of Science (AAAS), Benchmarks for science literacy, AAAS: Washington, DC. 1993.
[5] American Association for the Advancement of Science (AAAS), Project 2061: Science for all Americans, Historical perspectives, AAAS: Washington, DC. 1993.
[6] Arbanitakis D, Dimitriadis P and Papatsimpa L, An interactive multimedia programme for the primary school teacher: A new tool for the implementation on information technology in the teaching of science, 5th Panhellenic conference (with international participation): Didactics of mathematics and informatics in education, Thessaloniki, Creece, 2001.
[7] Bell RL, Lederman NG and Abd-El-Khalick F, Implicit versus explicit nature of science instruction: An explicit response to Palmquist and Finley, Journal of Research in Science Teaching, 35: 1057-1061, 1998.
[8] Bianchini JA and Colbrurn A, Teaching the nature of science though inquiry to prospective elementary teachers: A tale of two researches, Journal of Research in Science Teaching, 37: 177-209, 2000.
[9] DeBoer, GE, Scientific literacy: Look at its historical and contemporary meaning and its relationship to science education reform, Journal of Research in Science Teaching, 37: 582-601, 2000.
[10] Schrödinger E, Nature and the Greeks, Cambridge: University Press, 1954.

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Particle Physics Goes to School

Johansson KE

Introduction

Particle physics is dominated by large accelerators, kilometres in circumference, and detectors large as multi-storey buildings, making particle physics experimentation in the class room very difficult. The web based Hands on CERN education project tries to remedy this by making particle collisions from the Large Electron Positron Collider available at school. With the Hands on CERN project [1, 2], using digitised scientific data transmitted via Internet, schools can approach the physics frontline in the classroom. Students and teachers are able to explore the same scientific information as the scientists. The primary aim is to explore quarks and leptons, the fundamental building blocks of nature, and the fundamental forces in nature embedded in the Standard Model of microcosm.

Experiment and particle collisions

The particle collisions are used to explore quarks and leptons. Some of these only existed naturally at the very beginning of the Universe, but are now produced in high energy collisions at a few large physics laboratories. The experimental data are from the DELPHI experiment [3] at the Large Electron Positron Collider (LEP) at CERN, the European particle physics laboratory [4]. With the 1500 events, quarks, leptons and gluons, the mediator of the strong interaction, and the decay of the heavy Z0 and W particles, the mediators of the electroweak interaction, can be studied.

The Education material

The education material is composed of the 1500 events and the 3D event display of particle collisions, and background material about the Standard Model of microcosm and accelerator and detector information. In addition there is a program with which one can interactively play with quarks to construct particles and compose Feynman diagrams [5].

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The particle events

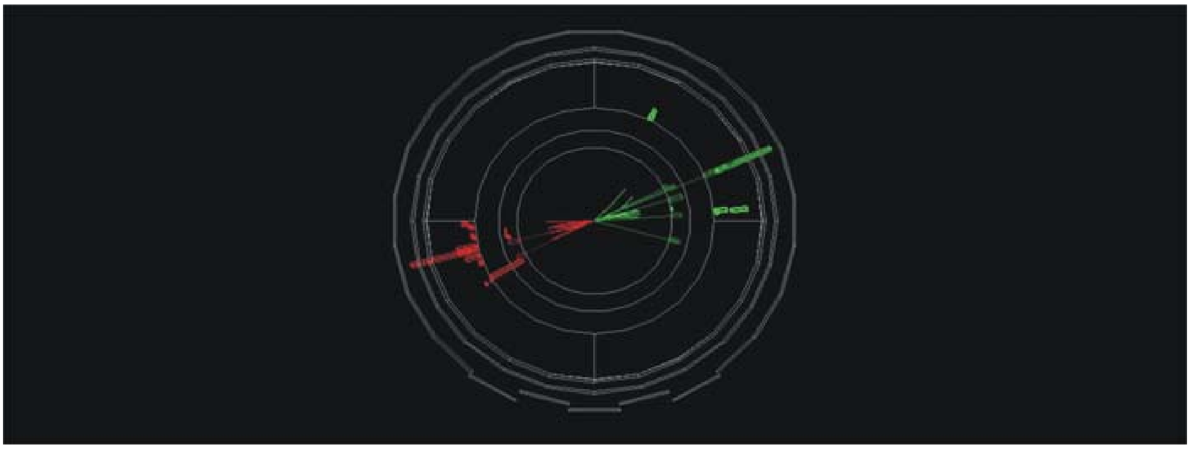

Figure 1. Two-jet event. The production of a Z0 particle decaying into a quark and an antiquark giving rise to two jets of particles deposing their energy in the calorimeters (rectangles)

At a collision energy of 91 GeV a Z0 particle is produced. It rapidly transforms /decays/ into a quark and an anti-quark or a lepton and an anti-lepton, where the lepton is an electron, a muon or a tauon. The quark gives rise to a jet of particles (Figure 1). One of the quarks can radiate a gluon, the mediator of the strong interaction, and give rise to a third jet of particles. The probability for this to happen is proportional to the strong coupling constant, α_s. The two-jet and three-jet events are used to determine the value of the α_s. At a collision energy exceeding 160 GeV two W particles can be produced. The decay of these particles gives rise to rather complex events.

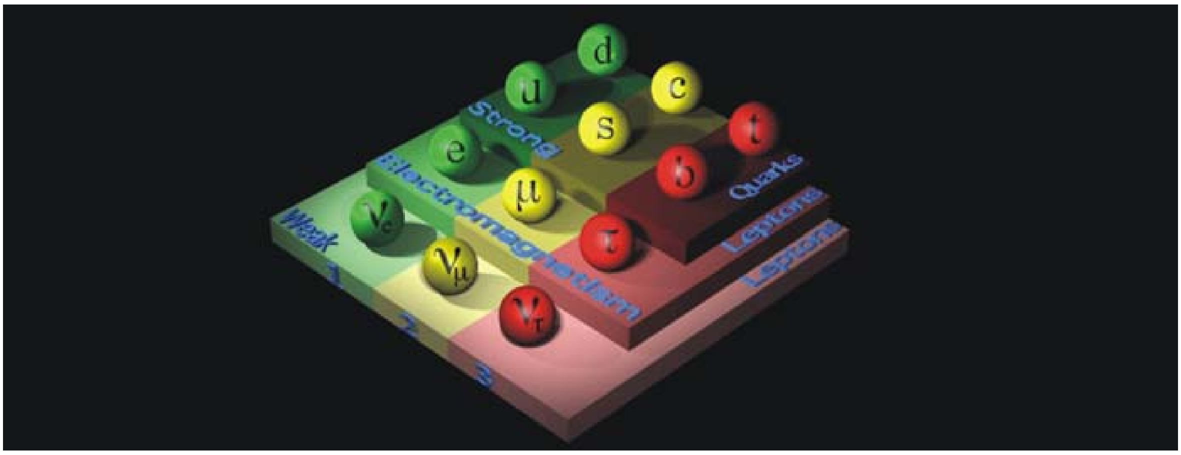

Figure 2. Interactions

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Projects for students and teachers

Several research projects have been organised for students and teachers using the Hands on CERN education package. At school the education project can be used from about an hour (study a few events and learn about quarks and leptons) to a day (explore a large number of events, study the Standard Model, determine the strong coupling constant and use the Fireworks of particle physics to construct particles. It has also been used in research schools for students at Science Laboratory and House of Science (Figure 3) [6, 7] and the European Masterclasses 2005 and 2006.

Research schools

During a two week course in astronomy and particle physics the 17 – 18 year old secondary school students studied the intricacies of high energy particle collisions and the origin of Universe [6]. Examples of the different type of events are shown in Figure 1. The first task was to classify the material according to the type of event that had taken place: Z^0 decaying into leptons or into quarks. If the event was identified as a lepton event they determined if it was an electron, a muon or tauon event. The quark events were classified according to the number of particle jets. The dynamics of Standard Model were discussed and from the experimental data they could determine the strong coupling constant and compare it with electromagnetic and gravitational interactions.

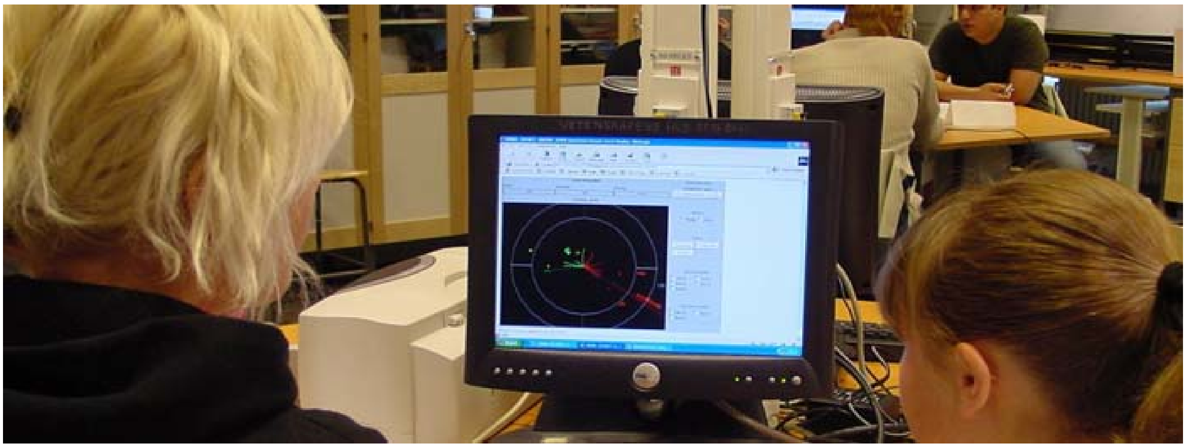

Figure 3. Research class students at House of Science working with Hands on CERN

Masterclasses 2005 and 2006

Close to 60 European particle physics institutes and 3000 students participated in the one day European Masterclasses 2005 [8] (Figure 4). Many of the participating groups used Hands on CERN to explore quarks, leptons and the Standard Model of microcosm. For this event the Hands on CERN was translated to several new languages, and it now exists in 15 languages. During a Masterclass event, high

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school students visit one of the participating universities or research centres for one day, they attend lectures on particle physics and perform measurements on real data from particle physics experiments. The computer work was sometimes complemented by experimental work exploring the properties of the electron and studying cosmic radiation using scintillator detectors or cloud chambers. The participants also got the opportunity to visit the research groups and experience the research environment at the universities. The evaluation of the Masterclass event showed that an overwhelming majority (over 80%) of the participants liked the Masterclasses, and that between 75 and 85% of the participants learned a lot about quarks and leptons, particle detectors, general particle physics and particle accelerators. Because of the successful event in 2005 the Masterclasses were repeated in 2006 with the same number of participating institutes and students, also including a US laboratory.

Figure 4. Students at the National Technical University of Athens taking part in the 2005 Masterclasses

International recognition

Hands on CERN now exists in 15 languages[11] including the two original languages (Swedish and English). In 2004 Hands on CERN has was selected a winner of the Scientific American Science and Technology Web award [9], and in 2005 it received the prestigious Webby Award in the Science category [10].

LHC and ATLAS

In the tunnel that housed the LEP collider until 2000 a new collider for accelerated protons is being installed – the LHC (the Large Hadron Collider). One of the large LHC detectors is the ATLAS experiment [11]. ATLAS will explore the fundamental

[11] Catalan, Czech, Danish, English, French, Galician, German, Greek, Hungarian, Italian, Norwegian, Portuguese, Slovak, Spanish and Swedish.

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nature of matter and search for new discoveries in the head on collisions of 7 TeV protons. ATLAS is a large collaborative effort by 1700 physicists including 400 students from more than 150 universities and laboratories in 34 countries (Figure 5).
The website [11] describes ATLAS and makes a tour to the theory of particle physics, the accelerator and the detector. Web cameras situated in the ATLAS cavern, accessed from the front page of the web site, show the status of the detector installation. ATLAS information material like brochures, films and posters have been translated to different languages by members of the ATLAS collaboration. A variety of information material can be obtained via the website.
The ATLAS Student Event Challenge will use ATLAS data and build on the best practise of the successful QuarkNet [12] and Hands on CERN education projects. The ATLAS Student Event Challenge will be an innovative education project to enhance student education and will provide them with access to real and simulated data and the opportunity to participate in a real particle physics experiment.

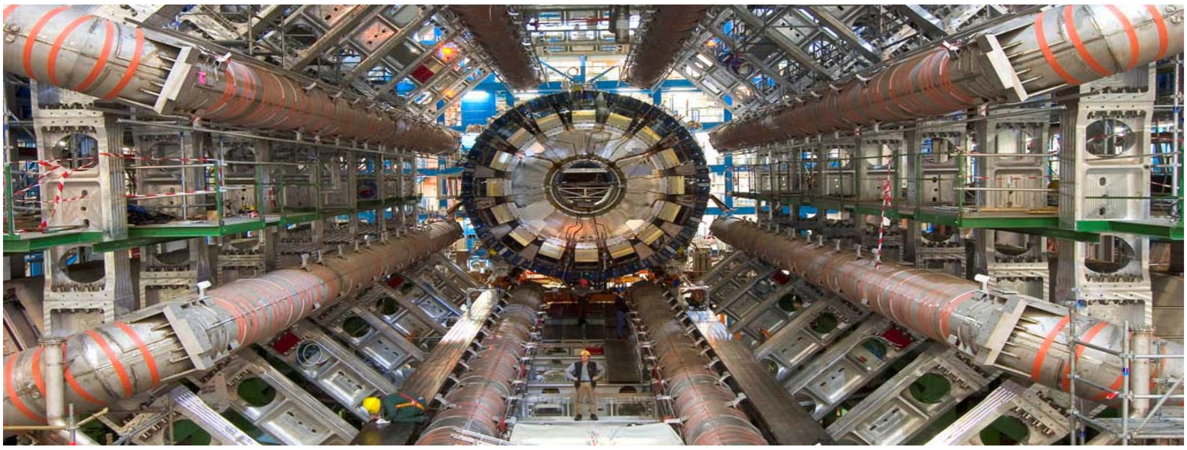

Figure 5. The ATLAS detector under construction at CERN. The man at the bottom of the photo indicates the scale of the detector

Summary

With Hands on CERN students at schools and universities explore particle collision data from the DELPHI experiment. Hands on CERN complements the traditional way of teaching physics and introduces a normally rather inaccessible experimental subject at school. Combined with classical electron experiments and explorations of the cosmic radiation it forms an attractive course in modern particle physics. The attention that Hands on CERN and the Masterclass events have received, shows that unconventional teaching methods can be very appreciated and that today's scientific experiments like the ATLAS experiment and other experiments at the future LHC collider have a role to play also at school.

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References

[1] Hands on CERN website: http://hands-on-cern.physto.se
[2] Johansson KE, Hands on CERN – a well-used physics education project, Physics Education, 41: 250-254, 2006.
[3] DELPHI website: http://www.cern.ch/Delphi/Welcome.html
[4] CERN website: http://www.cern.ch
[5] Symeonidou E, Fireworks of particle physics, Greek outreach Group project, http://www.physics.ntua.gr/eesfye/POP/articles/hadrons.html
[6] Johansson KE, Nilsson Ch, Engstedt J and Sandqvist A, Astronomy and particle physics research classes for secondary school students, American Journal of Physics 69: 577-581, 2001.
[7] Johansson KE, House of Science, a university laboratory for school, Physics Education 34: 342-345, 2004.
[8] European Masterclasses 2005 http://wyp.teilchenphysik.org
[9] ScientificAmerican.com, October 04, 2004
[10] Webby Award website: http://www.webbyawards.com/
[11] ATLAS experiment website: atlas.ch
[12] QuarkNet webpage: http://QuarkNet.fnal.gov.

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Kit and Method for Experiments in Physics/Mechanics

Tavares D and Da Fonseca RJM

Introduction

In 1960, after almost ten years working with high schools and university students in Brazil A. Dias Tavares (born 27/February/1917 died 26/February/1988) published a booklet entitled “The teaching of Physics” (“O Ensino da Física”) [1]. In that booklet he appealed to Dewey, Lewin, Battig, Mating, Vandell Kersh and others’ ideas [2 - 13] to consolidate a teaching method which he tentatively called “Teaching by Guided Rediscovery”. From these references we infer that Tavares’s method is a constructivist one and we are going to demonstrate his quite original constructivist work by describing his method and practices.

As the constructivism accent is on the learner rather than on the teacher a serious problem originates: how cans the student learns at his/her own rhythm using laboratory equipments to interact with and gaining an understanding of the involved matters? So at first, anyone interested in using these theories would be able to furnish experimental tools to every single student in order to accomplish the aims of subject learning. But in general this is a too much expensive to be accomplish. Therefore, the development of a kit of experiments was one of the necessary steps of Tavares work.

In this paper we discuss not only the well established work of Tavares, but also some changes he made but does not describe in his constructivist based method, when applying it at State University of Rio de Janeiro from 1970 until 1987. We can anticipate that his very original method accents again the teacher, but now as a kind of master which has the mission to deconstruct [14-16] the so called common sense of student. In this way teacher makes the knowledge construction easier to student and shortening the delay necessary to do that.

Theory and the Guided Rediscovery

The method essence as long as it was formulated can be quite well described in the following explanation to the students conceived by Tavares [1]:

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We are going to try teaching Physics to you, through a highly efficient method, the most efficient, since you do rigorously the things you are asked to do, since you study with persistence and work in fact. Perhaps you think that in such a manner it is not interesting and argue: if we would not have need to study and work to learn then we would have indeed a highly advantageous method. Unfortunately, we do not know any process able to do one learn without studying. We can anticipate meanwhile that the way we are going to try teaching you Physics perhaps is very near of this ideal if you soon fill enthusiastic by it to the point of thinking on it as an entertainment, a diversion.
You are not going to acquire knowledge, you are just going to use your brains to extract knowledge from observation and experiments, therefore you will use hands and tools with which will mount apparatus for your experiments and you will learn to interpret them. In your experiments you will see and understand the limitations that you will be exposed to. You will rediscover a large part of what mankind has discovered in hundreds of years; for this aim you will not use the same methods but some more efficient others; you will be easily driven or guided to the conclusions in the experiments we suggest.
Afterwards, all that you have learnt by direct experiment you will retain and boost with graduated drills and problems. The next step is doing your patrimony or acquired knowledge to grow like an alive organism in which all its components parts are functionally interconnected. We want that your knowledge to be not yours but you; we want to form your personality in such a way that you react to every situation in life which require the knowledge obtained here; we want, and this is our main objective, that you acquire the capacity of studying and solving new problems, inventing if necessary new methods and processes of research and investigation.
In short, what we intend to teach you is a mode to act, to think, to work, to investigate, to research on Physics, and not only an amount of knowledge which is a by-product of the real learning we intend to teach you.

These words can be seen as a summary of the method Tavares has conceived. At this point there were two major problems to implement this teaching method: the teachers who should work with it and the equipments for doing the experiments. Indeed, these two problems are still among the recurrent problems in teaching Physics.
In Tavares's work with high school students he recommended the construction of necessary material by students themselves.

(…we look for another solution since was quite evident that it was not possible in our high schools to obtain an individual practice class for every student. The encountered solution was to leave it to the own student and to subject to his/her own enterprise the realization of basic experiments with apparatus that himself would construct with little or no expense at all. [1]*).*

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Tavares soon perceived that it was not very operational as long as not all the students had the same abilities to make the adequate material. In this way, a teacher must also train the students who do not have the required abilities in them to detriment of Physics learning. So he idealized a very simple set of basic materials with which it would be possible to mount a succession of experiments.
At this point we should comment that the current training of high school teachers at our university involves making the necessary materials. In these courses we are very succeed but one part of training is to teach how to do the apparatus for the experiments.
The method as Tavares and some followers after him have applied can be described as strong activities in Laboratory or somewhere in which students have to mount a series of experiments (about 20 in fifteen weeks of lessons) at their own learning rate. The laboratory remained open a large periods for those students interested in use it out of lessons period. At every experiment the student had to do a report in a notebook and pass over the report correction. Afterwards student must pass over an oral examination about the theory and its experimental implications. Then, the student could pass to the next experiment. The grade attributed after this process was always the highest (10.0) because those conditions were satisfied only and only if the student had learnt completely the theoretical and experimental subjects involved in that experiment. It was very difficult to most students to reach the end of experiments list. The laboratory final grade (sum of all grades obtained divided by the total number of practices) almost ever was lesser than 10.0.
At the end of the course there was an experimental test based on those preceding practices and its grade was summed with that from practices to give an experimental grade. There was still a theoretical grade from theory lessons and with both grades one could reach that of the discipline.
However, the oral tests in laboratory are the most important part and this makes all the difference. There, the concepts are learned and their transference to real situations is evaluated. Besides that is the opportunity professor has to deconstruct the wrong concepts and misinterpretations of theory, experiments and real life situations. In some cases the student submitted to the oral test becomes very stressed because he or she cannot understands the reasons of his/her errors and then they begin to think there is some kind of persecution by the professor. Sometimes this process can be very difficult and unfortunately it is a part of the student transformation process [14-16]. The professor must have a very good preparation in order to meet with the requirements this work imposes. The number of students is also important but we have the experience of one professor and his assistant to attend fifty students in one group.

Hands on kit and experimental training

The first efforts to elaborate a set of materials able to mount some experiments of Mechanics used a few little wood boards, some nails, a hammer, a tin cover, an scale or a piece of one, a needle or pin, twine etc. That is enough to mount an experiment to relate a rod deflection with the weight causing it [1]. Besides that a lot

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of knowledge can be constructed about the weight of bodies, elasticity and so on. Figure 1 shows a scheme of the assembly and materials.
Some questions should be made about these set of materials: Would be possible to convert these quite raw materials in something more durable maintaining the simplicity of the mounting showed hereinabove? Would be possible doing simple experiments with simple components and still so obtaining a little experimental error? Could these components be used to a number of experiments in Mechanics? Will these apparatus serve to develop the abilities in the student? Could it be such small in order?

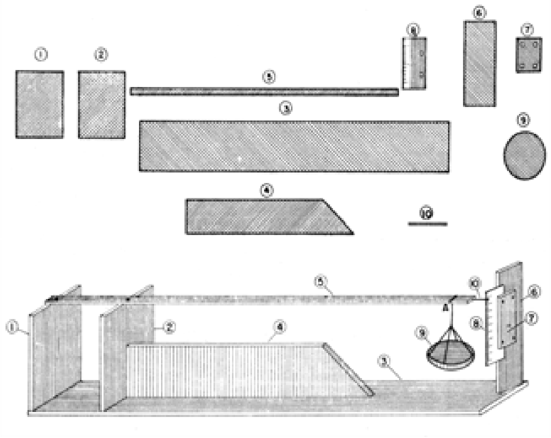

Figure 1 – A simple materials mounted experiment (component parts shown in upper side generate the apparatus below)

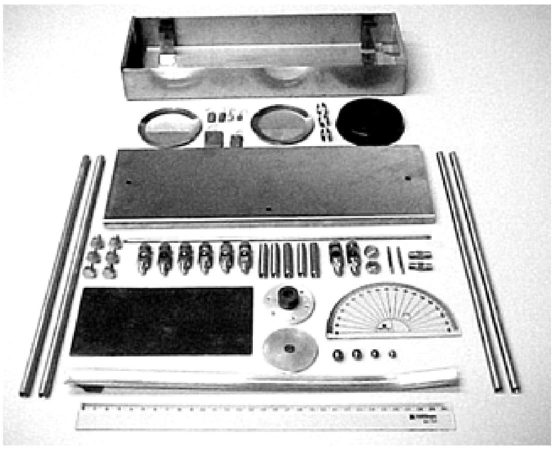

Figure 2. Photography of kit

Students carry it about like a book? Could be it so cheap that an interested but not rich student was able to buy one? Tavares tried to answer these questions constructing a more durable kit (Figure 2) all in metal accompanied by a few booklets [17] explaining introductive practices and associated theory. As can be seen in Figure 2 the number of kit components is not excessive and it is made in stainless steel and brass, except the rule and protractor. In spite of a quite small number of components a fair large number of experiments can be done with it on Equilibrium, Motion, Friction, Rigid Bodies, Angular Momentum Elasticity, Harmonic Motion etc. One of the most important pieces of this apparatus is shown in Figure 3, it is a coil spring. That coil is transformed in a dynamometer after a convenient calibration and will be used to exert the forces in the practices (Figure 4).
Therefore, one of the first practices, or the one of the first actions to operate the kit is turning the three furnished coil springs in calibrated dynamometers using the weights (0.5, 1, 2, 2, 5, 10 and 20 g) and scale (30 cm) in the kit. The student has to make a graphic for each one of the springs, and he/she will use these graphs for all experiments using the dynamometers. It seems very easy but actually it doesn't as long as median student are not quite able to make delicate handwork. So, there is a lot of training for the student contained in these very simple apparatus.

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In Figure 4 we can see an experiment of three forces in equilibrium. The student must measure forces in coil springs by measuring their deformation; afterwards he/she measures the angles with protractor. With experimental data students make the calculations in order to obtain the error between data and theory.

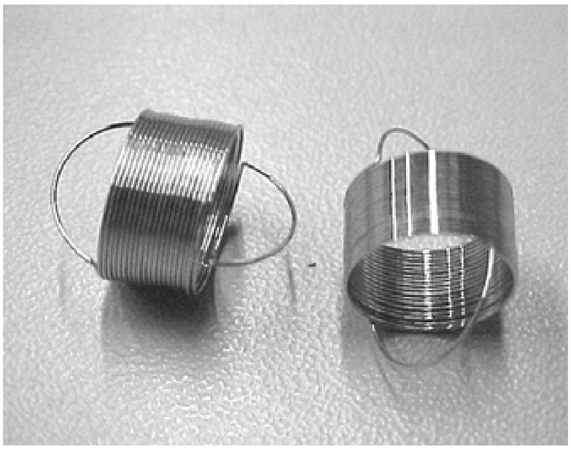

Figure 3. "Dynamometers"

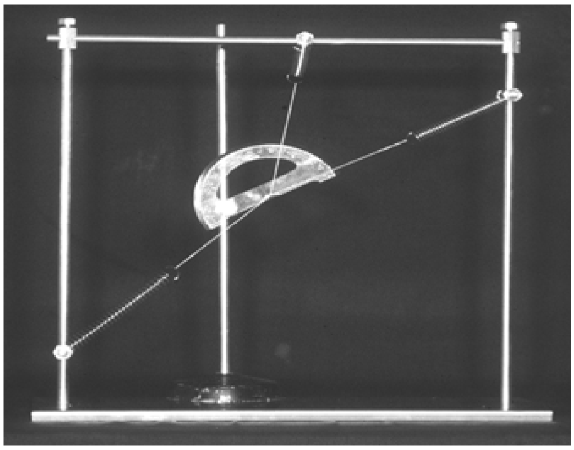

Figure 4. Equilibrium of three forces applied in a point

It is quite evident the point of forces application is static so the vector sum of measured forces must be null. In behalf of brevity it is convenient not extend too much this description and we pass to a list of the most common experiments which can be performed with apparatus:

1. Forces – 9 experiments;
2. Momentum – 6 experiments;
3. Balances – 7 experiments;
4. Friction – 2 experiments;
5. Atwood machine - 3 experiments;
6. Rigid bodies – 7 experiments;
7. Moment of Inertia - 5 experiments;
8. Elasticity - 3 experiments;
9. Hydrostatics and Surface Tension - 3 experiments;
10. Harmonic Motion – 5 experiments.

So, it is possible to do at least fifty (50) fundamental experiments in Mechanics with this simple kit.

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Discussion and Conclusions

We are going to discuss first of all if the questions posed in the preceding section may be answered by this kind of kit or apparatus.
It is quite evident we can convert some more or less raw materials in a simple apparatus. We may say that experiments like the one in Figure 4 can be mounted with simpler materials. In that case the kit will serve as model to help different mountings of the same experiment (one student might use a wood frame and rubber bands and discover rubber doesn't follow Hooke's law).
Experiments like that in Figure 4 present a very little error, in general 1% or better. The error in this case is evaluated comparing forces measured with the dynamometers with those calculated to obtain equilibrium condition with those angles.
From the list of possible experiments presented hereinabove we conclude that it is possible to mount a lot of experiments with this simple apparatus. We can add some more experiments in Hydrostatics, for example, adding a little graduated vase.
We consider that this kit can develop not only experimental abilities in students but also other abilities like improving transference between theory and real situations. The abilities of observation, registration of data, the searching for better results, the analysis of experiments looking for improving them, etc, are all extremely profitable for the students.
The all in metal kit dimensions are 33.5 cm long, 11.7 cm wide and 4.8 cm thick, cf. Figure 5. It weighs less than 3 kg, which is comparable to a notebook weight. So one can say it is very portable and can be carried about without great difficulties. In fact, at the first times (from 1970 to 1980) all the students entering the Physics course had their own individual kit. University lent the kits to the students and they could take along the kit and do the experiments at home.

Figure 5. Student at work (1976)

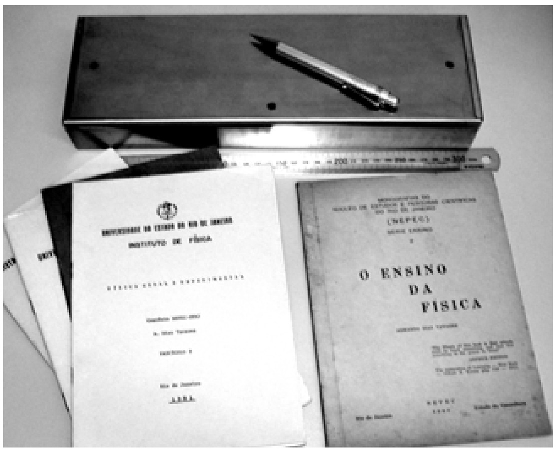

Figure 6. Kit closed for transportation

The materials used to construct the kit showed in Figs 2 to 5 are very resistant, stainless steel and nickel plated brass but we must say these kits have resisted for

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thirty years or more being used for thousands of students. They have stand very well with some repairs, spring coils (the most sensitive parts) substitution and other little services.
However, if the kit doesn't have to pass over such heavy-duty applications much cheaper materials like plastics and so on can be used. The prices also depend on the fabrication scale, the precision of results one wants to obtain from experiments etc, therefore it is quite true these that kits could be very cheap and within the financial resources of individuals and schools.
The important problem we can point out for teaching using this kit and the method "Guided Rediscovery" is the training of those teachers who will work with the students. If the teachers are not convinced of method advantages and they are not ready to assume a quite tiring routine of work, it is very difficult the method to succeed. It is necessary to have teachers very well prepared in both theoretical and experimental aspects of the discipline and they have to work hardly with this simple equipment to obtain better figures from the experiments and to learn the little tricks of each experiment. So, we have to emphasize the importance of teachers' training, from our experience in our University.
We can summarize reproducing the Arthur Bestor's sentence [18] which Tavares applied in his booklet [1] front cover:

> *The thesis of this book is that schools exist to teach something, and that this something is the power to think.*

Acknowledgements

We would like to thank very much: to FAPERJ by the financial support to preserve A. D. Tavares legacy; to Prof. Dr. A. R. R. Papa for many suggestions and corrections to this paper; to the Congress organizers by the logistic support received and, last but not least, to A. Dias Tavares whose hard work as a scientist and professor has influenced generations of physicists, engineers and others, including us.

References

[1] Tavares AD, O Ensino da Física, NEPEC: Rio de Janeiro/Brazil, 1960.
[2] Dewey J, Interest and Effort in Education Boston, Hougman Mifflin Co.: Boston, 1913.
[3] Dewey J, How We Think, Boston D. C.: Heath Co., 1910.
[4] Bernard HW, Psychology of Learning and Teaching, McGraw Hill: New York, 1954.
[5] Thorpe LP and Schmullir AM, Contemporary Theories of Learning, The Ronald Drussel Co.: New York, 1954.
[6] Lewin K, Dynamic Theory of Personality, Mc Graw Hill B. Co.: New York, 1935.
[7] Lewin K, Principles of topological psychology, Mc Graw Hill: New York, 1936.

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[8] Matting WF, The effect of kinaesthetic, verbal and visual cues in the acquisition of a lever positioning skill, J. Exp. Psychology, 47: 378-80, 1954.
[9] Battig WF, Transfer from verbal pretraining to motor performance as a function of task motor complexity, J. Exp. Psychology, 51: 371-78, 1957.
[10] Battig WF, Hoffeld DR, Seidenstein S and Bogden WJ, Supplementary Report Effect of verbal Pretraining on the Acquisition of a complex motor skill. J. Exp. Psychology, 59: 54 375, 1958.
[11] Vandel PA, Davis RA and Clugston HA, The function of mental practice in the acquisition of motor skill, J. of Gen. Psychology, 29: 243-50, 1943.
[12] Katona G, Organizing and Memorizing, Col. Univ. Press: New York, 1940.
[13] Haslernd GM, Meyer S. The Transfer value of given and individually derived principles, J. of Educ. Psychology, 59: 293-98, 1958.
[14] Bachelard G. La formation de l'sprit scientifique: contribution à une psychanalyse de la connaissance. Paris: Librairie Phylosophique J. Vrin, 1938.
[15] Suzuki DT. An Introduction to Zen-Buddhism, London: Rider and Company, 1969.
[16] Pirsig RM. Zen and the Art of Motorcycle Maintenance – an inquiry into values, Bantam Books: New York, 1975.
[17] Tavares AD. Física Geral e Experimental. NEPEC: Rio de Janeiro/Brazil, 1981.
[18] Bestor A. The restoration of Learning, New York: Alfred A. Knopp, 1955.

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Hands-on Activities with LEDs and Light

Voudoukis N, Oikonomidis S and Kalkanis G

Introduction

A serious motive for this work constituted the following questions. Is it possible to execute simple hands-on experiments with LEDs in order to find Planck's constant, electron's charge, the energy required to light the LED, the frequency of light emitting from the LED and to investigate the relation between the frequency and the energy of light emitted by the LED.
For this reason an experimental process was designed and the results was very encouraging. The activity is also proposed for the students of High school that have been taught the nature of light and basic elements of Quantum Physics (photons, Planck's constant etc). Nevertheless it is necessary a theoretical framework as an introductory fundamental lesson-material for LEDs and their way of light emission.

Theoretical framework

Light Emitting Diode (LED) is a special diode that emits light when connected in a circuit and biased in the forward direction. Otherwise it is a semiconductor device that emits incoherent narrow-spectrum light when electrically biased in the forward direction. This effect is a form of electroluminescence. The colour of the emitted light depends on the chemical composition of the semiconducting material used, and can be near-ultraviolet, visible or infrared.
An LED is a special type of semiconductor diode. Like a normal diode, it consists of a chip of semiconducting material impregnated, or *doped*, with impurities to create a structure called a *p-n junction*. As in other diodes, current flows easily from the p-side, or anode to the n-side, or cathode, but not in the reverse direction. Charge-carriers-electrons and electron holes flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon as it does so. LEDs will only light with positive electrical polarity. When the voltage across the *p-n junction* is in the correct direction, a significant current flows and the device is said to be *forward-biased*. If the voltage is of the wrong polarity, the device is said to be *reverse biased*, very little current flows, and no light is emitted. LEDs can be operated on an alternating current voltage, but they will only light with positive voltage, causing the LED to turn on and off at the frequency of the AC supply.

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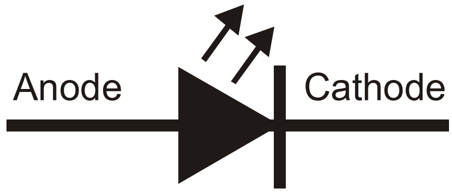

Figure 1. LED schematic symbol

The wavelength of the light emitted, and therefore its colour, depends on the band gap energy of the materials forming the *p-n junction*. In silicon or germanium diodes, the electrons and holes recombine by a *non-radiative transition* which produces no optical emission, because these are indirect bandgap materials. The materials used for an LED have a direct band gap with energies corresponding to near-infrared, visible or near-ultraviolet light.

LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have made possible the production of devices with ever shorter wavelengths, producing light in a variety of colours. The refractive index of the package material should match the index of the semiconductor, otherwise the produced light gets partially reflected back into the semiconductor, where it gets absorbed and turns into additional heat.

In nonradioactive recombination the energy released is dissipated in the form of lattice vibrations and thus heat. However, in band to band radioactive recombination the energy is released with the creation of a photon with a frequency following equation E=hf where the energy is approximately equal to the bandgap energy E=hf=hc/λ where c is the velocity of light in a vacuum and λ is the optical wavelength.

This spontaneous emission of light from within the diode structure is known as electroluminescence. The light is emitted at the site of carrier recombination which is primarily close to junction, although recombination may take place through hole diode structure as carriers diffuse away from the junction region. However, the amount of radioactive recombination and the emission area within the structure is dependent upon the semiconductor materials used and the fabrication of device.

When sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the *junction* between the *p* and *n* regions. In the *p region* there are many more positive than negative charges. In the *n region* the electrons are more numerous than the positive electric charges. When a voltage is applied and the current starts to flow, electrons in the *n region* have sufficient energy to move across the junction into the *p region*. Once in the *p region* the electrons are immediately attracted to the positive charges due to the mutual Coulomb forces of attraction between opposite electric charges. When an electron moves sufficiently close to a positive charge in the *p region*, the two charges "re-combine". Each time an electron *recombines* with a positive charge, electric potential energy is converted into electromagnetic energy. For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material (usually a combination of the chemical elements gallium, arsenic and

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phosphorus). Only photons in a very narrow frequency range can be emitted by any material. LED's that emit different colours are made of different semi-conductor materials, and require different energies to light them.
The electric energy is proportional to the voltage V needed to cause electrons to flow across the p-n junction. The energy E of the light emitted by an LED is related to the electric charge e of an electron and the voltage required to light the LED by the expression: $E = eV$.

Materials

1. battery 4,5 V
2. breadboard; cables
3. digital voltmeter; spectrometer
4. resistor 220Ω
5. five LEDs : red, orange, yellow, green, blue.

Experimental procedure

Implementation–design of the circuit

The circuit is shown in Figures 2, 3, 4 and 5. We used battery V = 4.5 Volt, resistor R= 220Ω (1/4 Watt) and five LEDs of different colours (red, orange, yellow, green, blue). The resistor is to protect the LED from too much current and to minimize the amount of current and voltage available to the LED. So we built five different circuits as we changed the LED D.
We select the value of R equal to 220Ω. This is a proper value. In Figure 2, when the forward voltage drop of an consequently

$$R = (V-VLED) / I$$

We suppose VLED = 1.9Volt and I = 12 mA. LEDs operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 *milli*amperes. Voltages and currents substantially above these values can melt a LED chip. So

$$R = (4.5-1.9)/ 12 \times 10^{-3} = 216.7\ \Omega.$$

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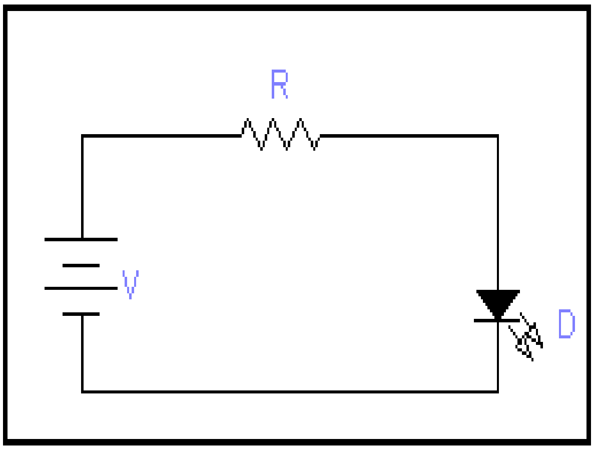


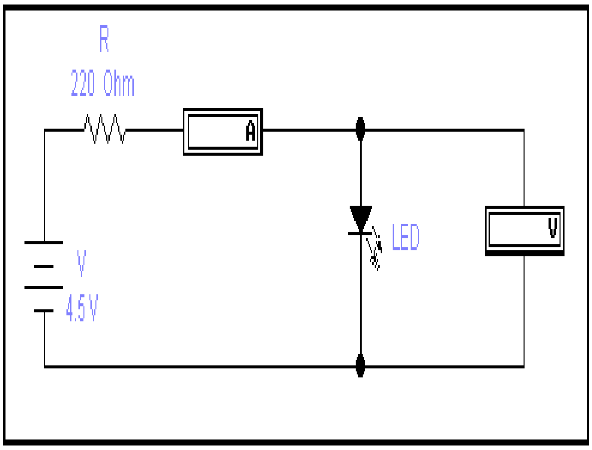
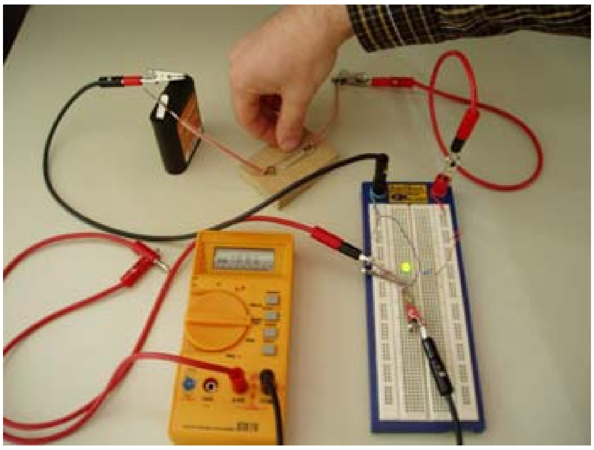
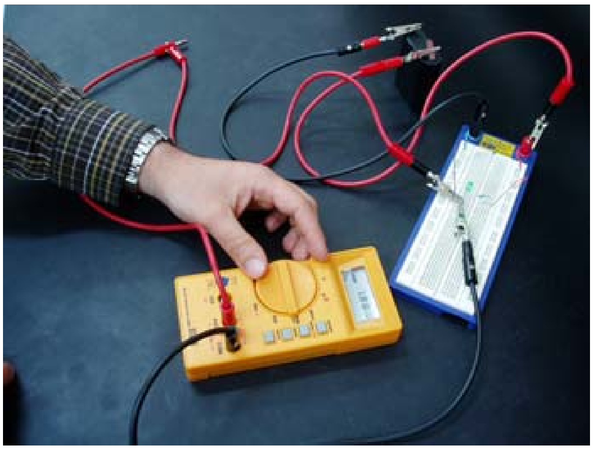


Figure 2 **Figure 3**





Figures 4 and 5. The experiment

Measurements of voltage across LED

We measured, with the voltmeter, the voltage across the leads of the LED. We turned on the digital voltmeter, connected the probes of the voltmeter across leads of the LED's and recorded the potential difference in volts across each of the LEDs. We constructed a data table (Table 1).

LED colour	Voltage ac. LED (V)	Energy (eV)	Energy (*x* 10^{-19} Joule)
Red	1.77	1.77	2.83
Orange	1.81	1.81	2.90
Yellow	1.91	1.91	3.06
Green	2.03	2.03	3.25
Blue	3.05	3.05	4.88

Table 1

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Finding the energy (an LED emit) from the voltage

LED colour	Voltage across LED (V)
Red	1.77
Orange	1.81
Yellow	1.91
Green	2.03
Blue	3.05

Table 2

The electric energy is proportional to the voltage needed to cause electrons to flow across the p-n junction. The different coloured LEDs emit predominantly light of a single colour. The energy of the light emitted by an LED is related to the electric charge of an electron and the voltage required to light the LED by the expression: $E = eV$ Joules. The constant e is the electric charge of a single electron and has absolute value 1.6×10^{-19} *C*.

Estimation of wavelength with use of spectrometer and calculation of the corresponding frequency

LED colour	Wavelength λ (nm)	Frequency f (x 10^{14} Hz)
Red	680	4.41
Orange	620	4.84
Yellow	580	5.17
Green	540	5.56
Blue	440	6.82

Table 3

Figure 6

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The spectrometer can be used to examine the light from the LED, and to estimate the peak wavelength of the light emitted by the LED. Suppose we observe the red LED through the spectrometer, and we find that the LED emits a range in colours with maximum intensity corresponding to a wavelength as read from the spectrometer of λ = 680 nm or 680 x 10^{-9} m. The wavelength is related to the frequency f of light and the speed c of light (c=3 x 10^{8} m/s) with the equation c = λ f. So we have f = c / λ and for the red LED is f = 4.41 x 10^{14} Hz.
We repeat the procedure for the four other LEDs.

Making plot of frequency against voltage.

With use of data of Table 4 we are able to plot frequency against voltage and make a prediction of mathematical function between them.

LED colour	Voltage across LED (V)	Frequency f (x 10^{14} Hz)
Red	1.77	4.41
Orange	1.81	4.84
Yellow	1.91	5.17
Green	2.03	5.56
Blue	3.05	6.82

Table 4

Calculation of Planck's constant

We calculate Planck's constant if take as granted that e = 1.6 x 10^{-19} *C*
We have hf = eV so h = eV / f

LED colour	Voltage across LED (V)	Frequency f (x 10^{14}Hz)	h (x 10^{-34} Js)
Red	1.77	4.41	6.42
Orange	1.81	4.84	5.98
Yellow	1.91	5.17	5.91
Green	2.03	5.56	5.84
Blue	3.05	6.82	7.16

Table 5

Calculation of electron's charge

We calculate electron's charge if take as granted that $h = 6.63 \times 10^{-34}$ Js
We have hf = eV so e = hf /V

LED colour	Voltage across LED (V)	Frequency f (x 10^{14} Hz)	e (x 10^{-19} C)
Red	1.77	4.41	1.65
Orange	1.81	4.84	1.77
Yellow	1.91	5.17	1.79
Green	2.03	5.56	1.81
Blue	3.05	6.82	1.48

Table 6

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Verification

We take e = 1.6 x 10^{-19} *Cb* and *h = 6.63 x* 10^{-34} J s
With use of V measurements we calculate the frequencies

LED colour	Voltage across LED (V)	Frequency f (x 10^{14} Hz)
Red	1.71	4.13
Orange	1.74	4.20
Yellow	1.85	4.46
Green	1.94	4.68
Blue	2.96	7.14

Table 7

The results are very close to the experimental values.

Conclusion

The experiments are successful because the experimental values and the correlated results are very close to the theoretical values. Also these experiments are very simple hands-on experiments that can be executed by students.

References

[1] Senior JM, Optical Fiber Communications Principles and Practice, Boston: Prentice Hall International, 1992.
[2] http://www.wikipedia.org/wiki/Light
[3] http://mrsec.wisc.edu/Edetc/modules/HighSchool/LEDs/6_LED_Expt_Teacher.pdf
[4] http://acept.la.asu.edu/courses/phs110/expmts/exp13

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Using Robotics in Classroom: LEGO Mindstorms™ and Physics

Cardoso J

The Área de Projecto in the portuguese curriculum

The last change on the portuguese secondary school curriculum introduced a new subject designated for the 12th grade students: Área de Projecto (to apply from 2006/2007). There will be no specific curriculum for Área de Projecto: the main goal is to provide the students an opportunity to develop investigation skills, integrating the various subjects previously studied and developing new subjects as well.
The problem chosen by the students should be significant for them, thus the teacher's role should be essentially to guide them in that choice. Nevertheless, the teacher should realize that for the science courses students, the essential approach to the problem should be done by the science point of view, as this is also a preparation for further (science) studies.

Using robotics in the classroom

We could say the implementation of robotics in portuguese main K-12 education is only at the beginning. In spite of some projects involving LEGO TC Logo™ in the past, there has been no systematic use of robotics. The LEGO Mindstorms robotics kit (developed at the MIT Media Laboratory, USA and released in 1998) and Robolab™ software allowed a wider use of robotics in education.
The release of these products, specifically developed for education, allowed its use by students ranging K-12. In Portugal only a few students had the opportunity to use them. With the recent introduction of the FIRST Lego League in Portugal, some schools could provide their students the opportunity to develop robotics projects in robotics clubs.
Although this is an extraordinarily important and valid implementation of robotics, different approaches are possible and desirable [1]. In particular, it is possible to use robotics in investigation projects, such as those expected to be done in Área de Projecto.

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Benefits of robotics in education

The appropriate use of robotics, in particular, the constructivist approach, may provide a variety of educational benefits [12]:

- reinforcement and development of abilities concerning other subjects, such as Physics, Math or Chemistry;
- promotion of interdisciplinary and integration of knowledge provided by other subjects;
- motivation for the study of other traditionally unpopular subjects [7], [11];
- motivation for school in general
- development of problem-solving techniques, persistence and creativity [9];
- development of formal thinking/abstraction [5]
- better understanding of models using and the associated constraints;
- development of cooperative work and investigation skills;
- better differentiation of teaching.

Advantages of the LEGO Mindstorms/Robolab

Among the several robotics kits, the choice lied on LEGO Mindstorms kit and Robolab, as the programming software. The main reasons for this choice are the following [12]:

- recognised credit of the products;
- non-demanding on particular electronics knowledge and techniques;
- easiness of construction and enthusiasm [11];
- ability to perform data logging;
- existence of a programming software (Robolab) also developed
- specifically for educational purposes;
- existence of other (free) programming software;
- open policy adopted by LEGO;
- provided support;
- price;

Using LEGO Mindstorms in Área de Projecto

When using robotics in education, many approaches are possible. In situations such as robotics clubs, the main purpose is usually to promote the students interest for robotics and science in general. The purpose of specifically developing and integrating physics (or other subjects) skills is not the main one. In addition, the attendance is usually optional.
As previously said, this kind of activities has great benefits, particularly up to the 9th grade, but it is possible and desirable to develop more structured and ambitious

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approaches. In fact, one of the best qualities of this kit/software is the capability to use it in very simple projects but extremely ambitious ones either.
The structure of Área de Projecto suits perfectly the purpose of approaching real, science/technology-based significant problems. The time constraint usually pointed does not apply on this case. This been said, the guidelines defined for the use of robotics in Área de Projecto are the following:

- Emphasizing of the physics role in problem solving. The declaration of 2005 World Year of Physics by the UN recognises the need to promote Physics among society and students in particular. In fact, Physics does play an essential role in present society, which is technology-dependent. When helping to define the problem to be studied and the strategies, the teacher should regard this fact.
- Differentiation of the difficulty level. The teacher shall guide the students through a series of increasingly complex approaches to the problem: teacher shall help students on defining investigations goals which are, at any moment, within their capabilities. Thus, frustration can be avoided, as well as it is provided opportunity to develop students' capabilities as deeply as possible. One could say that a robotics project has always a certain degree of success and is never finished. An evidence of this fact is the use of LEGO Mindstorms with very young children as well as in university projects.

Within these guidelines, two projects have been developed for further implementation. When defining the problems there has been an attempt to involve issues beyond "traditional" mechanics.

Autonomous solar vehicle (sun tracking device)

The essential of this project could be summarized as the construction and programming of a device capable of orientating a solar panel to be used by a solar vehicle.
On this project, from the robotics point of view, the main difficulty will be the programming, rather than the Physics involved. Nevertheless, the approach of such a problem demands the study of the solar cells and applications. This shall not be new to the students as this is a Physics subject previously studied in the 10th grade.
The context to the problem is intentionally left open: the main goal on the proposals is to provide the core guidelines, rather than a final project. Anyway we could suggest an integrated approach to a monitoring vehicle: more than one group would be involved in the project and one of them should provide the power mechanism.
For the panel orientation, 2 axes will be needed, therefore, it will all come to the construction of such a system and programming its behaviour. One can start with a single (vertical) axis system: this allows separating a complex problem into easier parts. Once this is accomplished, the second (horizontal) axis orientation will be

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similar. In addition it provides the opportunity to achieve partial goals along the project.
On the construction of the axis orientation system it will arise the speed problem: if the motor is directly connected to the axis it will turn too fast and it will be impossible to orientate it properly. The solution is to use several speed reduction mechanisms. In the following picture has been used a 24/8 and a 40/8 gear, which provides a 15:1 reduction.

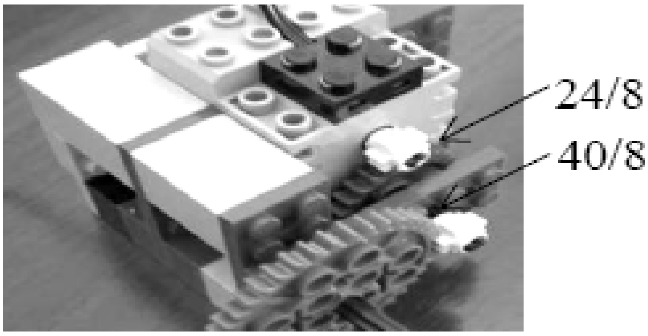

Figure 1. Vertical axis orientation system

To control the axis orientation will be used and attempt and error technique: using a light sensor to monitor the light amount, there will be made a slight change in the orientation and will be compared the light amount across the direction perpendicular to the panel, which is the light sensor direction. The control of the vertical axis with the motor A (connected on output A), can be programmed as Figure 2.

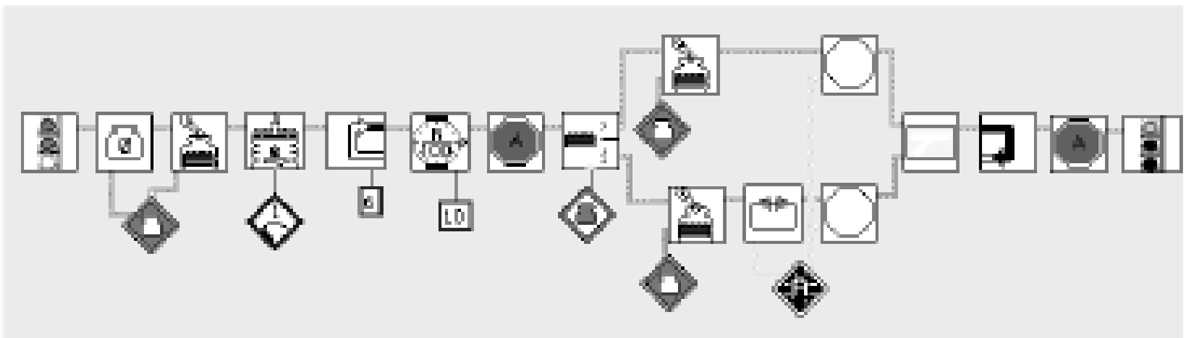

Figure 2. Vertical axis orientation program

In this algorithm has been used an interval of 0, 1 seconds to perform each movement. The output power has been set to 1.Using a similar technique for the horizontal axis, the structure of Figure 3 can be obtained.
In order to control the two-axis system, a similar algorithm can be used: the orientation on the motor B (horizontal axis) will indefinitely alternate with the orientation on motor A (Figure 4).

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With a construction similar to this and with this program, the robot will provide the requested orientation to the panel. In spite of that, the behaviour of the system can be significantly improved. For instance, the orientation process can be conditioned to a light decrease and the time interval can be successively reduced, which provides a smoother orientation. For further reference, see [12].

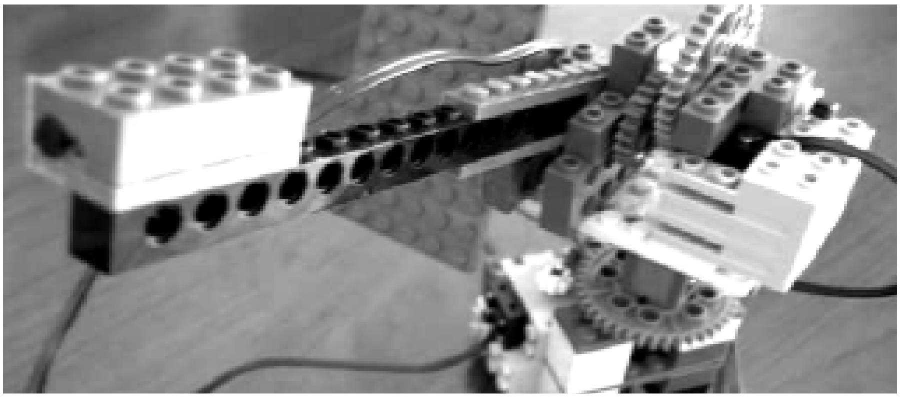

Figure 3. Two-axis orientation system

Study of the LEGO motor properties

This proposal focus on the study of the DC motors. Once again, there is not provided a specific context, although can be suggested the problem of moving an elevator: what is the best way to move an elevator, using a certain motor?
On this case, the programming is very easy and the main work will be the systematic survey of information about the motor properties. From the variety of questions related to this problem, we will be focusing here two in particular:

- what is the best way to move the elevator if we intend to minimize the time (maximum power)?
- what is the best way to move the elevator if we intend to maximize the motor efficiency?

In order to answer these questions, students will have to design a way to measure the energy obtained by the object (elevator) and the energy spent by the motor in various conditions. A previous study will show that for this kind of motor, the important factor is the torque/speed [12]. A particularly easy way to measure the energy obtained by the object is to move it upwards at a constant velocity. By changing the mass of the object, we change the motor torque.

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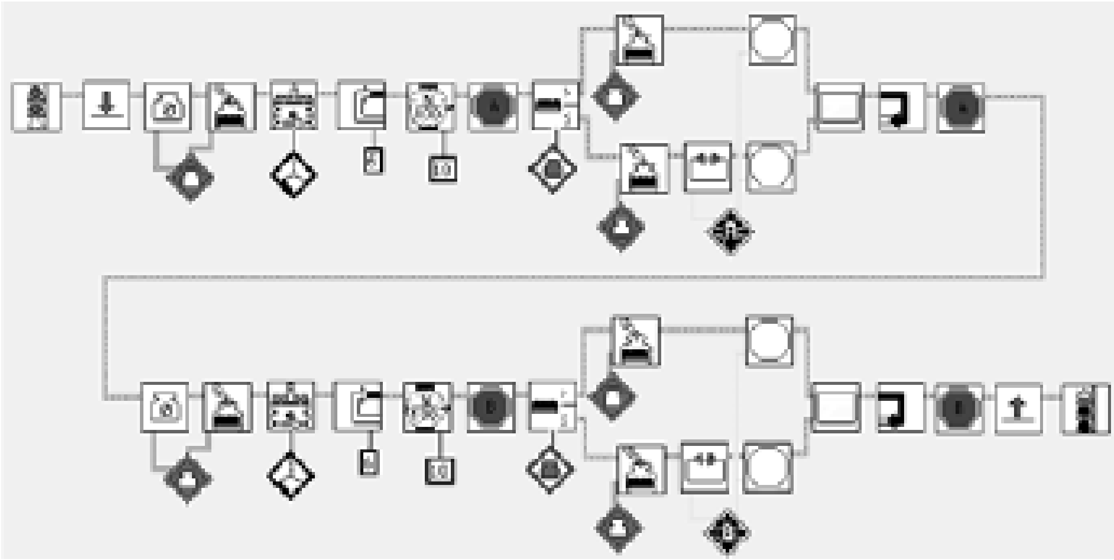

Figure 4. Two-axis orientation program

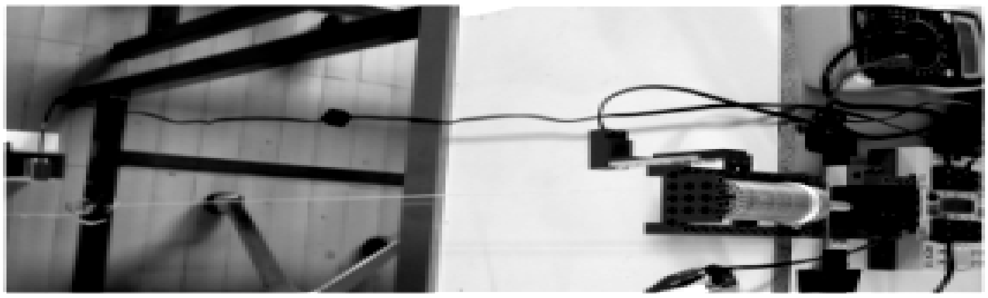

Figure 5. The experimental setup

The motor efficiency can be obtained by measuring the electrical power, using a voltmeter and an ammeter in simultaneous (measures have to be made during the stationary period). In alternative, DCP sensors can be used to measure and log these values. In our work, two light sensors were used to detect the star and the end of the stationary movement (Figure 5). Using this setup, and using a simple robolab program to give the time between the “gates”, calculations have been made and the following graphics were obtained (Figure 6.).
These results show that motor efficiency and power depend on the motor speed/torque in a different way. The power peak is obtained at a different speed/torque that would lead to a maximum efficiency. Thus, on an elevator design, the gear system should be different depending on what the purpose is: maximum power, maximum motor efficiency a balance situation.
The results could be obtained by theoretical considerations [12]. This allows students to compare the results obtained experimentally. Once again, we can say “there is no upper limit” on the project: although we realize the difficulty some students should have on trying to do this analysis, the teacher must have in mind that each student shall go as deep as possible.

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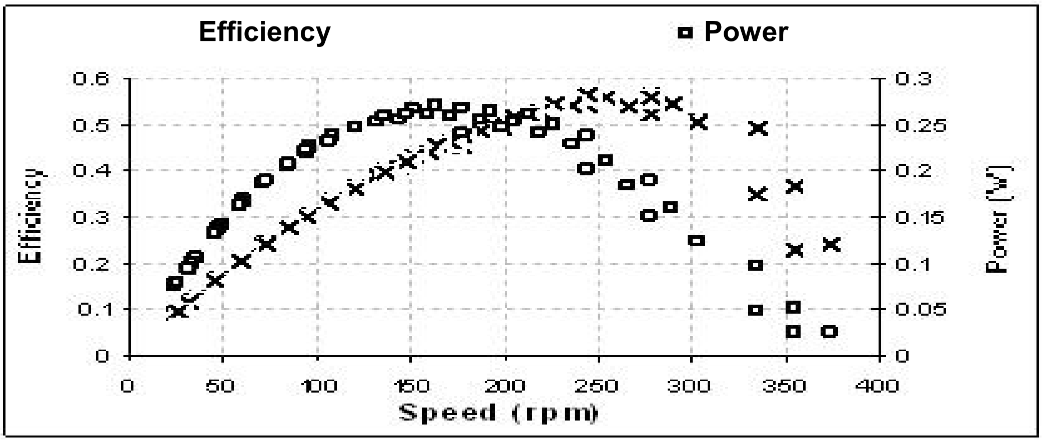

Figure 6. Efficiency and power *vs speed*

On this project, the focus is the systematic study of the LEGO motor (provided with LEGO Mindstorms kit). On doing that, students shall develop experiment design and data analysis skills as well as they investigate mechanics-electricity subjects. All this can be done with a specific goal but the study can also be taken as a base-study for other projects: the group that investigates this issue does not have to apply their conclusions, the work can be done in collaboration with other students whose work depends on these results. Thus, collaborative work skills will be developed within each group as well as among different groups. In fact, no investigation centre works alone!

Conclusions

On the two projects here summarized has been proved the possibility to use robotics, particularly the Mindstorms kit, to achieve the essential goals of Área de Projecto. Has been shown the possibility to develop significant problem-based projects with a strong emphasis on Physics. Has also been shown the suitability of the Mindstorms kit.

The constraints of the research work didn't allow verifying the concrete results from such integration. In fact, Área de Projecto will enter the 12th grade curriculum from 2006/2007. Additionally, there is no previous systematic work on the use of robotics in education in Portugal. Considering these limitations, the evaluation of the impact of robotics in education, particularly in Área de Projecto, has to be postponed for future investigations.

Other robotics projects – "Robótica para todos"

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During the past year, a robotics program has been proposed by Escola Superior de Educação de Viana do Castelo and funded by FCT (Fundação para a Ciência e Tecnologia).
The main goals of this program were: demystification of robotics; promotion of Science and Technology among young children (5th to 9th grade) through robotics; promotion of Science and Technology (particularly Physics) among future 1st to 6th grade teachers through robotics; the development of experiment design skills; encouraging the use of new approaches in elementary education by the future teachers, in particular, the study of Physics subjects on a constructionist approach.
The program implementation had two ways: one focusing on the future teachers and the other focusing on the young children.

Robotics with future teachers

The students were involved in two introductory Physics courses (Física I and Física II) and a Science course (Estudo do Meio Físico e Natural). On the Physics courses, the students defined a specific problem and studied it with the Mindstorms kit. In Física I, two groups developed their work around the motor behaviour issue: based upon the data provided by the teacher and the Physics concepts they produced as final product two elevator systems: a vertical one and an inclined plan. The inclined elevator has been inspired on the Santa Luzia elevator (a typical elevator previously existing in Viana do Castelo). Another interesting project, suggested by a group of students, was the control of a Cartesian diver by the RCX.
In these cases, the students were asked to think about possible situations to be studied. The final plan resulted from the negotiation with the teacher. In some cases the students didn't came up with any concrete proposal but in other cases (such as the Cartesian diver) the proposal was quite surprising! In the case of the Cartesian diver, the reason pointed by the group was the "need to learn more about the subject".
In Física II, the students used the Mindstorms kit to study a Thermodynamics subject: they constructed a house model to study the energy spent on acclimatization. The RCX used a temperature sensor to monitor the temperature and control the heating mechanism. The collected data was later used to study the effect of factors such as the upper temperature on energy consumption.
In the Estudo do Meio Físico e Natural course, the students also developed specific projects involving Physics. Due to the course and the desired profile to these teachers, the Physics concepts involved were not so deep. A few groups developed their works around the energy subject, particularly, the renewable sources of energy, some other groups were involved in the study of weather factors (construction of an anemometer, construction of a humidity sensor and monitoring of this factor, study of the temperature variation and the influence of the water proximity). Another interesting project was the construction of a spectrophotometer, based upon the study of light and colour.
The evaluation of the project's impact (based on the direct observation, the final works obtained, the reports presented by the students and the final survey) is very positive. The students (future teachers) were able to improve their image on

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Science and Technology, could enlarge their skills on constructing concrete materials and developed/applied theoretical concepts as well. It was quite surprising how easy the anemometer group did the calibration of their measure instrument.

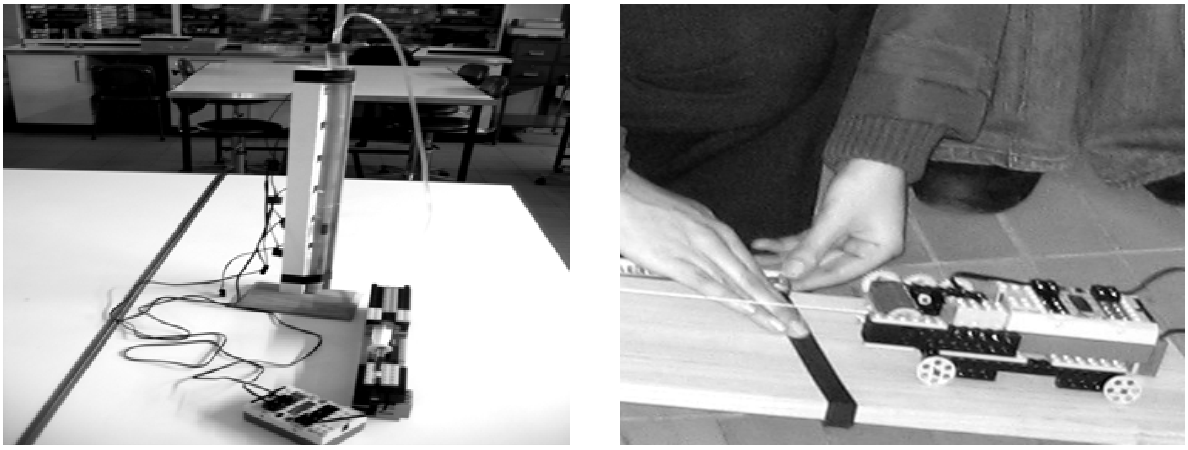

Figure 7. Cartesian diver and "Santa Luzia" elevator

The main issues involved on the introduction of robotics was the difficulty of construction shown by some students (which reinforce the advantage of using this kind of projects, as these skills are essential on future teachers) and the difficulty for the teacher to tutor so many different groups: have been up to 12 in simultaneous.

Robotics in a summer course

The robotics program involved two one-week summer courses. On the robotics courses, the students had a short introduction on robotics and developed their own robotics project. Some of the students who attended the first course came back on the second edition because they "enjoyed it very much" on the first edition.

The projects developed on these courses were much more specific: the main goal was not to specifically involve Physics (although Physics concepts and robotics are inseparable). On this situation, the main purpose was to allow the students to contact with such an interesting and important area as robotics.

Usually, the students tend to dislike the introductory part in comparison to the construction: they are anxious to get their robot working! There is a significant change on the attitude of the students when they see their robot doing something: those who were already very enthusiastic become even more! This applied not only in the summer courses: in every situation similar behaviour occurred. This is one more reason to promote projects where there are partial goals, easy to achieve: there shall not be the pretension of building "the final version of the robot" from the beginning.

From a written survey done at the end of the course, all the 29 participants said they liked. From the 29 participants, 2 (6,9%) said the course had been a bit below their expectations, 13 (44,8%) said it had met their expectations, for 9 participants (31,0%) it came above the expectations and 4 (13,8%) said it came much above the

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expectations. Beyond the limited statistic validity of this data, there is the student's observed behaviour: the best indicator of the student's satisfaction and involvement lies in for instance, in the fact that students "forgot about lunch" because they wanted to improve their robots in order to win the competition (this came very clear on the "sumobot" competition).

Final conclusions

It has been shown that not only is possible to use robotics in education but it is very useful, in particular, robotics can be used in situations such as Área de Projecto, where is intended to develop structured investigation projects.
Robotics has revealed an excellent way to study Science and Technology-based problems and provides the possibility to systematically involve and develop Physics concepts. This, along with the promotion of Physics (and Science in general) is quite essential in the present time, due to the need to motivate students into pursuing Science and Technology careers.
The integration of robotics in a formal context education has been discussed in the case of Área de Projecto. This determines some particular aspects, such as the inexistence of a formal curriculum, which allows the teacher to manage the available time without the usual curriculum constraints. This is one of the reasons we believe robotics to be very suitable for this purpose.
Beyond this, we believe to be possible to integrate robotics in "regular" classes. The work done by Barbra Bratzel [2] and Marie Abbatinozzi [1] reveals great possibilities on this matter. It would be desirable to continue this work, in particular, applied to the Portuguese education system.

References

[1] Abbatinozzi M and Adamec D, Exploring Physical Science Through Engineering, http://www.ceeo.tufts.edu/robolabatceeo/k12/curriculum_units/Physical Science_GRD9.pdf
[2] Bratzel B, Physics by Design: Classroom-tested Activities Using ROBOLAB and LEGO. Knoxville: College House Enterprises, 2005.
[3] Cavers S, Siong S, Astolfo D, Whitman L, Witherspoon T, Witherspoon A and Clague K, 10 Cool LEGO Mindstorms Ultimate Builders Projects. Syngress Publishing: Massachussets, 2002.
[4] Erwin B, Creative Projects with Lego Mindstorms. Addison-Wesley, 2001.
[5] Lau K, Tan H, Erwin B and Petrovic P, Creative Learning in School with Lego Programmable Robotics Products. Proceedings of 29th ASEE/IEEE Frontiers in Education Conference, San Juan-Puerto Rico, 1999.
[6] McNamara S, Cyr MRC and Bratzel B, Lego Brick Sculptures and Robotics Education, Proceedings of the ASEE Annual Conference, Session 3353, 1999.
[7] Nagchaudhuri A, Singh G, Kaur M and George S, Lego Robotics Products Boost Student Creativity in Pre-college Programs at UMES, Proceedings of the 32th ASEE/IEEE Frontiers in Education Conference, Session S4D, 2002.

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[8] Patterson-McNeill H and Binkerd C, Resources for Using Lego Mindstorms, Journal of Computing Sciences in Colleges, 16: 48-55, 2001.
[9] Petre M and Price B, Using Robotics to Motivate “Back Door” Learning, Education and Information Technologies, 9: 147–158, 2004.
[10] Portsmore M and Cyr MRC, Integrating the Internet, LabVIEWTM, and Lego Bricks into Modular Data Acquisition and Analysis Software for K-College. Computers in Education Journal, 11, 2001.
[11] Rogers C and Portsmore M, Bringing Engineering to Elementary School, Journal of STEM Education, 5, 2004.
[12] Teixeira J, Aplicações da Robótica no Ensino Secundário: o Sistema Lego Mindstorms e a Física (Master dissertation). Coimbra, 2006.

Paper presented at the 3rd International Conference on
“Hands-on Science. Science Education and Sustainable Development”,
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The UNIQUE AND UNIVERSAL Project Exploring and Sharing our Ecosystems through Scientific Processes

Erentay N and Erdoğan M

Introduction

In Turkey, the process of developing a National Environmental Action Plan (NEAP) was initiated in 1995, and completed in 1999. Recently, a 'Science and Technology Course Curriculum' has been developed by the Ministry of National Education with the cooperation of the Board of Education.

As far as the newly developed curriculum is concerned, it is important for the students to learn how to use their scientific knowledge outside the school. In the new program, the students' affective and psychomotor aspects are emphasized, as well as their cognitive aspects.

The dimension of the environment is highly emphasized in the new curriculum, when compared to the previous science education curriculum. Environmental issues are introduced with "learning by doing" methods instead of theory-based instruction. Not only hands-on but also minds-on activities can be improved by the new approach. In teaching and learning environmental issues, student-centred instruction methods such as discovery learning, inquiry learning, role playing and games are designed. Problem-based and experimental-based approaches are used instead of didactic approaches.

In this study, in order for the students to understand and interpret the interrelationships within ecosystems, field work (with particular emphasis on a water monitoring program) has been adopted.

Pohl notes [1] that Dr William Stapp from the University of Michigan launched an environmental program in 1987 that went on to become the basis of water quality monitoring in educational institutions.

Review of the Literature

As far as the research carried out by [2] is concerned, there is no correlation between students' knowledge about the environment and their behaviour towards nature. The findings of another study of 5^{th} grade children indicated that there is a negative correlation between these two factors [3]. This shows us that even though

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students have some knowledge about the environment, they are lacking in knowledge about how to apply this in real life.
As a result of this project, students will be able to use scientific processes to understand the cause-and-effect relationship of their scientific knowledge. They will be able to apply their knowledge in real life situations to alter negative aspects of human behaviour into the positive action.
Students will be able to gain an "ecological identity" by finding the answers to four basic questions [4];

- What do I know about the place I live?
- What is the source of living and non-living organisms?
- What is the relationship between the Earth and me?
- What is my role as an individual, what can I do?

Study Site

Mogan Lake is the wetland ecosystem that has been chosen as the target area to be studied by the author and the project team. It is a large, shallow lake located about 20 km south of Ankara in Turkey. There are several small villages around the lake. It is an important recreational area for the people living in Ankara. The Lake is highly eutrophic.
The Lake has been polluted by nutrients and other pollutants together with the domestic and industrial wastewater discharged from a nearby town, villages and industries.

Figure 1. Mogan Lake photographed by a Turkish student in the team

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Study Plant

Centaurea tchihatcheffii is an endemic plant in danger of extinction (according to the criteria used by the IUCN- The International Union for the Conservation of Nature and Natural Resources). It is also included in the list of the plants under preservation in line with the Bern Agreement [5]. The students in the author's school first planted the seeds of this flower in 2004 and have been in the process of adopting and conserving it voluntarily since then.

Significance of the study

In this pilot work, a water quality assessment model making use of hands-on science activities for students, together with the characteristics of an endangered species living in the surroundings have been studied.

Figure 2. The Yanardöner Plant (Centaurea tchihatcheffii) photographed by a Turkish student during the field work

Why Field Trips?

Field trips are significant, because by providing an active and effective learning environment, they can promote various aspects of student development. For example they;

- facilitate the learning and retention of abstract concepts [6]
- motivate students through increased interest and curiosity [6]
- teach scientific methods by example [6]
- increase science scores when collecting data monthly [6]
- increase student-student and student-teacher social interaction [6]
- provide useful experiences for students with behavioural problems. [6]
- facilitate a sense of community among students through shared experiences [6]
- together with museum exhibits, provide 'hands-on and minds-on' activities which encourage students to experiment and ask questions [6]

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Why Water Monitoring?

Water is significant. Water is life. Without water, no living organism on Earth can survive. As revealed in the study carried out by Pohl [1], the water quality monitoring study encourages the students to get involved in real life situations through the monitoring of a local stream or river.

Pohl also adds that monitoring water quality promotes students to create their own solutions and develop thinking skills.

Purpose of the Study

The *ultimate purposes* of the Unique and Universal Project are to:

- unite students from around the World through their understanding of the responsibility humans have to sustain the environment, not only for themselves but for all living things, upon which they depend for continued existence. Our students are the future leaders of the World, and they need to grow up with a sense of the importance of sustaining the environment
- help the students understand the relationships in nature by studying the impact of human activities in the environment through making use of scientific processes
- encourage the students to understand that threatened ecosystems and endangered species have both unique and universal values [7]

Specific objectives are to:

- increase the understanding of and gain practice in scientific procedures and practices, through investigation and research into endangered species
- increase knowledge, tolerance and appreciation of other cultures by communication between classrooms via the internet and other sources
- learn about the natural world and how human behaviour has impacted on the Earth
- increase knowledge and respect for science
- increase students' appreciation for scientific research and knowledge.

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Desired outcomes can be summarized as:

- developing awareness, tolerance and appreciation of the differences and similarities between different cultures across the Globe from each other
- increasing the knowledge of scientific practices
- increasing the practice of scientific procedures
- increasing critical thinking skills, for example by having students involved in many of the decisions in this project, creating their own presentations, small and large group involvement, local and global awareness
- promoting creative abilities by having students design their own presentations
- increasing self-confidence through positive cultural experiences
- improving other language abilities for Turkish children, and introducing Turkish to their partners
- increasing communication skills in a variety of ways
- increasing inter-personal skills by using both small and large teams
- interviewing a variety of people who are involved in this topic
- increasing awareness and knowledge of local/global environmental concerns
- generating discussion of problems and possible solutions of environmental concerns.

Methodology

Sample

At present, the majority of people collecting data are volunteers. They have an interest in their immediate environment which suggests that they would be interested in carrying out a monitoring program.

Figure 3. The Romanian children preparing a bulletin board for the project

Figure 4. The American students recording their observations

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In the pilot implementation of the Unique and Universal Project:

- Twenty-one 5th graders at the METU Development Foundation School and their parents participated voluntarily in the project. The study group is a combination of ten year old boys and girls.
- Twenty- two students in the same age group from School Number 5 in Satu Mare, Romania also took part in the project.
- Seven volunteer students aged 11-14 (grades 6 to 8) from Roland Park Country School for girls in the USA were the third partner in the project.

Data Collection

At the beginning and at the end of the project, assessment instruments including a knowledge test, an attitude questionnaire and a picture form of the endangered species were given to the students. Also, during the field work, immediately prior to and after completing observations and testing the parameters, the students were given two knowledge tests (one for testing water quality parameters at Mogan Lake and one for observing Yanardöner Plants).

Description of the Study

The time frame of the pilot implementation of the project was defined as October through June. The annual activity schedule was constructed with the author and her volunteer students on the Unique and Universal Project Team.

Figure 5. The Turkish students being introduced to water creatures during the field work

The students in the project team had organizational meetings every Monday after school, during which they researched the related topics using several sources with the guidance of the author, who was also their science teacher. They also

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discussed the issues with the research assistant from the Biology Department of Middle East Technical University (METU) who came to our school to deliver presentations about Yanardöner Plants. They visited the laboratories of the Biology Department of METU to observe the samples of daphnia.
The data collection instruments were prepared by the other author, from the METU Faculty of Education and these instruments were given to the students before and after the pilot implementation of the project. In addition, he carried out focus group interviews with the students. The students shared the knowledge about chosen endangered species to be studied in their target area with their overseas peers via e-mails, created a Unique and Universal Song (with each school in the project contributing a verse in their mother tongue), planted the seeds of Yanardöner Plants within a protected special area in their school garden and took care of them regularly.

Conducting hands-on experiments as part of field work

A significant part of the project was the field studies at Mogan Lake [7]. The first visit was planned by a small group of three volunteer students, who then acted as leaders of the team during the subsequent visits, along with the author. In the field work, qualitative and quantitative data were collected by the students. The qualitative data concerned the general quality of water aspects such as colour, odour and appearance which were tested subjectively by using the five senses.
Immediately prior to the test, a questionnaire with sample questions such as ‘C*an you tell the general quality of water without conducting scientific tests or using scientific equipment?*’ was given to the students and they were expected to write their answers on it before and after the practice [9]. As a whole, three types of parameters were observed and tested in order to get qualitative and quantitative data during the fieldwork. These were:

- *Physical parameters* of water quality such as temperature, depth, and turbidity.
- *Chemical parameters* of water quality such as DO (dissolved oxygen), pH, nitrates, phosphates, iron and copper.
- *Biological parameters* of water quality, such as phytoplankton, zooplankton, insects and amphibians.

Mainly, colorimetric tests were conducted to analyze water samples. Each pair of students tested their own water samples and conducted two tests (for example pH and DO) whereas the other pair conducted two different tests (nitrate and phosphate) [9]. Students shared their test results within their group so that each student had a completed data sheet.

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Figure 6. Two Turkish students recording their observations during the field work

The observed and measured parameters during the field work by the Unique and Universal Project Team were as follows:

- Colour, depth, and temperature
- Turbidity
- Ph
- Dissolved Oxygen (DO)
- Nitrate
- Ammonia
- Phosphate
- Iron
- Copper
- Bacteria.

During all the testing activities and observations, La Motte test kits and sampling equipment were used. The portable field laboratories containing all the equipment and chemicals were provided by La Motte Chemical Company, our laboratory equipment sponsor. The interrelationship between water and living species was observed and then interpreted by the students. Pre- and post- knowledge tests were administered. During the field visit, the parents of the students joined in the process of taking water samples from the Lake, in order to measure the physical and chemical parameters of the water quality.
On the same day, the students and their parents also had a chance to observe and study the characteristics of the Yanardöner Plant (*Centaurea tchihatcheffii*), which is endemic and endangered within this area.

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Figure 7. A Turkish student conducting a pH test, using La Motte kit

Figure 8. The Turkish students conducting turbidity test

A week later, during the follow-up science activity at the Project's regular meeting, the students had short discussions on their findings as they compared and contrasted the differences and the similarities in water quality among the three habitats which were Test Site A (within Mogan Lake), Test Site B (within Mogan Lake) and Test Site C (the neighbouring test site in which Yanardöner Plants grow). The observed physical characteristics of the chosen endangered plant were also discussed and recorded by the team during this follow up activity. Throughout the pilot study, the research about the endangered species and the target regions were exchanged amongst the students from Turkey, Romania and the USA.

Figure 9. Three Turkish students examining water colour

At the end of the term, the same data collection instruments such as knowledge tests, attitude questionnaires and the picture form of the endangered species (which were given at the very beginning of this study), were re-administered to the students and as the final step, the students were presented with an environmental stewardship certificate by their coordinator teacher.

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Findings

The author has observed that when introduced to a field based water monitoring program, students were able to collect, compare, classify and evaluate the data effectively. In addition, the students reported that they enjoyed the learning process far more than when they studied in the laboratory or in the classroom.
From direct observations and testing instruments applied in the author's school, all of the students showed their interest in joining the meetings regularly and in taking part in the field work.

Most of the students in the Unique and Universal Project Team were confident in applying their knowledge for testing physical and chemical parameters of water quality and able to express the cause-and-effect relationship between the test results and their impact on the ecosystem. All of them are keen to continue their studies next year, without being prompted. Letters of appreciation were received from the parents. Some quotations from these letters are given below:

- 'At the beginning of the school term, when my son told me that he would be volunteering in a project, I hesitated at first, because I have never seen my son showing any sign of interest on a particular subject. Then a couple of months later I was very surprised on seeing his enthusiasm, motivation and energy while studying in the project team. Soon after, everyone in the family started to get interested in Mogan Lake and Yanardöner Plants! It turned out that we all ended up being volunteer research assistants for the survival of a plant which I had never known before.'

- 'It is so significant that this project targets young students. The younger the children are, the faster it is for them to gain environmental consciousness.'

- 'It was a beautiful day in terms of organizations and experiments done. Once again I strongly believed that conducting hands-on experiments as part of field work was the best teaching strategy. It was very effective study not only for our children but for us as well...'

- 'This study has been highly successful in showing us what a scientific project is like. I have learnt a lot as well.'

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School : *Teacher :* *Name :* **ACTIVITY Nº : 2** ***Student Data Sheet*** ***Test Site A*** ***Study Site: Mogan Lake*** ***Time: 11.30 a.m. Air Temperature***	
WATER QUALITY TEST CONDUCTED	***TEST RESULTS***
COLOR	**Green**
DEPTH	**1 m**
WATER TEMPERATURE	**16 oC**
CLARITY / TURBIDITY	**50 cm from the surface (15 JTU)**
pH	**8.75**
DISSOLVED OXYGEN	**6 ppm**
NITRATE	**2 ppm**
AMMONIA	**0.5 ppm**
PHOSPHATE	**4ppm**
IRON	**1 ppm**
COPPER	**0.75 ppm**
PRESENCE OF COLIFORM BACTERIA	**Positive**

Table 1. Example of water quality monitoring data and test results

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Conclusions

As far as the outcomes of the activities are concerned, science education through hands-on experiments may be perceived as a new, effective and accelerated method for transforming the study of ecology both into classroom environment and into homes.

In every academic year, at least six field trips are to be organized in light of this pilot study; two in the first term, two in between terms and another two in the last term. Based on the outcomes of each year's study, a different quality monitoring program for water, soil and air is to be studied in order then to be adopted into the science curriculum in the author's school. Students will attend field trips together with their families. The interviews and research questions prepared by the authors will help determine the change in knowledge and attitude of the students together with their parents. The trips will be videotaped. The qualitative findings will be analyzed through qualitative methods and the quantitative findings will be analyzed through quantitative research methods.

Figure 10. The Monarch Butterfly studied by the American students

Figure 11. The Grey Stork studied by the Romanian students

Students will publish the results on the website so as to share their knowledge with as many children as possible both nationally and internationally. They will also carry out the mission of sharing their vision with students all over Turkey. During the second year they will survey an agricultural area close to their school. They will also study Toy Birds, soil analysis, soil pollution and the materials causing the pollution. They will apply similar hands-on scientific techniques in the third year for air quality monitoring program. The workshop that will be carried out in the conference will include the assessment of water quality parameters and interpretation of the results by making use of hands-on experiments for colorimetric analyses and the data charts

It is the author's hope that this information will be used to educate public, and promote collaborations between NGO's and educational institutions, so as to form a sustainable future not only for the human kind but for all creatures in the universe.

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I owe a special debt of gratitude to Professor Dr. Jim Westgate. Without his support, I would never have been able to share knowledge and ideas with my American colleagues. Special thanks to Prof. Dr. Ali Yıldırım for his continuous encouragement and motivation. Thanks to the METU Foundation School for its encouragement to carry out the project. Thanks to La Motte Company for their technical support with water monitoring test kits and sampling equipment. To these dedicated teachers, we extend heartfelt thanks for their great contributions in our project: Martha Barss, Science Teacher at Roland Park Country School, Baltimore, MD, the USA, Ancuta Nechita, English Teacher in School Number 5 Satu Mare, Romania. Thanks to Jill Aslan for her contributions to the study. And finally special thanks to my 5th grade students and those in other schools, who have been volunteers in this project.

References

[1] Pohl RR, An Evaluation of the Learning Outcomes in Environmental Sciences from Field-Based Water Quality Environmental Unit, Unpublished Doctoral Thesis, Curtin University of Technology, Australia, 1999.
[2] http://adt.curtin.edu.au/theses/available/adt-WCU20010822.135254/
[3] Alp EA, Study On Students' Environmental Knowledge and Attitudes: The Effects Of Grade Level and Gender, Unpublished Master Thesis, METU, Ankara, 2005.
[4] Erdoğan M, A Curriculum Design For A Fifth Grade Environment Course, A project report submitted to METU, Faculty of Education, Department of Educational Sciences, Ankara, 2005.
[5] Thomashow M, Ecological Identity: Becoming a Reflective Environmentalist, Cambridge, MA: The MIT Press, 1995.
[6] http://www.ecoschools.org/new/newsletters/es0206.pdf
[7] http://www.tea.state.tx.us/curriculum/science/GuidelinesBW.pdf
[8] Erentay N, Nasıl Bir Doga Egitimi? [What Kind of Nature Education] / Bilim ve Teknik Dergisi TUBITAK Mart, 2006.
[9] Can T, Mogan Gölünde Bir Gün, [A Day at Mogan Lake]. Bilim Çocuk Dergisi, TUBITAK, Haziran, 2006.
[10] Taylor BE, Wetland and Water Quality, 2003.
[11] http://www.uga.edu/srel/kidsdoscience/kidsdosciencewetlands.htm

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Teaching Electrical Engineering through Demonstration of Real Devices and Computer Modelling: Electromagnetic Gun and a Miniature Circuit Breaker

Krizaj D, Penic S, Tacar D and Drnovsek B

Introduction

Teachers are continuously seeking methods for better motivation of students. It is not difficult to find parallels between good motivation and a learning success. Besides, we all agree that learning should not be only gathering information but being capable of using this information in practice. Although computers and computer animations are still a very important means of motivation, we believe the most attractive approach would be to use both - real as well as virtual experiments. Furthermore, there are many possible ways of using real as well as virtual experiments. There is certainly not only one good solution but rather a large variety of possible ways to efficiently incorporate real as well as virtual experiments in the learning process.

We present in this paper a concept of teaching basics of electrical engineering at the faculty level (1st year of studies) through a demonstration of real experiments and use of several approaches in order to achieve improved understanding of the underlying concepts.

The core of a concept is a (real) experiment: a device that incorporates two devices in one. The first is an electromagnetic gun that is in reality an electromagnetic valve and the second is a miniature circuit breaker (MCB). The first device is prepared mainly for explaining the basic principles of electronics and formation of electric and magnetic field while the second is a real apparatus made by a local industry. The name for the device »electromagnetic gun« is used mostly for the purpose of raising interest. We have successfully used this device at the expositions for youth that our faculty organizes each year at a local technical museum and as a supplementary motivation based material in the classroom. One can explain through it some basic principles of electrical engineering such as charging of capacitors with electric charge, rectification, operation of an electromagnetic valve, conservation of energy, etc. We will present some of these concepts in this article.

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Construction of a device

The device is shown in Figure 1. The most visible part of the device are a bank of capacitors (five of them with capacitance approx. 70 μF each), a voltmeter (used to show the charging process), the electromagnet with a tube for “loading” the “ammunition” (ping pong ball), the transformer used as an isolation transformed and a printed circuitry with necessary residual elements used to run and monitor the experiment. On the side of the case is mounted a miniature circuit breaker.

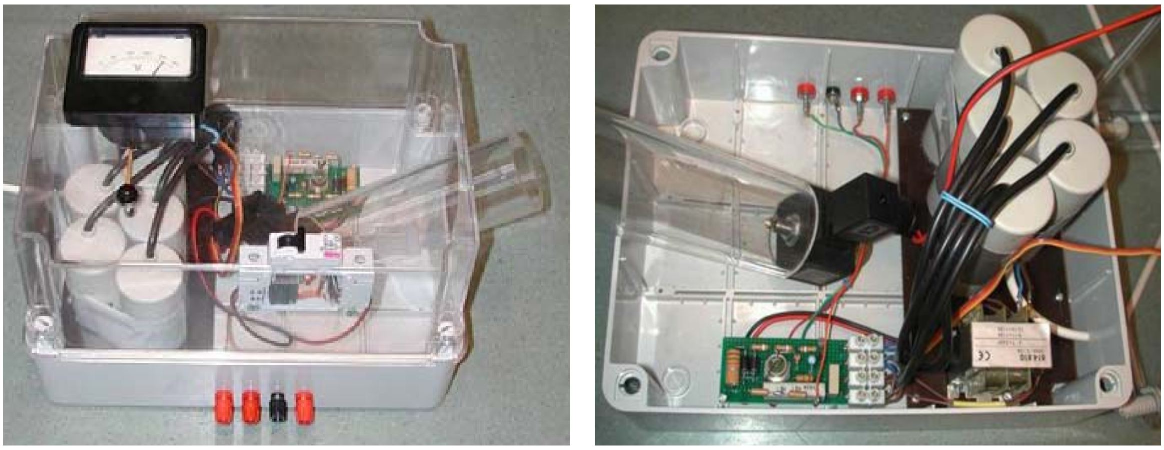

Figure 1: Electromagnetic gun and a circuit-breaker. The capacitors are charged using simple half rectification. The energy is released through the electromagnetic valve (if the MCB is in the off state) or through the MCB (if it is in the on state). On the front side is a MCB with one side removed so the discharging event (small spark) can be observed. Current and voltage signals of the charging and discharging event can be monitored by connecting the device to the oscilloscope

Operation of a device

The device operates as an electromagnetic gun and/or as an electromagnetic miniature circuit breaker. They are connected in parallel so if the MCB is in the off state, the released current is fed directly to the electromagnetic valve. In case the MCB is on, its resistance is much smaller than that of the electromagnetic valve, especially in case of a sharp current discharge (that we are practising in this configuration). We use simple rectification from AC 230V source (home appliance) with a single diode to rectify the current and charge the capacitors. The charging is slow (complete charging is achieved in about 30 seconds) in a sense that it can be tracked visually on the voltmeter mounted on the top of the case. Furthermore, special pins are added to the side of the device so the capacitor charging (rectification principle) can be tracked on the oscilloscope (Figures 3, 4 and 5).

After the capacitors are charged they can be discharged through the electromagnetic valve or through the MCB. Instead of a simple mechanical switch, we use an electrical element - tyristor. The reason is relatively large discharge current (several amperes) that could lead to destruction of a mechanical switch after

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its frequent use. Furthermore, we have an opportunity to demonstrate the operation of a tyristor as well.

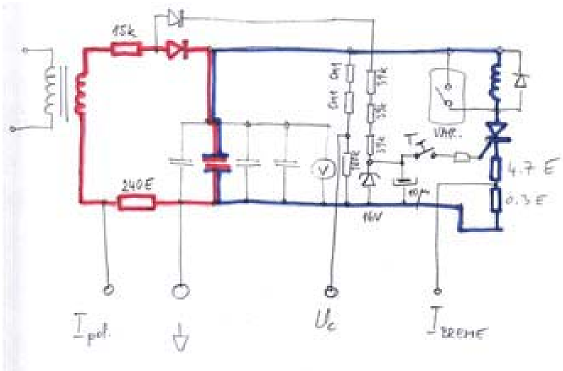

Figure 2: A sketched drawing of a device with two main circuit loops. Left (red): charging loop, right (blue): discharging loop

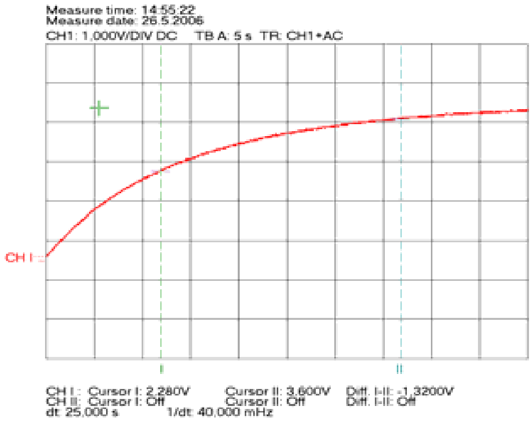

Figure 3: Capacitor charging demonstrated through quasi exponential increase of capacitor voltage

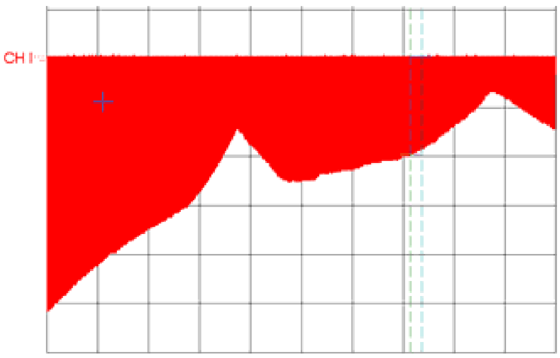

Figure 4: Charging current is decaying as expected. However, some still not well explained current bumps are observed at not completely charged capacitor voltage

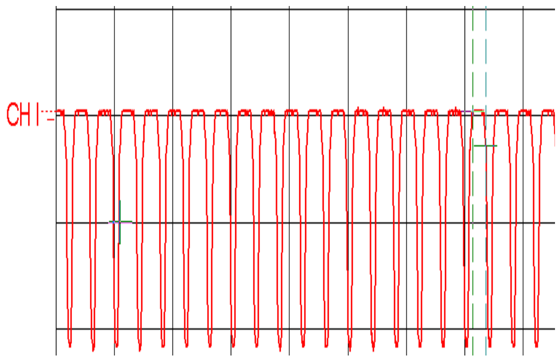

Figure 5: Zooming a detail from Figure 4 would give the following current signal

If the energy from the charged capacitors is released through the electromagnetic valve, the force on a piston is sufficient to shoot a projectile into the air. Most frequently we use a ping-pong ball as a projectile. A resistor of a small value is used to demonstrate the discharge current on the oscilloscope (Figure 6). In another experiment the MCB is in the on state and the capacitors are discharged through the MCB. The current waveform is much sharper and much higher currents are achieved (Figure 7). The second part of the curve shows similarities with the current through the electromagnetic valve. In fact we observe action of a parallel connection of a miniature circuit breaker and the electromagnetic valve.

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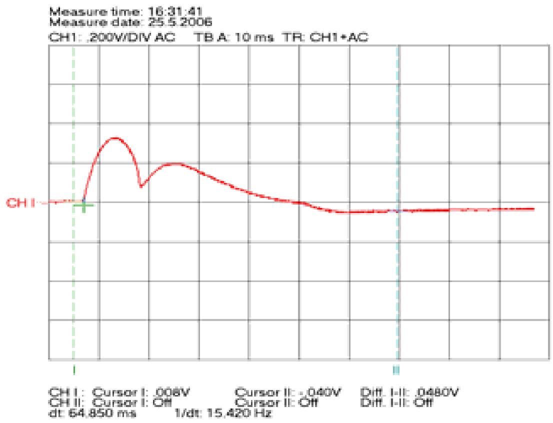

Figure 6: An interesting current discharge through an electromagnetic valve is observed. The reason is inductivity change invoked by movement of the piston inside the electromagnet

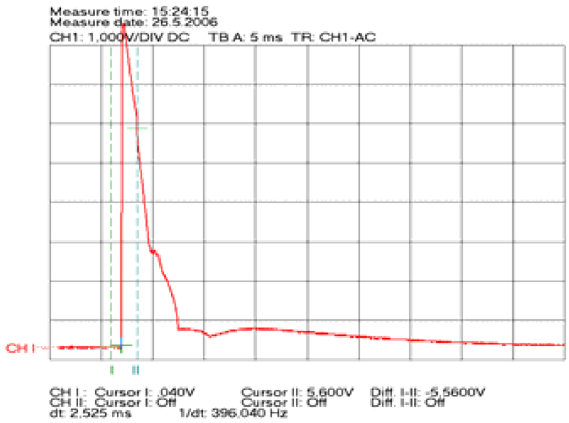

Figure 7: A discharge current observed when the MCB was released

Demonstration of high-current tests performed on miniature circuit breakers

The miniature circuit breakers are required to sustain very high currents – they have to remain in the off state even if extremely large currents destroy the device. Therefore the producers have to perform tests where the miniature circuit breakers are subjected to currents of several thousand amperes. Due to requirements of instantaneous high currents (at a voltage of about 250 V) these tests are performed in special testing room located near the electric power station. These tests are very attractive since breaking of such high currents results in flashing, sparks and noise. Figure 8 shows a picture of one such event.

Figure 8: Sparks and noise at testing of MCBs subjected to currents of several thousand amperes

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The students observe these photos and figures and discuss the following procedures: what are the requirements the producers have to meet, what are the maximal currents at disconnection, what are the spikes in voltage signal (due to the arc formed), why is the current not completely disconnecting the device after the spark, etc. We also discuss some important parameters such as dissipated energy at the disconnection, time to complete disconnection, etc. Discussing these parameters through the theoretical knowledge they have gained through the lectures gives them a sense of importance of the (otherwise useless) theoretical learning phase.

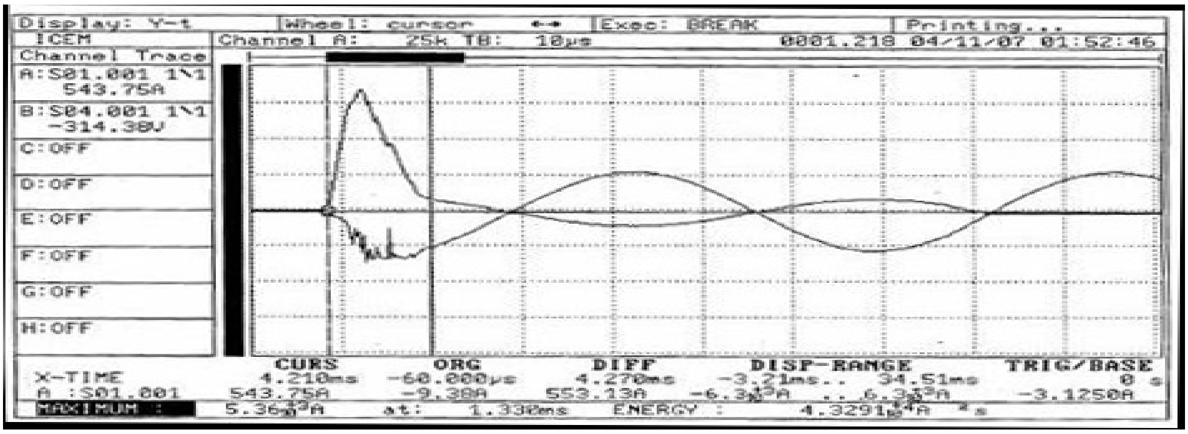

Figure 9: Current and voltage of the circuit breaker in a disconnecting (breaking) phase

Modelling

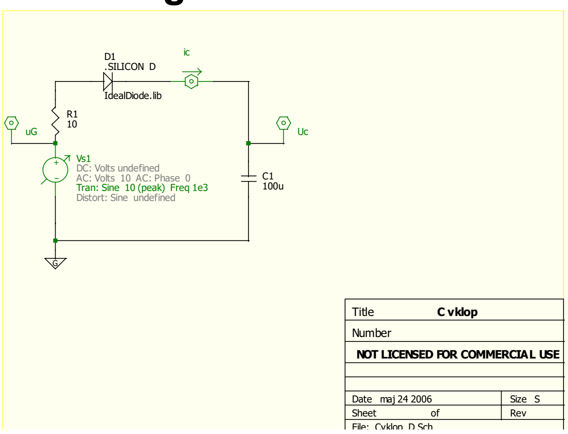

Figure 10: Schematic layout for modelling capacitor charging constructed with 5Spice (www.5spice.com)

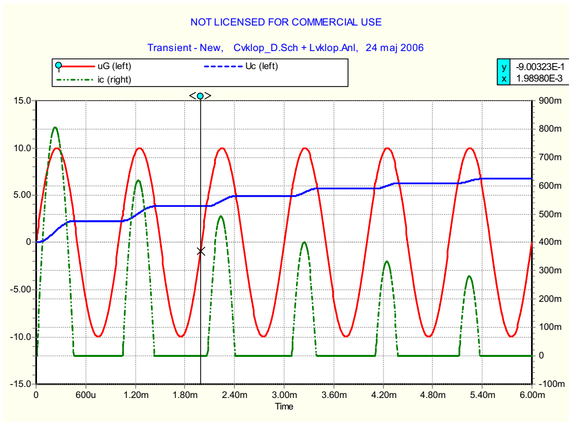

Figure 11: Source voltage, capacitor voltage and circuit current. An increase of capacitor voltage and decrease of charging current can be observed

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Several possible ways of modelling are discussed. First we remind the students of the charging and discharging events discussed at the lectures and then show some alternative ways of modelling these events. One possibility is through use of the programs for circuit simulation. At the University level most often the program SPICE is used, although some students come from secondary schools with some knowledge on simulation using programs such as Electronics Workbench. For information purposes we demonstrate a version of a SPICE program called 5Spice that has a capability of using a graphical user interface.
First, the charging process is modelled and discussed. The result of simulation is presented in Figure 10. The similarities and differences between the simulated and the measured curves are discussed and attributed to the differences between the ideal and real elements. Discharge is modelled using a series RLC circuitry. A large current increase is observed and compared to the measured one (Figure 12). The most notable difference is a double kick that is observed at measurements but not in the simulation. The reason is the time dependant (more exactly movement dependant) inductance of the electromagnetic valve that is in the simulation disregarded. The most important message is that simulation gives a good and nice (graphical) insight into the basic principles of operation of the device, however, the practice would bring some non-ideal conditions that would also need to be discussed and explained in order to understand the operation of the device in depth and to be able to improve its design and operation. An important part of the electromagnetic gun as well as the miniature circuit breaker is an electromagnetic valve. Its operation is modelled using numerical simulation program Femlab (www.consol.com) that enables study of magnetic field distribution inside the element. The magnetic field density is visualized using arrows (vector field) as well as colours (absolute value of magnetic field) as presented in Figure 13. Concepts as magnetic field lines, permeability, magnetic energy, force, inductivity etc. are discussed.

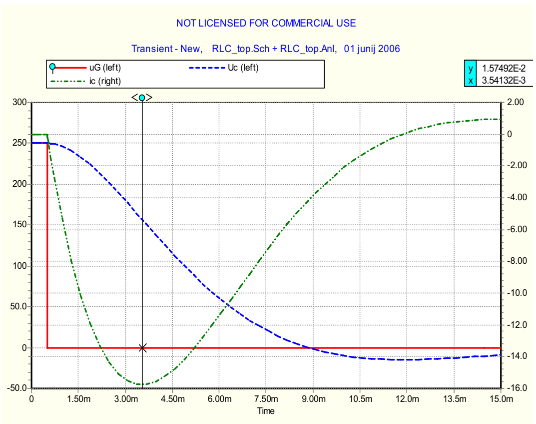

Figure 12: A discharge process is observed through Spice simulation.

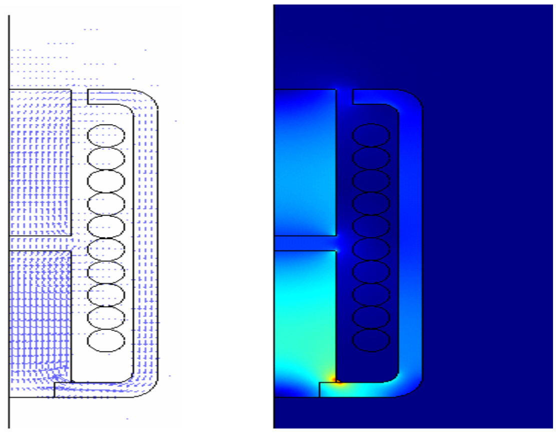

Figure 13: Numerical simulation of magnetic field inside the electromagnetic valve.

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Discussion

We have shown a device that we have developed in order to demonstrate to the students the operation of real devices and discuss the details of design and implementation. It is used in the first year of University level of study of electrical engineering.
There are several reasons for development of such devices:

With a lack of hours for practical work (more than 100 students can attend lectures) we need to add some flavour to the explanation of the theoretical basics.
The students want to know why they will use the knowledge they are attaining. We have to show this not through experiments used to demonstrate the basic principles but through the operation of real devices.
At the moment we do not have special classes to perform computer experiments (modelling) although this is our long term goal. In the meantime, we give the students opportunity to be informed on the possibilities offered through the computer technologies and try to motivate them to use them on their own. Programs such as Matlab or Spice are used in higher classes but we would like to introduce them already in the first year of studies.

Conclusions

In order to motivate students for the study of electrical engineering in the first year of university studies we are continually searching for new methods of teaching. Through several years of experiences we have learned that students are not only interested in real experiments but also want to see how they will be able to use their knowledge in real life. For this purpose we started to develop devices that are at the same time used for demonstration of basic principles of electrical engineering and are containing knowledge that is applicable in real life. In this paper we showed a device that is incorporating an electromagnetic gun and a miniature circuit breaker. Through discussion of design and operation of the device the students learn such material as rectification principles, charging and discharging phenomena, energy stored in electric and magnetic field, etc. It is intention of the authors to share ideas as well as devices with other researchers and pedagogic workers that would see the same benefits of this type of supplementary material for learning basic electromagnetic phenomena.

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Indoor Interactive Science Museums in School

Dorrío BV and Villar R

Introduction

New educational tendencies consider the importance and influence that informal learning has in the constructing of scientific knowledge [1], in which various interests, agents, values and actions come together and interact, and this is why it necessarily entails a balance of all this system, which is directed towards growth and development. Amongst the various intervention strategies that exist to bring people closer to Science, what stands out are the new interactive museums [2-3] which emerged at the end of the 20th century with the appearance of a new public with new scientific-technological demands which gave impetus to a conceptual change in traditional museums, they stopped being mere collecting objects, to become one of the fundamental bases of education for people. At present, interactive science museums [4] have opened their doors to a public eager to satisfy their natural curiosity in a world which is highly technical.

However, real specific situations do not always answer to or come near to this new conception of a scientific museum, which is partially explained by insufficient funding, the absence of specialist in many of the tasks related to the sector and the apparent discrepancy between the museum and educational world.

The educational world can set into motion new mechanisms and performance strategies in the learning of Science by using the existing resources in running a museum, by always choosing the use of specialists in the varied areas involved, so that all the potential that this sector should develop increases in value and also by creating the necessary channels so that the school, as a whole, becomes an active element, as a recipient of the value and service of this particular system of communication [5] such as: scientific value, cultural value, educational value and the social value organized in the heart of the educational community, as occurs in certain concrete cases [6].

In this essay we present the theoretical premises related to the objectives, results and methodology associated to the design, assembly and evaluation of an Indoor Interactive Science Museum (IISM) in the school itself. The practical execution of these ideas has been carried out during the last three years in various teaching centres coordinated by the Universidad de Vigo within the Hands-on-Science network [7].

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Objectives

The main objectives of our proposals are centred on promoting a playful and contextualized approximation to Science by creating an interactive museum within the formal learning environment itself [8-11]. To achieve this objective it is necessary for other more specific ones to be achieved, amongst which we could mention:

- The creation of a general information framework for the museum's visitor, so that the visitor has an organized and documented presentation available of the interactive modules which they can use.
- To spread, in the interactive museum, the existence of signifiers linked to the contents of a formal curriculum.
- Create a self guiding interpretive tour organizing the movement of the public so that it is possible for them to make the most out of the experience.
- Help in the comprehension of concepts, principles and laws demonstrated through the installation of self-explanatory interpretative panels.
- Organize the public's movement within the interior space, allowing for their attention to be called to certain signifiers noticed with difficulty by the visitors.
- Highlight the concepts related to daily reality and the previous experience of the visitors.
- Put into practice the actual techniques of interpretation which contribute to awakening feelings and committed attitudes with the values in question.
- Create other elements of interpretation which are easily available and of personalized use.

Methodology

In this proposal we attempted to set into motion a process directed to all agents related with it: teachers, pupils and families, covering an important chronological section of the population, based on the presupposition that it is possible to import the interactive museum model into the school environment in which the resources involved are linked to the creation of a communicative system in the school, different to that traditionally used which is defined by the unidirectional mode teacher-pupil. As in all communicative experiments, it is also possible to identify here as the basic elements: the transmitter (the museum space itself in the school), the recipient (represented above all in this case by pupils and their families), the message (numerous and heterogeneous, made up of a set of signifiers previously selected by the teacher amongst many possibilities) and the medium (understood as the techniques and procedures that are used to ensure the success of the communicative system).

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Figure 1. UVigo IISM

The methodology for the organization of an informal learning experiment of this kind needs to be based on pedagogical criteria, which once defined, orientates the construction of the same devising the pedagogical relations of the learning and communication system [12]. Thus, once a group of pupils and teachers (agent) have made the decision to carry out a learning experiment through the implementation of an interactive museum for the school community (subject), the imminent question is to clearly define the fundamental ideas or concepts (object) which are intended to be transmitted in the school itself (medium). Figure 2 shows the relations (pedagogical, didactic, of teaching and learning) which are established according to the discourse or set of messages which are trying to be transmitted and the objectives set out [11]. All the concepts dealt with will necessarily have to be related to the academic curriculum, be coherent with the objectives of the activity, accessible in their presentation and have a hierarchical organization. For its presentation and transmission several mediums will be considered which will consider the possibility of several reading levels and will be orientated towards the stimulation of several capacities: observation, use, mental agility, use of the senses, etc…

The agents who act in the setting into action of the experiment should involve, as a minimum, the group of teachers related to the subjects and a group of pupils who voluntarily join the activity. Any other kind of professional contribution will enhance the project, but on the contrary, this will not be possible if it is by unilateral decision or imposition by one of the parts. It will be necessary to define the figure of the coordinator of the teamwork in order to organize, distribute tasks and supervise the phases of coordination and/or creation of the medium in a way and form which we have designed to materialize the experiment. These agents will participate in the carrying out of the whole process: the preparation of the discourse, execution of the medium, transmission agents,… becoming themselves active elements of the medium and of the same evaluation.

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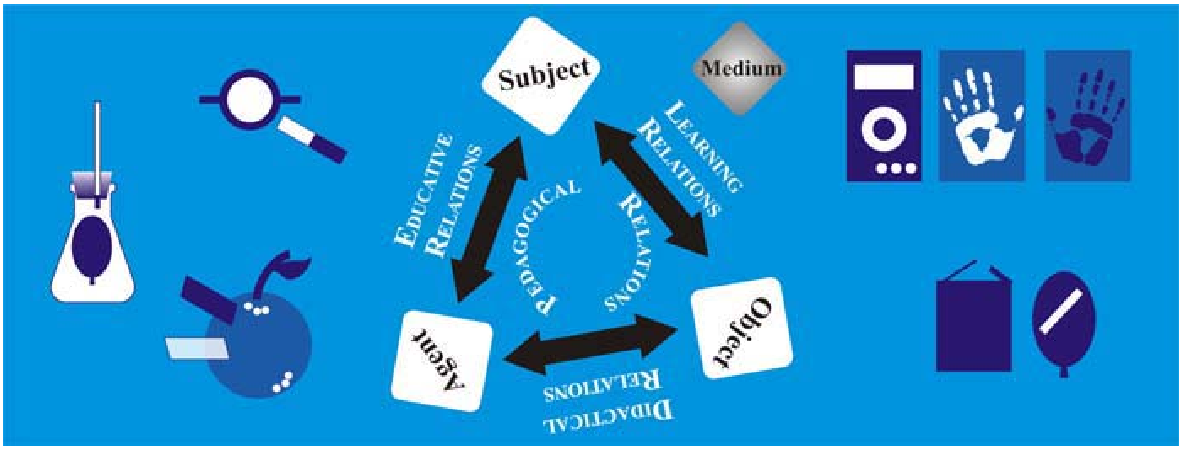

Figure 2. Pedagogical relations in Indoor Interactive Science Museums in School (based on Legendre 1983)

The definition of the medium requires theoretical and practice proceedings for the materialization of the setup as a learning situation. This means the definition itself of the necessary physical space, which must be the centre itself in which formal education takes place: a laboratory, a playground, a classroom, an auditorium, an assembly hall, a gym… The interior organization of this space must be coherent with the tour layout and the presentation of the contents, it being usual to organize the direction of the visit, although sometimes on occasion it is possible to setup experiments which allow the visitor to freely choose according to their interests. In the event of a spatial organization of the experiment existing, it must be duly indicated.

Figure 3. Auga da Laxe Secondary School IISM

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In relation to the role that the voluntary pupils (agents) should develop in support of the transmission of the contents, we can say that they must transform themselves into real interpreters of the selected message. Thus, each person will be in charge of an experiment or set of experiments related thematically and far from being limited to waiting for visitor's questions they should show a receptive attitude by being prepared to talk and arouse curiosity with simple explanations, using a language that is accessible and also explain its relation to daily life. They should be prepared to listen and express themselves in a correct manner and tone, using their hands to point and always be situated in front of the visitor. In like manner, the pupils involved in the experiment become protagonists of a rich and motivating experiment due to the novel value it presents.

Figure 4. Escolas Proval Secondary School IISM

For the presentation of the contents which are intended to be shown in this communicative system, a selection must be made from an immense wealth of information available at present. In order to do this the interests of the pupils, the time available, their material needs or conceptual level will have to be taken into account. Once the selection phase of the written information is over, the same criteria are used for the graphic information. The use of plans, drawings, sketches, photographs, maps, etc is essential to improve the perception of these realities. In the communicative systems that are trying to be built, the public, helped by the necessary infrastructure, carry out the visit according to their own rhythm and interests.
As a general rule, the contents that we want to transmit should have some point of contact with the reality or daily life of the public and they should be offered in an attractive way. If it were not so, we would run the risk of failure due to the loss of interest during a visit which may have nothing in common with the social, cultural or motivational reality of the public for whom it is directed. The use of everyday materials for the physical production of the interactive modules establishes

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important relations between scientific learning and personal experience so that pupils easily assimilate the fact that the theoretical contents of a classroom have an immediate reflection in their lives.

Figure 5. A Xunqueira Secondary School IISM

The contents of this design can be classified as follows:

1. Informative, of a generic nature, they correspond to a level of reading directed towards all the visitors. They are formed by clearly stated messages about the objects they can visit, the nature of the visit, itineraries, the instructions to follow, points of interest, information area and recommendations on the approach to be taken.
2. Interpretive, more specific and containing messages with significance about concrete aspects of the diverse interactive museums. These contents are thematic; they are organized according to their specificity on several levels. For their presentation sentence-topic titles will be used, continuing with texts made up of a maximum of 100 words with an attractive, understandable message, relevant to the Ego which receives it, with a logical outline and a central idea. Also, this message has to attract attention, have credibility and be short. These messages will be basically installed on panels near the significant elements (the interactive modules) to which they refer to.

Besides the self-explanatory panels it is very useful to have certain publications which contribute to the interpretation of our school museum. This material of personal use, which has the advantage of being taken and read whenever the user

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wants to, can be used by others; they provide detail and nearly always are a souvenir of the experience.

Figure 6. Poio Secondary School IISM

To be more precise, we are referring to different kinds of publications which, amongst others, will be suitable for obtaining the structural objective of offering several levels of reading. Accepting the obvious, that the putting up of posters is to all appearances unsatisfactory, the printed media turns out to be more precise and concrete, allowing a thematic deepening, for example a guide book (available for teachers who accompany the pupils during their visit and offers the possibility of deepening the communicative experiment for the sector which is interest in it) or leaflets (which gives all the information of a general and practical nature in order to favour the correct development of the self guided tour by the pupils who can receive the leaflet in the museum itself or beforehand in the classroom).

Evaluation

All educational participation projects should consider as the final stage, the creation and setting into motion of some kind of mechanism which allows for the evaluation of the functioning of the same and observes the weak points once it has begun, so that necessary strategies can be designed to eliminate them.
There are several evaluation mechanisms [13] for these kinds of activities directed towards the public and which, in general subject the project to a preliminary test with a reduced group of visitors made up of a similar public to which it is directed, apart from the system of preparing a brief and studied questionnaire that the public can answer in a totally voluntary and anonymous manner, and which would be offered and collected by the voluntary pupils.
In regards to the first of them, there are currently several tests provided by the same theory on interpretation which allows for the evaluation of certain aspects,

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such as the medium used for the interpretation, the analysis of the interpretative potential of the same, the role of the monitors, etc. Once this phase has been passed, we are now interested in establishing the evaluation mechanism of its effectiveness for the public and the attainment of the proposed objectives.
Finally, a meeting with the voluntary pupils who worked on the experiment, following a pre-established questionnaire, will give important complementary information of the experiment and with it the success of the activity will be measured. The results of the monitoring and evaluation will permit the discussion of the mechanisms of correcting errors and shortcomings pointed out or suggestions that are easily incorporated, as long as they benefit the project.
The results obtained from these kinds of experiments carried out [14-16] show on the one hand, a limited presence of pupils in conventional interactive museums in the context of their extra-school activities but on the other hand a big interest and enthusiasm in participating in the set up of this kind in their own schools. Apparently, they consider it to be a useful source of information and that it shows daily applications of Science and Technology.

Conclusions

Interactive museums are important factors devoted to teaching the public. The importation of the model into the world of formal learning can be an additional tool to bringing Science and Technology closer to pupils and it also becomes more relevant for them. In this essay we have theoretically presented the methodological guidelines needed to carry out this process, showing in addition the most common advantages and difficulties. The results obtained over the last three years, with these kinds of experiments in the centres coordinated by the Universidad de Vigo within the Hands-on Science network are highly satisfactory as reflected in the high level of participation and motivation of the pupils. It seems sufficiently proved that the pupils learn better when they explore the phenomena and concepts for themselves. It is the teacher’s task to give them the indications and tools they need in order to explore and learn. We believe that interactive museums in schools allow pupils to approach Science as apprentices and discoverers. Possibilities are multiplied if the pupils are given the opportunity a posterior to carry out similar experiments on their own with real, simple and common materials such as those used during the activity.

Acknowledgements

This work could not have been carried out in a practicable way without the help given by the pupils and the members of the institutions coordinated by the Universidad de Vigo and associated to the “Hands-on Science” (110157-CP-1-2003-1-PT-COMENIUS) network of the Socrates/Comenius programme of the European Union, to all of them we wish to express our most sincere gratitude for the excellent work carried out.

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References

[1] Wellington J, Formal and informal learning in science: the role of the interactive science centres, Physics Education, 25: 247-252, 1990.
[2] Resnick LB, Learning in school and out, Education Researcher, 16: 13-20, 1987.
[3] Ramey-Gassert L, Learning Science beyond the classroom, Elementary School Journal, 97: 433-450, 1997.
[4] http://www-2.cs.cmu.edu/~mwm/sci.html
[5] Rennie L and McClafferty TP, Science Centres and Science Learning, Studies in Science Education, 27: 52-98, 1996.
[6] http://www.exploratorium.edu/cils/
[7] http://webs.uvigo.es/h-sci/
[8] Zollman D, The Physics Activities Center. A mini-exploratorium, The Physics Teacher, 12: 213-216, 1974.
[9] Quin M, What is hands-on science, and where can I find it?, Physics Education, 25: 243-246, 1990.
[10] Sampere SM, The Neon sign, The Physics Teacher, 37: 140-141, 1999.
[11] Legendre R, L'Éducatión totale, Ville–Marie: Montréal, 1983.
[12] Dorrío BV, Rúa A, Soto R and Arias J, Hands-on Physics Bibliography, Proceedings of the 1st International Conference on Hands-on Science, Teaching and Learning in the XXI Century, Divjak S (Ed.), 2004 July 5-9, Ljubljana, Slovenia, University of Ljubljana, pp.: 119-124, 2004.
[13] Korn R, Introduction to Evaluation: Theory and Methodology, Berry N and Meyer S (Eds.), Museum Education: History, Theory and Practice,The National Art Education Association: Reston, pp.: 220-238, 1989.
[14] Villar R and Dorrío BV, Science interpretation in high school, Proceedings of the 2nd International Conference on Hands-on Science. Science in a changing education, Michaelides PG and Margetousaki A (Eds.), 2005 July 13-16, Rethymno, Greece, University of Crete, pp.: 184-189, 2005.
[15] Rodríguez S, Fernández J, Asín JA, Lago A and Dorrío BV, An informal interactive science and technology centre, Proceedings of the 2nd International Conference on Hands-on Science, Science in a changing education, Michaelides PG and Margetousaki A (Eds.); 2005 July 13-16, Rethymno, Greece, University of Crete, pp.:190-195, 2005.
[16] Villar R and Dorrío BV, Aproximación a la arqueología: un ejemplo de interpretación del hecho científico, Íber, 48: 115-125, 2006.

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The Role of Science Centres and Museums in Teaching Science

Kothari S and Kothari A

Introduction

An important step in the direction of enhancing the role of museums and science centres could be after a natural calamity, or much better before something of the sort occurs, to make people aware of the science behind it, so that people don't link it to superstition.

In India, we find a dichotomy, where on one hand; there is widespread technological awareness in IT hubs like Hyderabad and Bangalore, and on the other, there are beliefs among people that natural calamities occur because of some wrongdoings of theirs in the past life. Thus, there is employment of godmen and others of the kind.

India is today facing global problems like Tsunami, Bird flu, Earthquake, Manmade Disasters (like Bhopal gas tragedy) etc; so the need today is felt all the more for greater scientific spread of understanding among the masses. This calls for the development of participatory exhibits and low cost material. Manthan has made short term programs on these topics which were made very effective by using this material.

For example, after the earthquake in Kutch in 2001, the kits for Vigyan Prasar prepared by us on 'Understanding Earthquakes' became very popular amongst students and the community. This served a dual purpose, firstly, there was better understanding of the phenomenon along scientific lines, and secondly and more importantly, there was spread of science and its importance among the youngsters. The thing to be noted is the that Manthan used low cost toys and other material to explain things like precautions to be taken before, during and after an earthquake, for example, a simple slinky was used to explain seismic waves.

We concluded from this exercise that existing exhibits and programs could be made very effective by using participatory elements in the exhibits. That is because putting an idea in the form of an interactive exhibit is very different from an explanation or experiment in the laboratory. Our exhibition on Solar Eclipse helped communities to understand this phenomenon. It also helped to create awareness against superstitions related to Solar Eclipse and more than a million people used our safe solar viewer to view the eclipse in 1999.

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Figure 1

Our experience taught us that getting the community to be a part of the experiment helps to generate and maintain interest in the activities. Manthan has distributed many activity kits related to scientific phenomenon in order to get the children involved, once an interest is generated and curiosity aroused, the student remains interested in the subject. The activity kits would consist of colouring pictures, making cut outs and other things, little information booklets, do-it-yourself little experiments and many such related activities.

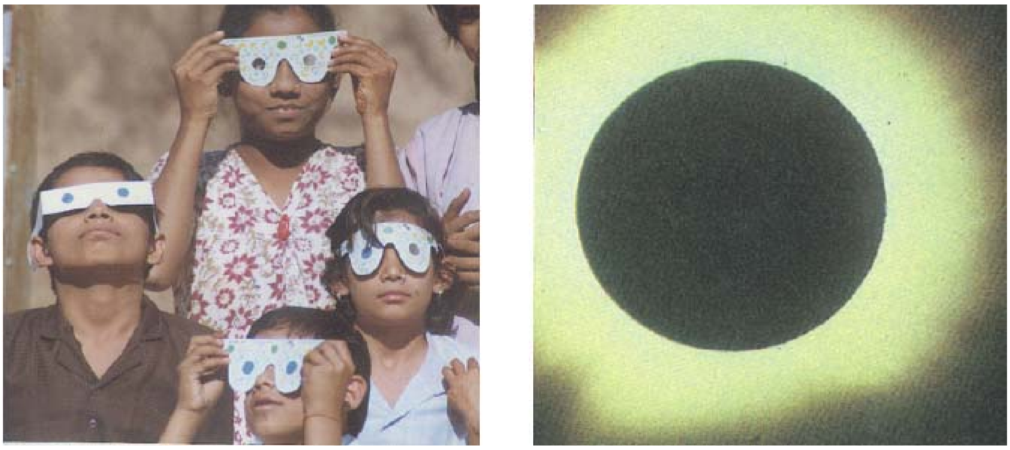

Figure 2

Low cost thematic science kits and other carry home materials generate great interest. A child or any member of the community takes away mini museum idea to his/her home. It is something like mobile science centres. Manthan also designed some 'Interactive Radio Programs outreach material for National Council for Science & Technology Communication / DST, Govt. of Indi based on science. It collaborated that with the distribution of kits to registered listeners, which could be

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used according to the instructions on the radio. This was a very popular show and generated a lot of response and enthusiasm from students.
Before the Radio program on Biodiversity, we sent thematic science toys (made from paper) to the registered listeners.
Our kit on Nature designed for the 'National Natural History Museum', New Delhi was very popular amongst students. The material designed in such a way that by displaying, one could create a mini museum on his/her table.

Figure 3

Jathas have been another innovative way employed by Manthan as Low cost travelling exhibition. They act as mobile science centres, and are especially feasible for developing countries. Two reasons can be pointed out for this, firstly, because they are low cost in assembling and secondly, because they are made from locally available resources. This makes them more easy-to-identify-with in a rural set-up. In the north western parts on India, camels and bullock carts are widely used as modes of transportation. Manthan made use of this to display science.
Our Camel cart science centre went from village to village with science Exhibition, Participatory toys, Mini library and Puppet Show. These were items that the villagers were familiar with and at the same time were interested in, so it was easier to get them to participate in the activities, than through a typical museum or science centre where things are displayed with captions, but which a rural person finds difficult to operate.
It was cost effective, local, and excitable and communicated through the vernacular medium. It is a classic example of where the villagers can't come to the prestigious science centres, so the centres go to them.
Another aspect of science popularization that must go hand in hand to make the science centres more effective is the building up of local and regional networks with common objectives that can help in dissemination of Developmental Ideas faster. These networks can act to communicate common contents, information, ideas, and objectives. This also makes it is easy to implement common programs. This can be facilitated by having a network of NGOs working on grass root levels. Another way

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is to take the district level administration into confidence which can lead to smooth functioning of any Science Development related project.

Figure 4

Our local network in Kutch is working with Regional and international networks in the field of Science and Technology entrepreneurship program of Anjar Knife manufacturers. This district of Gujarat is famous for its knives, but there were a number of problems in this. One was the lack of innovation in the design of the knives which proved to be hindrance in the sense that the obsolete designs were not very market savvy. Also, the knives were made in the little village of Nanareha and were sold cheaply to middlemen who made huge profits. So, the original craftsperson was not getting the required level of profit. In collaboration with the National Institute of Design, Ahmedabad, new designs were created for these knife manufactures. A German exchange student worked on this project and also paid a visit to Anjar to get an idea of the ground reality.
Manthan in a big way participated in the Jathas also, the mobile exhibition with eye catching posters and games and promoted the culture of Scientific Thinking.

Conclusion

Museum and Science centres provide an excellent media to communicate Science for developmental causes. The only area where action needs to be taken is in making them reach out to larger strata of the society and get more people oriented towards it. There is a lot that needs to be done where other than governmental measures; NGOs can play an important role and substantiate the governmental measures with those of their own.
It must also be kept in mind that 'What needs to be communicated?' is clear and well defined.
Developmental programs can be made effective by creating participatory and thematic exhibition. Museums can reach larger segment of the society through that innovative outreach programs. Developmental ideas can be disseminated through

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local travelling exhibits, low cost material and folk performances with the help of networks, which can disseminate developmental ideas among the masses. Workshops can be conducted, and travelling museums can percolate into remote areas. From exhibitions on camels in Northern India to Science teachers travelling on elephant backs to reach villages not connected by roads, Science Communication should be open to new approaches.
Finally, it is important that the process of science communication doesn't stop at the level of dissemination of information for it to be more effective, it is important that this knowledge is used for implementation of developmental programs. Schemes need to be initiated for this purpose too.

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A Low Cost Science Toy Workshop under the Banyan Tree

Kothari A and Kothari S

Figure 1

Storage of science toy making skills opened

The village potter showed us his favourite science toys and ideas used to make them. Some of them were done with amazing imagination and clever material handling like clay.

- Siphon Elephant toy
- Magic Water Pot toy
- Ganges Pot
- Non-Sinkable clay fish
- Clay Bird Calls

They all had a great aesthetic appeal and had certain traditional features. Amazing part of the toys were their science factor and humour.

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Siphon elephant toy

Figure 2

It has a hidden siphon. It will take water from its trunk and pour water out from the tail. We have used this toy as a base for children to develop some siphon toys ideas.

Magic water pottery toy

This lovely little pot will pour out water when a thumb closing its mouth is moved and air pressure occurs.

These types of toys were used by our groups for village children's science entertainment shows. The children were inspired to create toys based on same operational procedures from waste tins, waste small clay pots and similar material.

Ganges pot

It is a double walled pot. The double wall contains water. Outwardly the pot is empty, but yet poured out water every few minutes. The trick is the Air Pressure hole

Sinkable clay fish toy

Normally baked clay is heavy then water. But in this particular toy special clay with tiny air hole is used. This creates a deception of a heavy object. Really speaking the numerous holes with air make it float on water.

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Media of olden days

In Olden Times these types of toys and handicrafts travelled with travellers and carried stories related to people and life. They were the media of olden days.
Even today these types of material inspire several activities.
Based on clay toys concept our own group started thinking about low cost toys, which can be created from low cost not cost material. We wanted to use them in small village schools, which had no activity material. They had almost nothing as educational activity support.

We started thinking, experimenting and producing

The group members who were involved in R&D for making toys, educational concept support material, production and ultimate evaluation. We remained busy for a year or so. Our first package of paper toys was presented to All India Science Popularization Travelling Group (JATHA) or and they had a sizable demand.
Our mini Science Toys became a part of village children's life wherever the JATHA group presented its science programmes. Media took the note of our little Science toys. They were used in-group presentation, they were shown in Science folk plays and they were discussed on National Radio Network (AIR). The response was very rewarding for all those who had worked on the project just for the love of this noble activity.

Media supports. The science toy activity supports the Media

We had been invited by Department of Science and Technology, New Delhi for joining them on a discussion to examine the possibility of low cost Science toys and activities related to their unique Broadcasting Project 'Human Evolution' A Radio Serial'.
(This serial was the longest Science Serial in the broadcasting world, which broadcasted in 17 different languages simultaneously)
All India Radio 'AIR' National Broadcasting System and Department of Science and Technology gave us their problem, which had following major points:

- Design along with scientific experts and broadcasters for outreach material like Science Toys, Science Games and Science Activities.
- They should be created and pre-tested and then mass-produced.
- They should reach all the corners of the country by postal mail or truck roads and related to appropriate topics schedules for broadcast.
- The toys, games, puzzles and other material should be very low cost so that it can reach almost one hundred seventhly five thousand registered member listeners.
- The packaging should be water resistant as India is a land of and heavy rains.

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– The material should be so designed that the child gets involved in do-it-yourself activities and produces alternatives, which are creative.

Figure 3

Basic presentations were convincing enough for all India Radio and Department of Science and Technology Gov. of India

All India Radio is a very mammoth organization having an experience and complex network covering the whole country and operating in various languages and dozens of dialects.

For this Science Radio Serial they collected from our vast country best Science producers and contents people.

Our presentation was based on the points discussed above.

Contents support was provided to us by Department of Science and Technology's NCSTC branch for the preparing the basic presentation to joint group of Radio producers, scientific scriptwriter and educationalist.

Flow chart inter-relationship of Media-Broad cast science toy/games and activity kits

The group was explained by MEPS the flow chart of outreach material kits which had certain games, projects, toys, science activity suggestions and a variety of the things.

This was India's largest network for Science education low cost Science toys, games and activities.

While developing the toy-game-activity kits the following salient points were being considered by the design group.

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Proper involvement of contents people and integrated design group formation

When a group is working on Science toys useful for areas like Health, Sanitation, physical sciences, life sciences and certain socially related aspects, core discussion with contents experts is very helpful. The group must form a unified structure, where the design group understands contents group and vice a Varc.

Constantly working with children while project developing the science toys-take children's input

Children have a great creative resource hidden in their brain, when freedom is assured they let loose their imagination and bring forth very impressive outcome. Their ideas can form the core of science toy designs ultimately to be used for low cost mass production of toy ideas.
This mass production is not an industrial mass production to hit the market but to spread idea seeds, which will provide a scope for individual creativity to develop new ideas.

How did the science toy game activity triggered of a serious of science toy making activity among a number of science toy, game and activity outreach material kit?

- Mass Communication Media related toy-making activity has a great potential.
- Feedback always provides newer ideas for toy designing activity.

What technologies were used in creating science toys, games and activities?

In just 20 cents per kit containing 12 to 15 activities, toy and games mix was to be produced, packaged and were to reach distant corners in a country like India.

- The kits contents were to be worked out along with science experts.
- For an example our space kit received a detailed consultation from a NASA trained space scientist that was trained in space travel.

At the same it was to satisfy the children's group in a small village in Panch Mahals tribal belt.
It was a great experience for the creative design group.

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For making a simple toy like fission happening toy, we had an expert from ISRO to advise us ISRO stands for Indian Space Research Organization. These scientific experts had to come down to the children's level. Several alternatives were needed.

Figure 4

Concepts of Radio Broadcast on Scientific topics were to be correlated.
Material, which took, complicated electronics devices for public exposition of ideas were reduced skilfully in simple two pieces of paper-engineered toys.
Fission card is a good example.
This idea is presented here to draw the attention to the fact they very good with results can be achieved from low cost materials like paper and card.
There is another example of our successful mass produced science toy, which is simple and has charmed several hundred thousand children. It is 'Heat Absorption Pack'
It is white paper pocket divided into two parts A&B. A is covered with black colour while B is white. The child has two similar metal coins. Each portion A&B contains equal metal coins. The pocket is to be put under the sun for 5 minutes.
Then the child has to touch both the coins and find out which one in warmer. This toy works very well in warm a country like India.
Low cost paper and card are very pliable, yields to modern duplication methodologies, bring fourth needed colour demand. It is simple enough for idea spread.

We were convinced that while designing us must keep following in mind

'Toy is any material with which the child plays”
Some of our new volunteers came from a comparative affluent background to them branded expensive plastic toys meant toys, For them paper and card, clay or wires were no material to be considered for toy making.
After a passing through a small turmoil the group came to a conclusive agreement.

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Some the characteristics for science broadcast outreach kits' material agreed upon were as follows:

- Low cost material
- Simplicity in assembling
- Easy paper engineering
- Contents clarity
- Brief captions
- Multi language captioning or notes system
- Easy and water proof packaging
- Mailing-friendly
- Built in feedback system
- Replicable
- New Idea inspiring
- Real Low cost (US 20 cents for a package with 15 toys)
- Auditor worthy documentation

This project was a creative design project but at the same time it had many demands in comparison to signal-person creative project. At this point professional planning of the project turned out to be very useful. In final production of work our low cost small experimental workshop helped us. Workshop was an old apartment with a small outdoor work area.

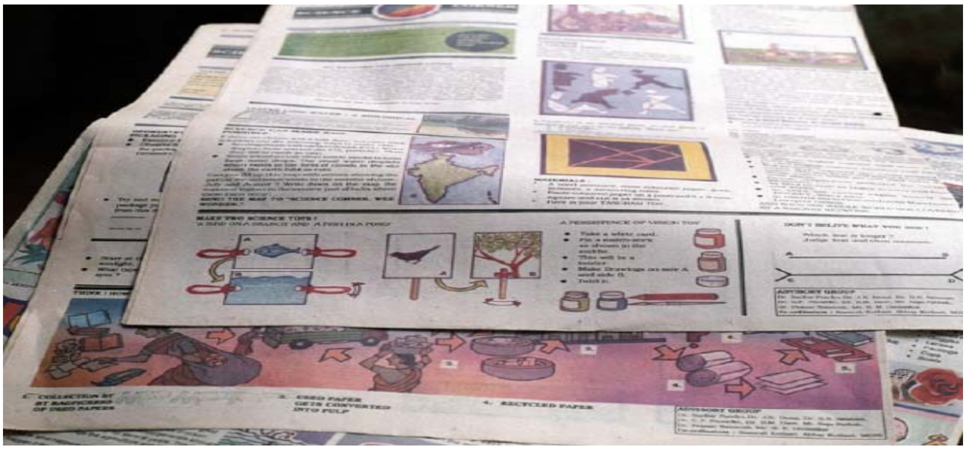

Figure 5

Amazing off shoots from the basic science toy making activities

Let us be clear that when we are talking of making toys we certainly do not mean heavily industrialized activities of medium scale business houses. Modern times for

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any propagation of good ideas one needs large number production, and also an ever-expanding information network. One has to employ technology but the core expanding information network. One has to employ technology but the core activity will have roots in the individualized group activity.

MEPS toy-activity had several amazing offshoots growths.

All developing countries strongly feel the need of involvement of the child in science and technology. In our country there is a planned approach to the development of science projects for toys and games for the children.

There are annual science conventions fairs and camps for children. Every year hundreds and thousands of children in each region develop ideas for science toys projects and presentation.

Largest Media Group gets involved in this mini media games and toy

Our national daily newspaper specially generated for the region felt a great need for toys, games and activities. The newspaper was Time of India.

They located my group and will request us to experiment for two years a weekly page, which should have 'make-it-your-self' science toys games and activity.

The feedback was great. A special mail-receiving box had to be created on the main gate.

It was a great reward for a group, which peacefully developed simple science toys, games and puzzles. They were constantly enriched by children's inputs.

Figure 6

Paper presented at the 3rd International Conference on
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Affordable and Efficient Science Teacher In-Service Training

Margetousaki A and Michaelides P G

Introduction

In all modern, technologically advanced societies, special measures are taken for an effective Science teaching [1] with the necessity for a generalized Science and Technology Literacy an explicit objective [2]. In order to be useful, this literacy must be focused on principles and methodology rather and not being limited to factual knowledge on specific data, techniques or themes. This implies that in order to be understandable and assimilated by the students, the scientific knowledge that the Science and Technology teachers possess has to be transformed appropriately to teaching activities but it seems that teachers lack, in general, this skill. As a consequence, Science and Technology are considered as difficult subjects [3] although they are rather simpler [4] and possess inherent advantages [5]. This constitutes a significant problem in most of the advanced countries. Another relevant matter is the existing outline of the Science and Technology syllabus and the way of teaching. In the majority of the cases the subject matter does not include advances like relativity or quantum physics that are known for more than 5 generations and require a (qualitatively) different approach than the Aristotelian one of classical physics [6]. The teaching is in general narrative [7] with the teaching book as the only resource [8]. This practice implies that scientific inquiry skills, an explicit common objective of the Science curriculum, are not developed. As a further consequence, a difficulty seems to exist to discriminate between data from observations and their interpretation.

Within the observations made above, it is evident that there is a need for an affordable, sustainable and efficient in-service training scheme for the Science teachers. Such a scheme has been described in [9]. This scheme has two main axes: a. face-to-face training courses, and b. online training courses. The face-to-face courses focus on the learning of the recent theoretical paradigms on the Science teaching and the relevant supporting pedagogical principles. The e-learning system to be developed will be used by Science teachers and specialized scientists in the area of Science Teaching and is based to the configuration of Figure 1 (for more details see [9]).

The focus of this scheme is on the promotion of the collaboration and cooperation between teachers, schools and institutions involved in the Science teaching and in

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Science Teaching education. The fundamental philosophy is that learning can be developed and enhanced through the sharing of knowledge and best field practice experience of different groups involved in such activities. A further objective is the establishment of a network of people including scientists, school-teachers and researchers to promote Science and Technology education. In this aspect membership consortium is intended to be open to any colleague wishing to participate.

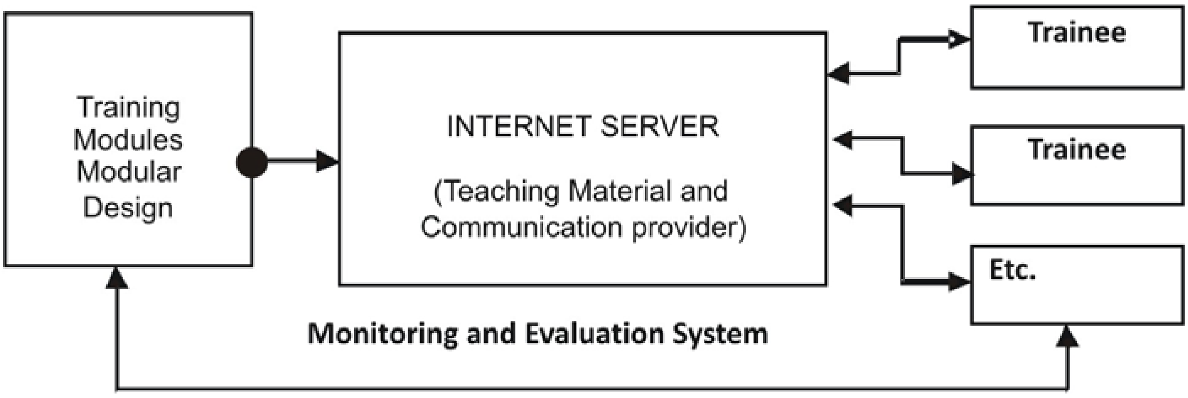

Figure 1. The e-learning system

This scheme presents a direct inherent advantage to the Science Teachers of primary and secondary schools, especially those in rural areas where modern equipment and counselling are sparse. Indirectly, through the improvement of their teachers, the pupils of the corresponding schools and the various groups involved in the activity will benefit. Groups that may be involved in this activity are Universities, schools, Institutions for Science Teaching, Science teachers and specialized Science trainers. It is expected that the different groups will collaborate in order to have a better achievement according to their aims and objectives with every group being able to benefit from the exchange of experience and knowledge in the field. This ‘individualised benefit’ is another advantage of the scheme.
Based on the context described an application was approved by the European Commission under the SOCRATES – Comenius 2.1 (Training of School Education Staff) [10].
The activities of this project are organized in three phases:

1. The first one consists of the development of training modules.
2. The second phase consists of a traditional test delivery of (some) training modules developed and (a rather extensive) evaluation. Phase 2 is necessary in order to obtain comparative evaluation results between the traditional face to face and the e-learning deliveries.

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3. The 3rd phase will consist of the transformation of (some of) the training modules developed to distance education training material with a test delivery and its evaluation. It is expected to last 10-12 months.

The project has begun its implementation and we present here results from the test evaluation phase from The University of Crete partner. Similar work is ongoing with the other partners of the project.

Implementation

One traditional face-to-face seminar was delivered four times during the period from March to May 2006 in the form of an intensive training course. The 1st was delivered in Nicosia Cyprus, to (secondary education) Science teachers as part of their pre-service training (3 training hours). The 2nd was in Heraklio Crete, to secondary education Science teachers (6 training hours in two consecutive days). The 3rd was also to secondary education Science teachers in Rethimno Crete (6 training hours in two consecutive days). The 4th was to primary school teachers in Rethimno Crete (6 training hours in a whole afternoon). In all 4 seminars the same two persons (P. G. Michaelides and M. Tsigris) were used as trainers. In the 4th seminar (to the primary school teachers) another person (N. Tsagliotis) presented also the basics of the reformed primary school Science books. In all seminars there was also an observer (A. Margetousaki of the authors).

The contents of the seminar were a selection of topics from different areas of the school curriculum, mainly from Physics and (to a lesser extent) from Chemistry. The seminar was mostly focused on the didactics adopting a teaching approach within a Hands on Science Teaching context [12]. More specifically, examples of relating Science to everyday life observations [13, 14] and experimentation with self made equipment [15] were discussed. The seminar was organized as follows:

- One (short) part where the theoretical basis of the teaching approach adopted was presented in an interactive way.
- One part where examples of relating observations from everyday life were located and a study approach indicated.
- One part where examples of self made experimental devices and instruments were presented. The construction of self made equipment and instruments was made with simple, easy to find materials and is appropriate for a better understanding of the basic Science concepts. Teachers had the opportunity to watch all the process of the construction, the use and the ‘debugging’ that in some cases is necessary when constructing these devices. During this stage the trainees had an opportunity (limited because of time constraints) to get involved in these constructions and carry out the corresponding experiments or measurements. A short discussion on errors and of possible construction pitfalls was also made.

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- Then a rather extensive discussion took place on the usefulness of the material presented to the school curricula, on possible problems, constraints or difficulties that teachers could face in the classroom or during the preparation of the lesson of the day and how to deal with them.
- It must be noted that:
- Science in primary school is a common course. In the first 4 classes it is within a ‘Study of the Environment’ school subject with topics from the natural and the human environment. In the 5th and 6th classes there is the school subject ‘Science’ with topics from Physics, Chemistry and Biology. There is also the school subject ‘Geography’. In this, topics from natural Geography, especially of the Greek and the European area, form most of the syllabus but there are also topics from anthropography and from the solar system and its neighbourhood.
- Teachers in primary school do not have a specialist education or initial training in Science. They teach all school subjects one teacher to one class or, sometimes in small villages, to two or more classes... This is true for schools with less than 6 teachers who have to teach the 6 classes (grades) of the primary school. In primary schools with a large number of students and 6 or more teachers an informal allocation (sharing of teaching responsibilities) is usually made with two teachers teaching the upper two (5th and 6th) classes (grades) one responsible for Mathematics, Science, and Technology (usually a male teacher) and one responsible for Humanities [11].
- Secondary education schools in Greece include the middle school (Gymnasium, grades 7th to 10th) and the upper school, Lyceum or Technical Vocational Lyceum (or, previously, Technical Vocational school, a middle school). Science in secondary education schools is taught as separate subjects (Physics, Chemistry, Biology, etc).
- Science Teachers in secondary school have a (University) degree in a Science subject (Physics, Chemistry, Biology, Geology, etc) and they are entitled to teach any of the Science subjects in secondary education schools, as needs arise. In practice they are assigned to teach Science subjects according to their own Science specialty. There is also an informal tendency [11] for male teachers to be assigned the responsibility of the higher grades and of Physics and Chemistry.
- Students’ attitude to Science subjects (along with every other school subject) in the upper secondary school (general Lyceum) is oriented towards the written entrance to higher education general examinations. This means that learning activities like experimentation are not within the students’ priorities or within the tasks undertaken by the teachers (in these conditions, it seems to be loss of time).

Upon the completion of each seminar the (teachers) trainees were asked to fill anonymously a written questionnaire. The aim was to check on the trainees’ impression to the teaching approaches adopted and to trace (possibly) their training needs.

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Analysis of the questionnaire.

An analysis of the questionnaires is ongoing and some results already obtained are presented in this section.

There were 107 trainees participants in total from which 93 were Secondary school teachers and 14, the Rethimno (p) row, were Primary school teachers as is depicted in 'Table1. Participants'.

As shown in Table 2. Sex, 48 (45%) of the participants were females and 59 (55%) were males. For the primary school teachers the participation was 9 (64%) females and 5 (36%) males.

	Frequency	Percent
Heraklio	47	43,9
Rethymno (s)	39	36,4
Rethymno (p)	14	13,1
Cyprus	7	6,5
Total	107	100,0

Table 1. Participants

	Frequency	Percent
Female	48	44,9
Male	59	55,1
Total	107	100,0

Table 2. Sex

The figures above are consistent with the corresponding percentages of teachers in the Greek schools. From these 107 participants we got 72 (67%) questionnaires as is depicted in the following Table 3. Questionnaires from the seminars and Table 4. Sex. Of the 8 primary school teachers who filled the questionnaire 4 were males (50%) and 4 were females (50%). Their degree qualification is depicted in Table 5. Degree where the 8 primary school teachers are classified as 'Other'.

	Frequency	Percent
Cyprus	7	9,7
Heraklio	29	40,3
Rethymno (s)	28	38,9
Rethymno (p)	8	11,1
Total	72	100,0

Table 3. Questionnaires from the seminars

	Frequency	Percent
Female	27	37,5
Male	45	62,5
Total	72	100,0

Table 4. Sex

A (significantly) lower response rate is observed for the female participants, likely even more for the female primary school teacher participants. On this observation, it is evident that a detailed analysis should rather differentiate between male-female participants and between primary – secondary school teachers participants. Because of the as yet small sample we examine the rest of the questionnaire as a whole restricting the results to the general trends only.

The participants were asked:

If the topics presented were useful with choices to answer; extremely useful, useful, just a little, not at all. The answers are presented in Table 6. Usefulness.

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If the topics discussed were related to the school curricula with possible choices to answer; much related, a little relate, not at all related. The answers are presented in Table 7. Relation with the curriculum.

	Frequency	Percent
Other	32	44,4
Physicist	40	55,6
Total	72	100,0

Table 5.Degree

	Frequency	Percent
Extremely useful	32	44,4
Useful	39	54,2
Least useful	1	1,4
Total	72	100,0

Table 6. Usefulness

	Frequency	Percent	Valid %
Very much	32	44,4	50,8
Little	29	40,3	46,0
Not at all	2	2,8	3,2
Total	63	87,5	100,0
Missing	9	12,5	
Total	72	100,0	

Table 7. Relation with the Curriculum

	Frequency	Percent	Valid %
No	8	11,1	11,4
Yes	62	86,1	88,6
Total	70	97,2	100,0
Missing	2	2,8	
Total	72	100,0	

Table 8. Different teaching perspective

If the seminar presented another teaching perspective with possible choices to answer; Yes, No. The answers are presented in Table 8. Different teaching perspective.
If they would attend again a similar seminar with possible choices to answer; Yes, No. The answers are presented in Table 9. Attain again.
If they think that this seminar would be interesting to their fellow teachers with possible choices to answer; Yes, No. The answers are presented in Table 10. Are other teachers interesting?
On the two (open) questions about the positive and about the negative aspects of the seminar the responses are presented in 'Table 11. Positive points of the seminar' and in 'Table 12. Negative points of the seminar' respectively. Of the participants (refer to 'Table 11. Positive points of the seminar'):

- 31% found the simplicity of the constructions very positive,
- 18% mentioned that they found very prototypal the experiments,
- 43% mentioned as very positive the teaching method proposed during the seminar,
- 8% think that the seminar was a chance for further speculation on the teaching of Science.
- There was a percentage 29% who did not answer this question.

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	Freq.	%	Valid %
Simple constructions	16	22,2	31,4
Prototypal	9	12,5	17,6
Teaching approach	22	30,6	43,1
Speculation	4	5,6	7,8
Total	51	70,8	100
Missing	21	29,2	
Total	72	100	

Table 11. Positive points of the seminar

	Freq.	%	Valid %
Little Time	18	25,0	43,9
Subject	5	6,9	12,2
Organizatio n	10	13,9	24,4
Theory	8	11,1	19,5
Total	41	56,9	100
Missing	31	43,1	
Total	72	100	

Table 12. Negative points of the seminar

Correspondingly as negative points of the seminar were mentioned:

- The time spent was not enough to cover the subjects by 44% other participants.
- The organization was not appropriate (24%). This category covers a wide variety of statements including: ‘the subjects should be related to the curriculum’, ‘teachers (i.e. the trainees) should participate at the procedure’ or ‘I would prefer to participate myself at the experiments’.
- Almost 20% of the respondents mentioned as a negative point that there was too much theory in the seminar.
- 12% of the respondents mentioned as a negative point that the topics discussed were mainly from Physics.
- A significant 43% did not answer this question.

	Frequency	%	Valid %
No	22	30,6	32,4
Yes	46	63,9	67,6
Total	68	94,4	100,0
Missing	4	5,6	
Total	72	100,0	

Table 13. Distance learning seminar

	Frequency	%	Valid %
No	6	8,3	9,0
Yes	61	84,7	91,0
Total	67	93,1	100,0
Missing	5	6,9	
Total	72	100	

Table 14. Application

On the question if they would participate in a similar seminar organized with Distant Education methods the results are depicted in Table 13. Distance learning seminar. Interesting is the respondents’ answer to the question ‘Can you apply the topics discussed/ the knowledge acquired to your classroom?’ which is depicted in Table 14. Application. The vast majority (more than 84%) answer ‘yes’. However a (small) number of these positive answers continue that this may be done on the prerequisite that they would have the time and the infrastructure.

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Commentary

The data presented earlier show that the seminars were accepted by the teachers – trainees in a very positive way. However, a detailed analysis, especially on the criticism performed is appropriate and ongoing. However we would like to add a few comments based on the (informal) discussions the authors had with the trainees.

1. Many of the participants believe that the theoretical framework was extremely extended and in many cases was characterized as useless (see also Table 12).
2. There was a vivid interest on the experiments and the constructions (see also Table 11).
3. Straightforward or indirectly many of the participants admitted that they have not experience at all with this kind of application or teaching approaches in the classroom. Comments made are ‘There are no books’ ‘It is not anticipated by the ministry’.
4. Schools in secondary education are equipped with labs and the necessary tools for the experiments. Although there is equipment in schools, the main negative point mentioned was that there is no need for this kind of experiments because they are not useful for the entrance examinations to higher education.
5. Many of the participants mentioned the simplicity and the prototypic nature of the constructions (see also Table 11).
6. It was understood that through this kind of applications it is possible for the teacher to be a collaborator or partner of the children through the learning process in the laboratory.
7. In the end of the seminar many expressed the desire to be capable of performing these experiments presented during the seminar, and bypassed the point that these experiments were part of a broader context applying in a certain teaching methodology. They seemed to focus on the certain cases, instead of the teaching method proposed with those cases as starting points.
8. Another thing that came out from the discussions is the need expressed from the teachers to work on the constructions and try to perform the experiments themselves, a point mentioned also in the questionnaires too.

Epilogue

The results show that there is great interest for the teaching model of Science proposed during the seminars. Teachers seem to be interested in the idea of quantification of the experiments and the involvement of the pupils to the experimental process. Teachers are willing to have further training in this field and are also ready to use the online training method of Science teaching. It is also obvious that there is an extended training gap concerning the science teaching as shown from the fact that teachers are willing to participate in a training seminar of this kind again and from the fact that they think that other teachers would also be

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eager to participate too. The main negative point of the seminar mentioned from the participants was the lack of time, which seemed to be very short in comparison with the subjects inquired. Maybe there is a need for a more extensive seminar where there will be provision for teachers' active participation to the construction of the equipment - instruments and the development of the experiments. This way they will have a direct experience and they will be able to work on the idea of self-made apparatus.

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References

[1] See for example a synopsis for the case of England in Susan Barker and Pilar Reyes, 'Why be a Science Teacher?', pp.: 57-68 of Vol. II of the proceedings of the University of Cyprus, '1st IOSTE Symposium in Southern Europe – Science and Technology Education: Preparing Future Citizens', Paralimni-Cyprus 29/4-2/5 2001.

[2] Institute for Science Education and Science Communication' related to the teaching of Science and Technology to students of a non Science related career, b/for England and Wales, 'Science: The National Curriculum for England', c/for a more general review, Karidas A and Koumaras P. 'Scientific (and Technological) Literacy for All: Presentation of a Research Model and an Attempt to Constructing a Relevant Proposal', pp.: 89-97 of Vol. I of the proceedings of the University of Cyprus, '1st IOSTE Symposium in Southern Europe – Science and Technology Education: Preparing Future Citizens', Paralimni-Cyprus 29/4-2/5 2001.

[3] Krystallia H, 'Difficulties in Transforming the Knowledge of Science into School Knowledge', pp.: 76-82, of Vol. II of the proceedings of the University of Cyprus, '1st IOSTE Symposium in Southern Europe – Science and Technology Education: Preparing Future Citizens', Paralimni-Cyprus 29/4-2/5 2001.

[4] As may be inferred from the fact that, in human history, they appear and advance earlier than other sciences.

[5] For example their subjects of study are easily perceptible through the senses, an irrefutable advantage for most of the compulsory education students who, in a Piagetian context, have not as yet reached the formal logic stage.

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[6] The necessity on the modernisation of the Science curriculum has been pointed out in: George Kalkanis 'Which (and How) Science and Technology Education for Future Citizens?', pp.: 199-214 of Vol. II of the proceedings of the University of Cyprus, '1st IOSTE Symposium in Southern Europe – Sci. and Technology Education: Preparing Future Citizens', Paralimni-Cyprus 29/4-2/5 2001.
[7] Deborah C, Smith and Daniel C, Neale 'The Construction of subject-Matter Knowledge in Primary Science Teaching', pp.: 187-243 in 'Advances in Research on Teaching', Vol. 2 • 1991 'Teacher's Knowledge of Subject Matter as it relates to their Teaching Practice', edited by Jere Brophy, JAI Press Inc.
[8] Athanassakis A, Environmental education and teachers' tendencies, Department for Primary Teachers' education of The University of Crete, Ph.Ed. Dissertation, 1992.
[9] Michaelides P, An affordable and efficient in-service training scheme for the Science Teacher, paper presented at the Sixth International Conference on Computer Based Learning in Science 2003 (CBLIS03), University of Cyprus, Nicosia, Cyprus, 5-10 July 2003, pp.: 792-799, 2003.
[10] Project AESTIT, Contract 226381-CP-1-2005-1-GR-COMENIUS-C21. A web site (http://www.clab.edc.uoc.gr/AESTIT/) is also being developed.
[11] Private own data within the context of an ongoing project on school practice.
[12] Learning Science requires the involvement of the student in activities of observing, experimenting, making hypotheses to explain the data observed, planning and realizing experiments to discriminate between different hypotheses, making generalizations in the form of models and communicating the results of their study. Hands on Science includes all these activities but places an emphasis on the (usually neglected) phases of observation, experimentation and the (subsequent) collection of relevant data.
[13] Michaelides PG, "Everyday observations in relation to Natural Sciences" in Learning in Mathematics and Science and Educational Technology, University of Cyprus July 2001, Volume II, pp.: 281- 300, 2001.
[14] Everyday Thoughts about Nature, William W. Cobern, KLUWER, 2003.
[15] Tsigris M, The didactics of Science through polymorphic self-made experimental apparatus of quantitative determinations. An alternative proposal for the teaching of Natural Sciences, 2nd International Conference, Hands-on Science: Science in a Changing Education, July 13-16 2005, The University of Crete, 2005.

Paper presented at the 3rd International Conference on
"Hands-on Science. Science Education and Sustainable Development",
Braga, Portugal, September 4 to 9, 2006.

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Geometric Reasoning and Proof Problems in Geometric Dynamic Environments

Breda A, Neto T, Costa C and Costa N

Introduction

There is a consensus that deductive reasoning still has a central role in geometry learning. As settled by Gila Hanna [5], in the classroom the key role of proof is the promotion of mathematical understanding, and so, it is of significant importance to find out (more) effective ways of promoting mathematical understanding in proof environment. Considering some researcher's arguments G. Hanna [6] one of these potentially more effective ways is given by the use of dynamic geometry software (e.g. Geometer´s Sketchpad, Cabri Geometry), since they have the potential to encourage both exploration and proof, making it easy to pose and test conjectures. But, as pointed out by other researchers' studies (e.g. De Corte E. [1]) the use of computer technology is useless if the educational strategies and activities are not revised.

As mentioned by Mariotti, M. [7] it is reasonable to predict that the presence of new technology deeply transform the relationship between problems and knowledge and that the change will occurs at least in two respects: The problems that can be proposed to pupils and the solution processes, the available resources change and consequently the processes used to get the result change.

A number of researchers are now investigating the use of dynamic geometry environments and in particular their potential contribution to mathematical reasoning.

At Educational Studies in Mathematics 44 (2000), the first outcome of the PME Special issue series. This issue is devoted to analysing the influence of dynamic geometry software (DGS) on student's conceptions of mathematical proof while students are solving geometry problems involving proofs in an environment mediated by such software.

At ICMI study series, *Perspectives on the Teaching of Geometry for the 21 st Century,* are discussed a variety of aspects ranging from social and didactical issues to curriculum design and teacher preparation, beginning with a brief look back at the multiple and varying roles which geometry has played during the XX century.

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In this study these two last documents are an important basis of this work. The study empirical in focus, deals with some theoretical aspects of Duval [2] view geometrical reasoning.

Geometrical reasoning within mathematical thinking

In line with Pegg [9] we may distinguish two classes of cognitive growth: the global frameworks of long-term growth (e.g. van Hiele's theory of geometric understanding, Piaget's theory of cognitive development) development, and the local frameworks of conceptual growth (e.g. the unistructural-multistructural-relational- unistructural sequence of levels in the SOLO-Structure of the Observed Learning Outcome - Model, Biggs & Collis, 1991, Pegg 2003).
It may happen that a theory incorporates both global and local frameworks as is the case of the theories above mentioned.
Usually the global theories begin with the physical interaction of the young child with the world and, specify successive levels of abstraction based on the use of languages and symbols sophistication stage.
In Good [3] it can be found an interesting characterization of the thinking process:

> *an unregulated flow of ideas or stream of images, impressions, recollections and hopes; an undisciplined guessing that treads lightly and superficially over grounds and evidence in an effort to reach conclusions; the contemplation of ideas, or meditation, without any endeavour to control nature or experience; reflexive, cognitive, or critical looking into something for the sake of establishing belief and controlling action.*

As pointed out by D. Tall [12] one of the secrets of simplicity of thought in mathematics is its power of compression. Mathematical concepts compress in different ways in different realms of mathematics. It is an enormous compression to use a single letter like IN to stand for the whole natural numbers. In fact a great part of mathematics' notation provides illustrations of mental compression. The mental compression plays a crucial role in the development of mathematical thinking; it allows powerful thoughts in extremely simple ways.
For a successful development of mathematical thinking, solid links between ideas that are compressed – cognitive units (created by focus of attention) must be achieved going together with building links between these entities, in a boarder global awareness.
Clearly, activities performed repeatedly become automatic, allowing the creation of rich cognitive units promoting more sophisticated links.
In mathematics the nature of concepts may differ greatly. As exemplified in [12] the status of the concept *triangle* and the *concept* five are completely different. The concept *triangle* can be visualized as a mental object and described in terms of its intrinsic properties. This does not happen with the concept of number, which is attached with the process of counting.

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Following Duval view, [2], geometrical reasoning involves three cognitive processes fulfilling specific epistemological functions, which can be performed separately: **visualisation** (related to space representation), **construction** (use of tools) and **reasoning** (particularly discursive processes for the extension of knowledge, for explanation, for proof).
Figure 1 reproduces the Duval representation of the underlying interactions involved in geo-metrical activity. Each arrow represents the way a kind of cognitive process can support another kind in any geometrical activity. Arrow 2 is dotted because visualization does not always help reasoning. Arrows 5(A) and 5 (B) put in evidence that reasoning can develop in a way independent of construction or visualization processes.
For the skilfulness in geometry, according to Duval, is necessary to get pupils in school to see the communication between these three cognitive processes. His research on the development of geometric reasoning points to the following promising framework:

1. to develop the three cognitive processes separately;
2. work on differentiating visualization processes and between different reasoning processes in the curriculum;
3. bring to the scene the coordination of these three cognitive processes.

In section 4 we describe an empirical study where this framework is visible.

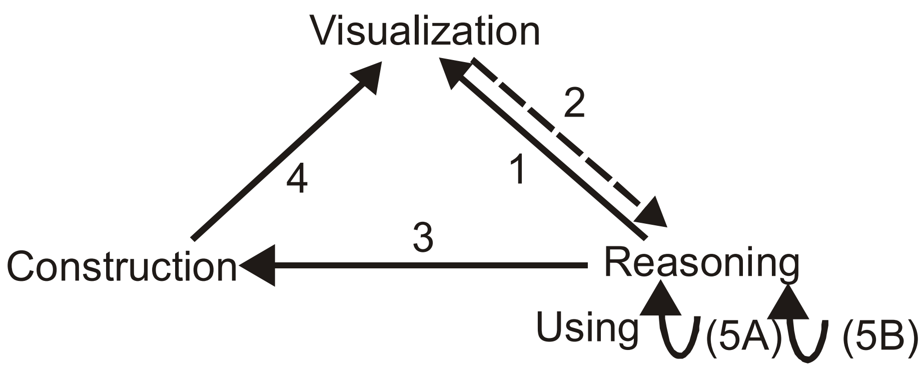

Figure 1. Duval's representation of cognitive interactions. Identification of gestalts and configurations in 2D or 3D. This identification depends on particular laws which are independent of the way of construction or of the discourse. (A) Natural speech (inner or external for naming, description or argumentation). (B) Propositions with the theoretical status of definition, theorem… for a deductive organization discourse

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The geometric reasoning within dynamic environments

Computers are seen for many teachers and researchers in mathematics education as a powerful tool to create rich environments for problem solving. Dynamic geometric software provide visual evidence which is considered to be a mean for generating conjectures using users prior geometrical knowledge and/or empirical experiments with the software (e.g. Geometer´s Sketchpad, Cabri Geometry).

The accessibility of dynamic software's with graphing capabilities, in classroom environment has given a new attribute of geometrical exploration; helping students in theirs geometric understanding. There use permits: to perform geometric constructions with a high degree of accuracy; to identify the meaning of geometrical statements; testing conjectures, exploring properties of the constructions they have produced or even "discover" new properties. (Hanna, [5]).

A key question raised by the intensified study of visualization is whether, or to what extent, visual representations can be used, not only as evidence for a mathematical statement, but also in its justification (Hanna, [5]).

Hadas, N. *et all* [4] present an original approach to induce students to produce deductive justifications. The authors intentionally wanted to identify the frequency of deductive explanations and the conditions which encourage them. However the appearance of other explanations, for instance visual explanations based on dynamic environments, lead to a categorization of the student's answers to the problems proposed intended to cause surprise and uncertainty.

By manipulating objects students can investigate invariant features, formulating hypotheses and test them visually. According to Schumann and Green [11] at present dynamic geometry environment are used for the following types of learning activities:

- *figure acquisition* (the student constructs a figure which satisfies a given requirement);
- *figure appropriation* (the student graphically transform the figure observing the preservation of its intrinsic properties).
- *property exploration*; the student also constructs or uses a predefined figure (activity) to explore a specific theorem or even a proof.

The evolution of dynamical environments led to a switch from the local step-by-step activity to the development of global awareness of relationships to solve problems.

The empirical study

The study we have carried out consisted in a design of a geometry problem folder and its implementation in a mathematics class with the objective of getting some understanding about the research question underlying this study, *how non Euclidean geometry can help student's developing their deductive reasoning?*

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We made use of non Euclidean geometries, namely the hyperbolic geometry (using the Poincare's upper half plane) to achieve these propose (the improvement of their proof understanding through a higher level of geometrical thinking).
In this paper we describe the performance of one pair of students during their activity in solving the proposed problems, adapting Duval´s representation of cognitive interactions. It should be pointed out that the study has involved 20 students in their 10^{th} of a Portuguese Secondary School (ages 15-16 years). The focus of our attention on only one pair of student's since they represent a class of student's performance.

The design of the problem solver

Here we exemplify the type of problems we have chosen for this experiment. Dynamic geometry sketches and scripts were prepared for students investigations during de sessions. Each sketch was constructed using The Geometer's Sketchpad and the sketches included facilities for hide/show.
As mentioned before we have followed the Duval's representation of cognitive interactions.
During phase 1, the students gained preliminary experience with Geometer´s Sktechpad Program.
In Phase 2, the students were involved in a proof-problem requiring definition and models of Incident Geometry.
Examples:

1. Find, in the Poincare upper half plane, the hyperbolic line through (1, 1) and (3, 3). In this geometry, through any two distinct points there exists a unique line? Justify. (The same question was developed in others models, namely in the Cartesian plane and in the spherical model).
2. Let l_1 and l_2 be hyperbolic lines. Show that if $l_1 \cap l_2$ has two or more points than $l_1 = l_2$.

Finally, in phase 3, students explore situations in order to become aware, for instance, of the significant statements as *Euclidean geometry theorems that require the Parallel Axiom will be false in hyperbolic geometry*.

Participants

A group of 20 students in their 10^{th}, 11^{th} of a Portuguese Secondary School (ages 15-16 years) participated in the teaching experiment. It was carried out during the standard class time with the research and their own teacher. The students worked in groups of two. None of them had significant experience on deductive reasoning and with dynamic geometry.

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Three pairs of students were selected by the research to participate in the case study. These six students, one boy and five girls, had different learning and cognitive strategies. Riding & Rayner [10], investigating individual differences characterized learning style as being a tendency to approach cognitive tasks with a preferred strategy or set of strategies, corresponding with a preferred mental set. They suggest that learners differ, in terms of two fundamental dimensions:

- *wholist-analytical*; the wholists ones prefer to keep a global view of the topic and the analysts ones tend to process information into component parts;
- *verbaliser-imager*; the verbalisers ones tend to present information in words, while imagers tend to present information in pictorial form.

Figure 2. The use of artefacts

Figure 3. The use of artefacts and visualization in dynamic environments

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Learning and cognitive strategies may be characterized by observing students or by allowing them to think aloud as they study. In a questionnaire and in a test diagnostic given to the student's at the beginning of this study, it was identified their weak experiences with solving problem, their poor basic geometric knowledge and their inexperience with geometric dynamic software.

The student's approach

In this sub-section we describe student's productions related to phase 2.

Models of geometry were introduced with the use of artefacts[12] (a music instrument, a sphere of acrylic) and scripts in dynamic geometry environments, see Figures 2 and 3.

According to Mariotti [7] the possibility of an instrumental approach seems rich and fruitful, contributing to the construction of meanings. After this stage, the students were involved in a proof-problem requiring models of Incident Geometry.

In phase 2, in the task: *Find, in the Poincare upper half plane, the hyperbolic line through (1, 1) and (3, 3),* Susana and Patrícia, after reading the problem, used the GSP tool to draw the hyperbolic line (Euclidian semi-circle) with the script Hyp_line.gss.

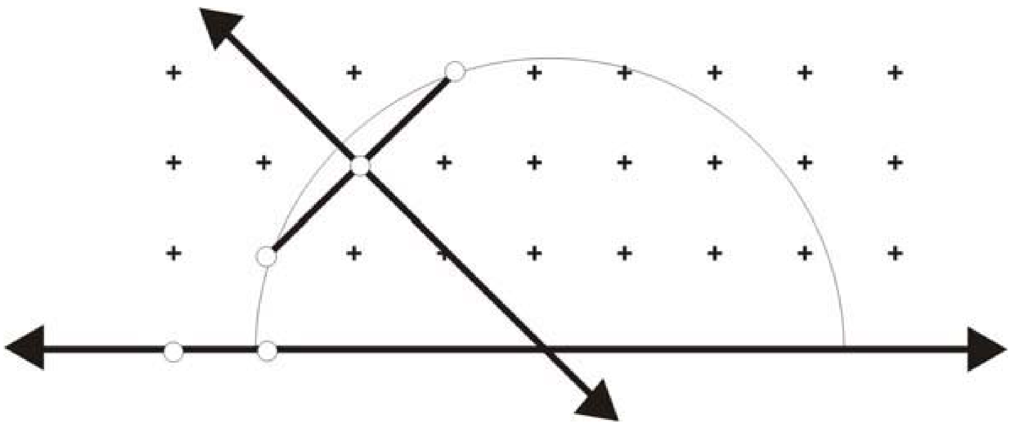

Figure 4. Student's support diagram during their solving problem

[12] There are many terms to refer to artefacts conceived for a specific use and a specific goal: tools, ins-truments…(Mariotti, [7])

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In what follows we describe the dialog between the students Susana (S) and Patricia (P) and the teacher during their deductive task using an analytical approach.

S.: I see…this is the line that goes through A and B. (Susana makes a diagram using Hyp_line.gss)
Teacher: But what is the analytic expression of this line?
S.: I don't know!
P.: Me neither!
Teacher: What is the analytic expression of the semi-circle?
S.: Now I know…(The student writes the general expression of an entire circle).
Teacher: Then, and in this case?
P. But we don't have the centre of this circle…..
S.: Actually, we only have the two points A and B… and the program does not give us the coordinates for the centre.
Teacher: Well, given two points of the circle, you can readily find the centre coordinates. Do you know how to do it?
S.: If we join A to the centre, we have the radius of the circle, similarly to what happens if we join B to the centre. However, we still don't know the centre…..
P.: I don't know….
S.: Wait… We know that the centre lies within the line that divides [AB] into two identical segments. Isn't that right Teacher?
Teacher: That is correct. Can you now give the expression for this hyperbolic line?

The students were able, with the teacher's assistance, to do the required specification. In this procedure the diagram (Figure 4) was in fact their real support to make deductions. They have used the visual reasoning not as an intuitive global stage but as a support to their deductive conclusions.
After they have written the analytic expression of the hyperbolic through points A and B, they "confirmed" by GPS (e.g., they have verified that the radius they found analytically was exactly the length between the semi circle centre and the point A).

Visualization ⟶ Argumentation

The posed question - *In this geometry, through any two distinct points there exists a unique line? Justify* – raised a discussion about its meaning in others geometries which was regulated by the use of GPS. They come to the conclusion that in the spherical model the incident property was not verified.

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In the second posed problem Susana gave an explanation based on the following diagram.

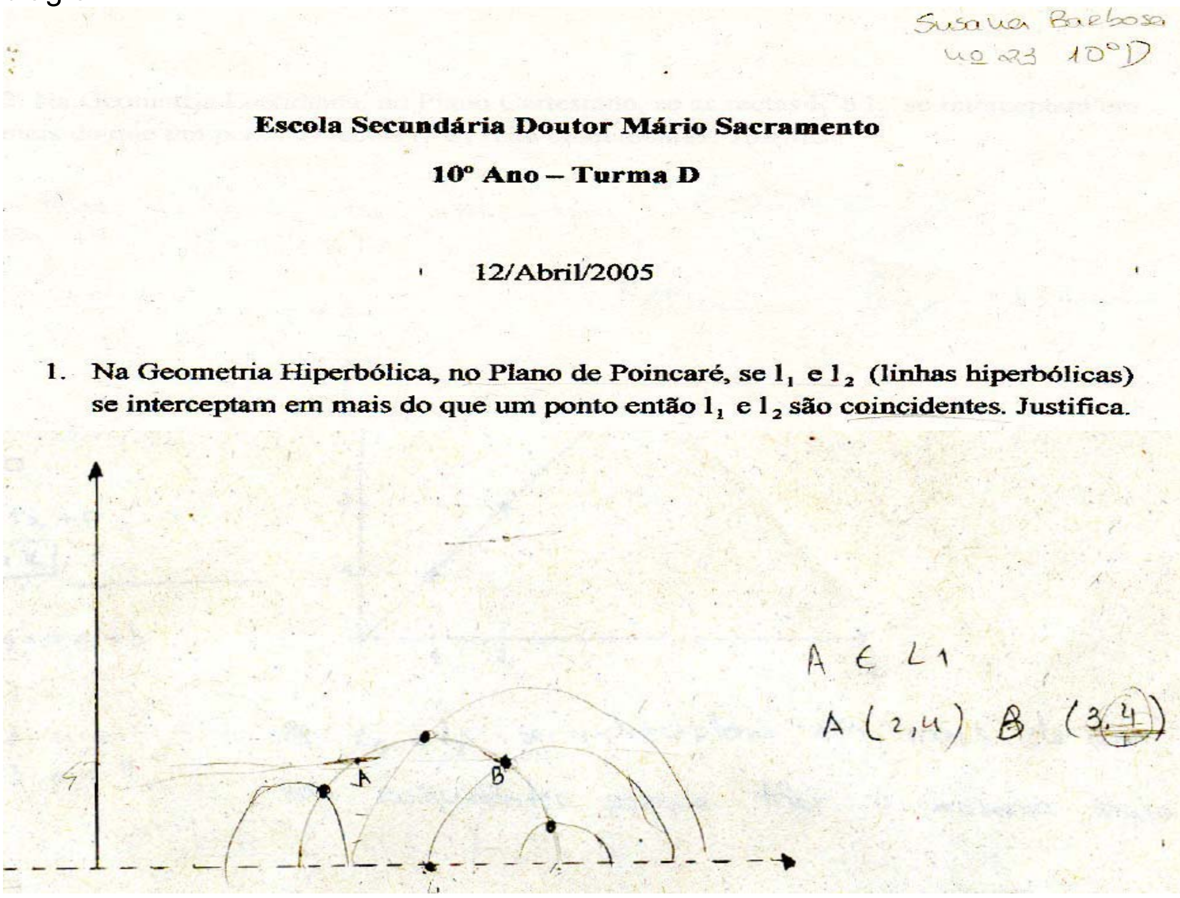

Figure 5. Task's first approach

Discussion (argumentation) between Susana (S) and Patricia (P).

S.: Haven't we already solved this problem? (1:30) (This question was formulated right away to Susana reading the statement of the problem)
P.: If they intersect in two points they are coincident…
S.: We have one, you see that …. (the student makes diagrams). It is not possible to draw another line (through the two points).
P.: Do they intercept each other?
S.: The two lines only intercept each other in one point. You see!? (the student continues using visual support)
P.: They can intercept each other in more....
S.: How? How? Only if they were coincident…
P.: ok!
S.: Yeah… but how do we justify it??

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Here Susana (S) and Patricia (P) provide, once more, an argumentation through visualization. The Susana`s question “*Haven’t we already solved this problem*?” shows that she was thinking in the solution of the previous task but she was not able to apply it. She went immediately to the exploration phase, using diagrams, without establishing links with results already obtained.
The students have felt necessity to justify their conjectures but they have not make the connection with the known result; *in the Poincare upper half plane, through any two distinct points goes a unique line.*
Meanwhile, these students were trying to find arguments to support their conjectures. Simultaneously they used some functionalities of GPS (Hyp_line.gss, Construct Menu), exploring a diversity of diagrams. Finally, they solve the proposed problem using an analytic approach spending a lot of time in the implementation of this approach.

Conclusion

Our study confirms the assumption that visual reasoning is more than an intuitive global and preliminary stage for the reasoning processes in general, supporting further reasoning. As expected the use of physical models in combination with virtual models brought a better insight to the significant role of a mathematical proof. If they were not confronted with situations were a minimal line joining two points could be a curved line instead of a straight line they were not able to see why we should prove that for instance, in the Euclidian plane the sum of the internal angles of a triangle is 180^{o}. In this empirical study the students followed the triangular representation (4, 2 3) of cognitive interactions described by Duval. In other words, they went through the cognitive interaction path:

Construction ⟶ Visualization ⟶ Reasoning

In respect to the construction level they went through all the three types of learning activities: *figure acquisition, figure appropriation* and *property exploration*, (Schumann and Green [11] description). The learning activities they went trough were determinant for the development of their deductive reasoning. It seems that the Duval’s approach is in fact a useful framework when working in dynamical environments and that the use of non-Euclidian geometry is not only a way to make student’s familiar with axiomatic systems but also a way to make evident the strength of a formal proof.

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ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

References

[1] De Corte E, Changing Views of Computer Supported Learning Environments for the Acquisition of Knowledge and Thinking Skills. In Vosniadou S, De Corte E, Glaser R and Mandl H (eds). International Perspectives on the Design of Technologies- Supported Learning Environments, Mahwah, Lawrence Erlbaum Associates, pp.: 129-145, 1996.
[2] Duval R, Geometry from a cognitive point of view. Perspectives on the Teaching of Geometry for the 21st Century, 1998.
[3] Good CV, Dictionary of Education, Mc. Graw–Hill: New York, 1959.
[4] Hadas N, Hershkowitz R and Schwartz B, The role of contradiction and uncertainty in promoting the need to prove in dynamics geometric environments. Educational Stu-dies in Mathematics, Proof in Dynamic Geometry Environments, 44: 127-150, 2000.
[5] Hanna GE, Proof, explanation and exploration: An overview. Educational Studies in Mathematics, Proof in Dynamic Geometry Environments, 44: 5-23, 2000.
[6] Hanna GE, A critical examination of three factors in the decline of proof, Interchange, 31: 21-33, 2000.
[7] Mariotti MA, Influence of technologies advances on student's mathematical-learning. In English L, Bartolini MG, Jones G, lesh R and Tirosh D (Eds.). Handbook of International Research in Mathematics Education, Lawrence Erbium Associates, 2001.
[8] Reston VA, National Council of Teachers of Mathematics. Principles and Standards for School Mathematics, 2000.
[9] Pegg J and Tall D, The fundamental cycle of concept construction underlying various theoretical frameworks. International Reviews on Mathematical Education, 37: 468-475, 2005.
[10] Riding R and Rayner S, Towards a categorization of cognitive styles and learning styles. Educational Psychology, 17:5-27, 1997.
[11] Schumann H and Green D, Discovering Geometry With a Computer, Chartwell Yorke: Bolton, 2000.
[12] http://www.davidtall.com/

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Method and Set-Up to One-Step Recording Rainbow Holographic Art Exhibits

Chisleag R and Leg M

In the last years, in the Laboratory of Holography of the University “POLITEHNICA” in Bucharest (UPB), the author has voluntarily trained, every two years, 2-3 master students from the National University of Arts in Bucharest (UNAB), with the intention to open way to introduce Holographic Art at UNAB, which, by now, does not have a Holographic Studio.

By considering the present scarcity of financial resources of both universities implied, it has been necessary, for training future art holographers, to make use of the existing in UPB: expertise, holographic equipment, silver halide holographic plates; to produce holographic exhibits to offer reconstruction of images in white light (not applying to lasers for reading, as for normal holographic reconstructions) and to reduce, as much as possible, the technological chain of the holographic process from idea to the final exhibit.

The conclusion has been that the Rainbow Holograms would be the most convenient holograms to start with to introduce Holography at UNAB and that there would be necessary to design a one-step technique to obtain directly the Rainbow Hologram Art exhibits, without intermediate recordings.

A Holographic Set-up, close to the one used by the author to develop Rainbow Hologram Interferometry [1], a set-up able to comply with the mentioned requirements, has been assembled and used with a scheme represented in Figure1 (when operating with diffused objects but conveniently changed for transparent objects – in a transmission configuration).

This approach might be considered a “Retro” one, but oriented towards a new opening – the Holographic Art.

The coherent light wave is generated by a laser (HNA 188, Carl Zeiss 1976), the emitted light having a wavelength (633 nm) convenient to the photosensitive materials used (Holographic plates ORWO) and enough coherence length. (~2m) for the set-up.

The laser wave is re-directed by the mirror O1 and divided in amplitude by a beam splitter BS (DA, in French and Romanian), in two mutually coherent waves (finally - Object and Reference).

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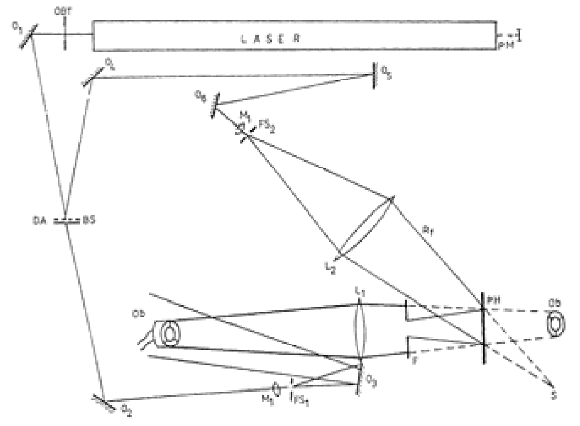

Figure 1. The Holographic Set-up for one-step recording rainbow art holograms (diffuse objects)

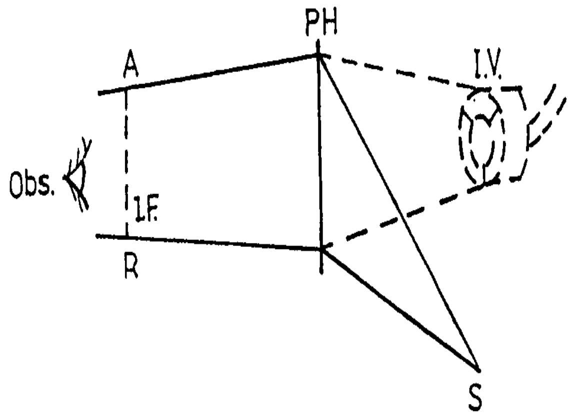

Figure 2. The reconstruction of the primary object wave with a point source S

One of these two waves illuminates the object Ob (of interest to the Art Holographer), after being enlarged by the lens M1 (usually a microscope objective) and filtered by the Spatial Filter F S2

The Lens L1, not quite usual in the standard holographic set-ups, is adjusted to generate, behind the Holographic Plate, PH, a real image of the object, Ob.

The cross section of the wave coming from the object is limited, by the specially introduced slit F, which plays an essential role in one step recording of the rainbow hologram.

By significantly restricting, in one direction, the size of the aperture which limits the cross section of the object wave, the slit F is ensuring the reconstruction with a polychromatic reading source, even of white light...

With a second lens L2,, there is projected a real image of the very small aperture of the Spatial Filter SF2 on a point S, behind the holographic plate PH, as to act as a virtual point reference source S for the hologram (which is to finally become an art exhibit).

All the components of the holographic set-up are fastened (magnetically or mechanically) to a holographic table of high stability, mechanically insulated from outside vibrations, vibrations that unfortunately could change the optical distances between components during the exposure time and destroy the stationary interference pattern when recording. The environment's temperature is maintained constant, during exposure.

The latent image generated in the photo-sensitive layer, during exposure, is embodying the real (recordable) interference pattern of Object and Reference waves impinging on the Hologram, and, by this, is recording the complex amplitude of the Object wave, as both the real amplitude and the phase of the Object wave.

After conveniently processing the photosensitive material (so that the amplitude modulation of the incident light by the recorded pattern, become proportional with the intensity of the incident field), the latent image becomes an image to be read.

To get a better luminosity, the hologram may be bleached – the absorption image being transformed in a phase image.

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The micro-relief structure appearing in the photosensitive layer (as local variations of the refractive index or of the thickness) may be used by transmission, as a transparent, phase, micro relief or may be covered with a reflecting thin layer of uniform thickness to be used by reflection, depending of the designed use of the Holographic Art Exhibit.
When illuminated by a reading source S (Figure 2), the Hologram reconstructs, both, the object's Virtual Image I. V. and the real image of the slit F used when recording the hologram. If the reconstruction light is polychromatic, there are reconstructed a set of dispersed parallel slits, and correspondingly a set of dispersed object images (“rainbow”), in the colours corresponding to each spectral component of the reconstruction light.
The Observer (Obs. In Figure 2), with the eyes placed along a really reconstructed slit image, sees the reconstructed virtual image of the object when looking "through" the reconstructed slit, in the colour corresponding to that slit. Moving the eyes normally to the slit direction (between A and R), the reconstructed image of the object (3-D, having “depth”, too) is seen changing the colour (and position), depending on the spectrum of the reconstruction source and on the eye’s position with respect to the reconstructed slit.
The reconstructed image has artistic value. It is bright, colourful, and changeable. The physical recording may be replaced by simulation on computer. The Art Hologram may be replicated on standard equipment, existing on the market.
The UPB and UNAP trainees in Holographic Techniques in Art have produced dozens of holographic Art exhibits which have been displayed on different exhibitions, usually graduation ones.

References

[1] Chisleag R and Cicei A, On Hologram and Speckle Interferometry Investigation of Electro-Acoustical Generator Active Surface Vibrations. An. St. Univ. “AL. I. CUZA”, Iasi, Romania, XXVI, 63-70, 1980.

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Chladni Plates: A Hands-on Energy Activity

Dorrío BV, Rodríguez-Muñoz S, Rodríguez-Lago A and Diz J

Introduction

The success of interactive Science and Technology museums from the end of the 20th century is made evident in the wide range currently available, the majority of them being the successors of the San Francisco Exploratorium [1], with one of their basic suppositions being that the visit should be a time of playful learning. The basically manipulative format of these centres fosters an interrelation between the series of concepts and ideas that are brought into play and the visitor, something that is not usually achieved in expository collections of traditional museums. The manipulative experience that interactive museums provide is essentially based on the appropriate combination of arousing curiosity and intrinsic motivation, the use of play and exploration, the use of different modes of learning (cognitive, psychomotor and emotional) and the support of the visitor's mental models and knowledge [2].
This interactive museum model can be brought into [3, 4] the formal world of teaching taking advantage of the vast amount of information that currently exists concerning experiments that can be simply carried out [5], which allows for demonstrations and mini-experiments to be carried out in the classroom, during usual explanations or in a wider context, grouped as an interactive exhibition. The latter activities involve the students to a greater degree than during normal classes, thus reinforcing class work as it allows personal use of the concepts using every-day materials and relating them to usual technological applications [6]. In this case, the teachers and students were responsible for the tasks of designing, building, assembling, organization and the carrying out of the experiment, thus increasing collaboration and their creativity between them. This process, as in all scientific work, requires ample knowledge of the pre-existing ideas and the capacity to adapt, improve and modify them in varied ways, an essential role which is developed by the teacher [5]. On the other hand, the pupil on building his/her manipulative model gains a deeper and fuller knowledge of the concepts involved.
In this essay, we present the most noteworthy results obtained during this experiment at the Escolas Proval Secondary School of Nigrán (Spain). The benefits, potential and general difficulties associated to the process become evident through the detailed analysis of one of the manipulative modules.

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Energy in your hands

As a natural continuation of the experiment previously carried out [7], the assembly hall of the Escolas Proval Secondary School of Nigrán (Spain) again turned into a small interactive museum [8] in which about thirty manipulative modules with their corresponding self-explanatory panel allowed the visitors to carry out activities, collect evidence, select options, form a conclusion or test their abilities [9], searching on the one hand for a balance between potential enjoyment and learning and on the other hand, combining the formal contents of a classroom with the exhibition itself. The materials used, which had not only qualitative but also quantitative aspects, were simple, inexpensive, accessible, easy to assemble, transportable and easy to handle, appropriate for all ages and any level of knowledge. The self-explanatory panels which accompanied each of the modules attempted to be visually attractive, with short/simple instructions/explanations which had the aim of guiding the previous knowledge of the visitor, prompting the visitor to explore for him/herself, to generate new questions, find the answers to those questions and to make more real the concepts involved.

Figure 1. Hands-on Energy exhibition

This was accomplished by making the visit a multi-sensory experience, stimulating the understanding of the contents which were brought into play, providing the opportunity to not only participate with their hands but also with their senses and minds and relating the contents with previous experience, their daily life and the contents of formal learning. Several pupils also carried out monitoring tasks during the exhibition (in some cases due to security reasons) with the aim of guiding the visitor to achieve an enriching experience and to avoid mere compulsive manipulation or the visitors becoming a passive recipient of information.
As a connecting link for all the modules developed, the energy involved in different processes was adopted, possibly one of the most universal and interdisciplinary scientific concepts, which has an important role in numerous areas of Science and Technology and its properties explains to a large degree the world which surrounds

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us [10]. In this manner, the visitor could experiment, in combination with other concepts brought into play, with the energetic level of different processes (noises and decibels, radiometer, pressurized rockets, hydraulic lifts, lights and consumption…), analyze thermal properties of different materials (avoidance of burning paper, burning an almond, does metal burn?...), see several energetic relations (magnetic brake, bicycle wheel…), generate energy (human battery, electric motor, thermoelectric helicopter, lead battery, Van de Graaff…), use their energy to provoke perceptible changes (spring, sonorous tubes, resonant springs, chaotic pendulum…), etc…

Figure 2. Hands-on Energy exhibition

An example: Chladni Plates.

The waves that surround us everywhere are at the same time a paradigm of energetic propagation in space. Its study is a fundamental basis of formal curriculum in a large number of scientific-technological subjects, in which the involved concepts are tackled from several perspectives and in differing depths. The Chladni plates [11, 12], an ideal complement for traditional one-dimensional introductory experiments on strings and springs, allows the creation and experimentation with stable waves in two-dimensional mediums, making visible in a spectacular and comprehensible way that which is apparently invisible and thus avoiding a good many conceptual errors deeply rooted in the related contents [13]. Traditionally a metallic oscillating plate is used with its edge free and a fixed point onto which fine grains of sand or something similar is placed on areas of the plate that do not vibrate to create beautiful complex but symmetrical patterns, similar to those formed on percussion instruments of membrane. These stable patterns known as vibration modes and associated with an audible frequency, are explained as the interference of reflected and transmitted waves in which the distance

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between the node lines (which joins points without movement) are directly related to the length wave of the travelling wave on the plate.

Figure 3. Working with the Chladni plate

Normally, the manual stimulation of the stable wave is carried out using the bow of a stringed-instrument (violin, violoncello, double bass,…) or a similar substitute (for example, a saw for metal in which the blade has been replaced by several nylon threads [14]) which requires certain skill and training. The delicate process can be made simpler if we replace human intervention with an electronic or acoustic stimulator [15], in which case patterns are achieved at any moment without hardly any previous practise, the range of frequencies can be used to create patterns and the transition between consecutive vibrating modes can be quantified. As a measure of precaution it is advisable to use earplugs as the most spectacular results are achieved with certain irritating tones.

Experimental assembly and results

Today it is possible to do the same experiment with less effort by using an electronic generator of waves and a loudspeaker instead of a violin bow. Although there is commercial equipment with all the necessary material, including plates of different sizes and geometry [16], we have tried to use common and inexpensive elements which are easily accessible in any teaching centre, such as a sound amplifier and a loudspeaker sound box.
Our experimental setup consists on four main elements:

1. Signal generator. We used an electronic signal generator with the following characteristics: sine, square and triangular waves, adjustable output level (with attenuators to allow a wide range of levels), continuous adjustable

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frequency and different scales (10-100-1K-10KHz minimum), digital frequency meter. This element is very important, since an exact measurement is needed to find the resonance frequencies of plates and to be able to repeat the experiment again in the same conditions. This kind of signal generator, however, is very common in electronics and physics laboratories.

2. Sound amplifier. It could be used almost any available sound amplifier. We used a music amplifier with an output power in the range 20-50W.
3. Loudspeaker (acoustic box). We used an acoustic box with one loudspeaker covering the whole range of frequencies. It could be used a common acoustic box like those of hi-fi music systems, home cinema or similar. The loudspeakers should have a nominal power enough to be connected to the amplifier without risk of damage. It could be used only an speaker without acoustic box, but we preferred this by two reasons: the box itself can be used as an stand for the experiment and at low frequencies the front and back waves of a speaker can interfere, reducing the available power. In our experimental setup the acoustic box is placed in a horizontal position, and serves also as a fixing point for the Chladni plate. So it should be large enough to hold the plate and fixing elements.
4. Chladni plate. We used a square aluminium plate of 60x 60cm, with a thickness of 3mm.

The assembly can be made in two steps:

1. Electronic connection: the signal generator is connected to the power amplifier by a coaxial cable with a BNC connector in one side and a jack or RCA connector in the amplifier side. In some cases, this cable should be made if not available. The amplifier is connected to the loudspeaker by a two wire cable (this cable has no special requirements but a certain minimum diameter).
2. Mechanical assembly: This part is a little more difficult. The aluminium plate should be firmly kept in place over the acoustic box, but at the same time we can only fix it by a few points (typically only one in the centre of the plate). So it should be used a strong screw or piece of metal. In our case, we used as fixing point the grid that protects the loudspeaker, making sure the plate was exactly over the speaker to maximize the acoustical coupling between them. This kind of assembly is different from the most common ones, in which the central fixing point is attached to the speaker or mechanical vibrator. In our case the fixing point becomes a node instead of a vibrating point.

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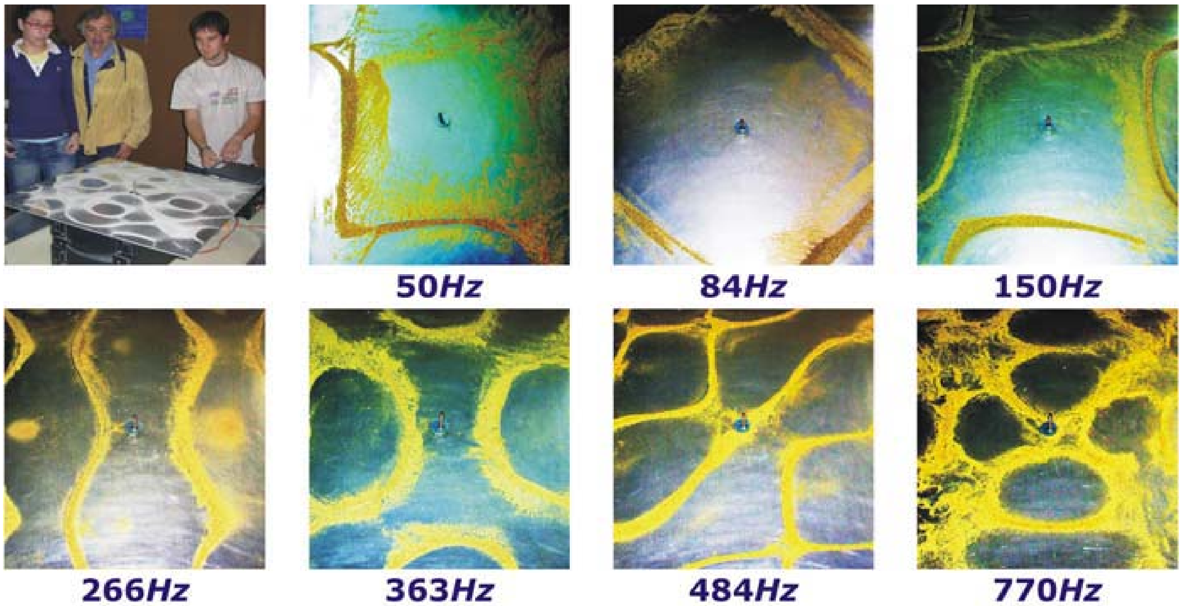

Figure 4. Chladni figures at different frequencies

Another important difference is the way of energy transfer to the plate, in our case the transfer is by acoustical coupling (i.e. through the air) while the most common method is by mechanical transfer with a coupling element. This kind of coupling can result in a loud noise while making the experiment, what is a little disadvantage, but on the other hand the mounting is easier and more resistant, and there is no need to use a special (and expensive) mechanical vibrator. When all the elements were connected and assembled, we started making trials to locate the resonance frequencies of the plate and get different patterns. We had to adjust both frequency and sound level, since the overall response of the system (generator-amplifier-speaker-box-plate) widely varies with frequency. Every resonant frequency found was carefully registered to be able to repeat the experiment another day. We found many different patterns, from the simplest to very complex ones. For developing the patterns we used beach sand.

The educational possibilities for widening the field of performance once the basic experimental assembly has been set up are numerous and varied as the vibration patterns depend on many variables. Thus, node lines can be forced in certain areas of the plate by direct contact by the experimenter or with a certain weight or by changing the support point; changing the materials (type, colour, size) used to see the nodes (including antinodes [17]) (sand, sugar, salt, small pieces of paper, aluminium powder, silica beds, talcum powder... [18]; or by varying the actual features of the oscillating plate (metallic or transparent [19], its thickness, geometry…).

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Conclusions

The results obtained during the experiment of setting up a small interactive museum with the theme of energy are highly satisfactory: the exhibition received during the week that it was running over five hundred pupils from five secondary level teaching centres. This same exhibition was later set up in other centres of the immediate surroundings. At the same time, the experience has encouraged the pupil’s creativity and a reliable manipulative approximation towards Science and Technology in the pupils directly involved. The high level of involvement with the experiment is made apparent in their wish to carry out similar experiments a posteriori.

The experiment analyzed related to the Chladni plates demonstrates the potential and versatility of manipulative experiments as a learning tool. As improvement for this experiment we are planning to use a computer generated waveform to drive the sound amplifier. It could be done with a simple PC with a sound card and a program that we have already written to adjust frequency and level. This kind of program can also be found in several internet places, and eliminates the only element that some schools could not own, that is the signal generator. Finally, it is possible to make a specific amplifier for the experiment using common electronic circuits like TDA2050, whose schematics and PCB could also be found in internet.

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References

[1] http://www.exploratorium.edu/

[2] Semper RJ, Science museums: Environments for Learning, Physics Today, 11: 2-8, 1990.

[3] Campbell J, Canterbury´s Physics display facility, Physics Teacher, 27: 526-529, 1989.

[4] Pinkerton KD, Interactive Hallway Physics for elementary schools, Physics Teacher, 29: 166-168, 1991.

[5] Dorrío BV, Rúa A, Soto R and Arias J, Hands-on Physics Bibliography, Proceedings of the 1st International Conference on Hands-on Science. Teaching and Learning in the XXI Century; Divjak S (Ed.), 2004 July 5-9; Ljubljana, Slovenia, University of Ljubljana, pp.: 119-124, 2004.

[6] McCullough J and McCullough R, The role of Toys in Teaching Physics, AAPT: MD, 2000.

[7] Rodríguez S, Fernández J, Asín JA, Lago A and Dorrío BV, An informal interactive science and technology centre, Proceedings of the 2nd International Conference on Hands-on Science. Science in a changing education,

ISBN 978-989-95336-2-2 ©Hands-on Science Network 2008

Michaelides PG and Margetousaki A (Eds.), 2005 July 13-16; Rethymno, Greece, University of Crete, pp.: 190-195, 2005.
[8] http://webs.uvigo.es/h-sci/provalg2006.htm
[9] McLean K, Planning for people in museum exhibitions, ASTC: Washington, 1993.
[10] Smil V, Energies, MIT Press: Cambridge, 2000.
[11] Waller MD, Chladni Figures: A study in Symmetry, Bell: London, 1961.
[12] Rosing TD, Chladni´s law for vibrating plates, American Journal of Physics, 50: 271-272, 1982.
[13] Moreno JM, Some difficulties in teaching the properties of sounds, Physics Education, 33:101-104, 1988.
[14] Pitre JM, Chladni plates: how big can they be?, The Physics Teacher, 34: 508-509, 1996.
[15] Jensen HC, Production of Chladni figures on vibrating plates using continuous excitation, American Journal of Physics, 23: 503-505, 1955.
[16] http://www.pasco.com/
[17] Comer JR, Shepard MJ, Henriksen PN and Ramsier RD, Chladni plates revisited, American Journal of Physics, 10: 1345-1346, 2004.
[18] Graham GR, DIY physics, the paper scraper paper, Physics Education, 24: 25-29, 1989.
[19] Ouseph PJ, Chladni plates for the overhead projector, American Journal of Physics, 59: 665-666, 1991.

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A Space Education Hands-on Experiment Using the Principle of Action and Reaction in Elementary School

Oliveira Reis NT and Dias Garcia NM

Space exploration in Brazil and in the world

The dream of reaching the skies is one of the most ancient mankind's desires [1]. Astronautics, that is, the manned or unmanned exploration of outer space represents one of the most recent sciences and practices in the history of science and technology. Space Era has begun in the context of cold war between the United States and the former Soviet Union and it started when the first satellite constructed by man – the Sputnik I was launched by the former Soviet Union, in October 4, 1957. After that plenty of spaceships, probes, satellites, space stations, space telescopes and other artefacts have been launched to space with a wide range of purposes.

The benefits derived from space exploration are accounted in diverse areas: telecommunications, medicine, environment monitoring, general research in science and technology. According to Haggerty [2] the benefits resultant from space exploration, or spin-offs, are found in the development of rescue equipment, entertainment products, special clothing, prosthesis material, water purifiers, robotic, superconducting materials, optical fiber and other applications of great economic and social impact.

Being a continental-sized country with a large variety of natural resources, early Brazil became aware of the importance of developing national space products, processes and services for its socioeconomic progress, conducting since the 1960's space activities with the creation of the Aerospace Technical Centre (CTA) in 1954, the National Space Research Institute (INPE) in 1971, and the Brazilian Space Agency (AEB) in 1994.

In 1993 it was launched the First Data Collecting Satellite (SCD1) by the American Pegasus rocket and Brazil became the 16th country in the world capable of designing, developing and operating a space platform [3]. Furthermore, Brazil and China are partners in the development of the series of remote sensing satellites CBERS (China-Brazil Earth Resource Satellite). Brazil has also the Alcantara

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Launch Centre (CLA), a privileged centre on the Atlantic coast outside of Sao Luis very close to the geographic and magnetic equator of Earth.
Recently, as part of the upcoming centennial year celebration of the flight of Santos Dumont in his 14 Bis, the first Brazilian astronaut and cosmonaut Marcos Cesar Pontes has gone into a space mission to the International Space Station (ISS) and there developed scientific and educative experiments.

Space Education

Space science and technology education consists of a singular nature tool capable of offering students an integrated and global understanding of scientific and technological facts and phenomena. It can represent the motivation of the curiosity and interest of the students on processes, products and services derived from space environment exploration so that offering an interdisciplinary understanding of science and technology along with the manner they affect daily life. In this perspective space education contributes with the teaching/learning process in science, mathematics and technology [4].
Space exploration and its outspreads are transformed in the axis from which it is presented scientific, mathematical and technological contents. This theme may be the starting or reaching point from which it is developed the pedagogical classroom work. Hence, space education has the potential to be helpful in the scientific literacy of elementary school students, taking into consideration the fact that in the first years of schooling the interest for sciences and technology is captured and it is consolidated the first scientific models and conceptions.
Space education somehow began when the professional staff – composed by doctors, masters, and specialists – necessary to the development of the first space activities were constituted.
Nevertheless, only in the 1990’s it has been recognized the necessity of working knowledge and practices of space education among teachers, children and teenagers in elementary and secondary school, in spaces of formal and informal education, aiming to contribute to scientific and technological preparation of students as well as to disseminate the consolidated space programs, their careers and socioeconomic benefits.
On the other hand, presently there is a large variety of space education programs around the world. It can be mentioned countries such as the United States, Russia, Canada, Japan, France, Brazil, Israel and so on.
We can illustrate with the NASA’s Program for Education [5], from the American space agency. It reaches great successes in offering activities and resources for both students and educators in formal and non-formal educative spaces for all educational levels. Courses for students and teachers on space subjects, workshops, lectures and visits to space centres, distribution of printed and on-line material are some actions of the Agency. NASA has also several links in its home page (http://www.nasa.gov) related to education.
Additionally, there are international initiatives such as the International Space Week (http://www.spaceweek.org), reaching space education organisms from over 50 countries, consisting in the largest public space event in the world, promoted by the

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United Nations since 1999. UNESCO by its turn has launched its space education program in the year 2002. There is also the Globe Program, a NASA initiative involving more than 100 countries, about 24 thousand teachers and 14 thousand schools consisting of a scientific education hands-on program for initial and intermediate level students, in which teachers go into training and students realize scientifically valid measurements and report it to scientists and international colleagues through internet.
In Brazil, there is a program named AEB School, which develops a series of activities and events aiming to spread the Brazilian space program and to motivate young students towards science and technology.
In 2004 and 2005, the Brazilian Ministry of Education (MEC) in partnership with the Brazilian Space Agency (AEB), in occasion of the National Week of Science and Technology promoted courses on “Remote sensing – the use of satellite images as didactic resource in secondary school” in five Brazilian capitals.
In accordance to these tendencies and initiatives, the United Nations Office for Outer Space Affairs emphasized on occasion of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), realized in Vienna, 1999, the importance of working space sciences and technology education in schools as development factor for the nations, hence, according to the conference papers, “Education and training in space science and technology can provide many developing countries with opportunities to modernize and pursue a more dynamic development” [6]. Space education has been regarded as a vehicle of approaching children and teenagers from careers in science and technology.

Some basic notions on Astronautics

Astronautics is the science and practice of extra-atmospheric or outer space exploration by manned or unmanned artefacts developed by human beings. Following it is presented some concepts and basic notions of Astronautics present in the astronaut’s life in outer space.

The outer space environment

Outer space is the space surrounding the uppermost reaches of the atmosphere of Earth and where we can find all objects of the Universe [7].
Although being a void this space can be thought as an environment through which it pass freely radiation and objects. For many reasons, it is an inhospitable environment for human life. One of its characteristics is the nearly complete absence of molecules so that density is so reduced that they can be inconsiderable. On Earth the atmosphere exerts pressure in all directions. At sea level pressure is of 101 kilopascals whereas in space it is nearly zero.
The temperature range in space is also one of the main constraints for human life in such environment. In space, at an Earth’s distance from the Sun the sunlit side of the objects can climb to over 120º Celsius whereas the shaded side can plummet to lower than minus 100º Celsius [7].

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Other factors encountered in space environment include weightlessness, electromagnetic radiation that is not filtered by atmosphere (as the ultraviolet), meteoroids and debris from previous space missions.

Working in space

One of the characteristics of space environment is weightlessness experimented by astronauts and objects carried inside the spaceship. This weightlessness can be explained by the fact that as rigorously we do not have “sensors” which allow us to evaluate the weigh force we perceive it through the inner efforts we face in daily life. For instance, we can imagine ourselves on feet in a bus stop. Earth’s gravitational field exerts a force named weigh on all particles that constitute our body. As we are stopped over a resistant surface we do not submerge in the direction of the centre of Earth, but our body is comprised, which causes an inner effort of compression equivalent to our weight, which gives us a null resulting acceleration. So we have the perception of this compression that has the same value of our weight, so that we can feel it.

Hence whether we consider an individual moving under the action of its own weight only (without any inner effort) he will feel “zero weight” This happens during freefall or during a trajectory as the one described by the projectiles or in any orbit described by space vehicles.

Here on Earth, to lift or move an object, one should be with their feet firm on the floor and need to subdue the gravitational force which acts on the object in order to develop the task. In space, due to the sensation of imponderability the objects can be easily moved but the astronaut must have a platform capable of offering him enough resistance to overcome the inertia of the object to be moved.

Also on Earth surface, boxes placed on over another present friction caused by compression of their surfaces of contact which must be subdued for that they can be moved one in relation to the others. In the environment of a space vehicle, these same boxes do not comprise and the friction does not have to be subdued to move them. Certainly their inertia will not change but due to the absence of friction, it is quite easy to push them softly in the space environment.

As a result and considering that in space it is also valid the principles of quantity of energy and movement, and in spite of the weight an object presents on Earth, when in orbit, one single crewmember can move and position it easily provided that he has a stable platform from which to work, with enough inertia and capable of offering the necessary support for the execution of the tasks. On the other hand, the apparent imponderability can also make it difficult the astronaut activities, depending on the inertia of the platform to which he is connected.

Hence, standing on a platform such as a spaceship – of great mass and inertia – the astronaut can realize tasks impossible to be realized on Earth, because of the weight of the objects involved. Nevertheless, if the astronaut is not on a stable platform of reasonable mass and inertia, such as a space shuttle, to push an object provokes the flotation of object and crewmember in opposite directions [7].

Therefore, considering that in his activities the astronaut does not always have a stable platform to stand on, simple tasks, such as using a tool or pushing a glass, in

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space, can become complex, for both the tool and the glass and the astronaut can undesirably move, fact that demands him exhaustive trainings for that with complex and combined movements he is capable of transmitting the desired moves to the objects and tools.

Figure 1. Astronauts working in space

Figure 2. Student realizing the spinning chair experiment

Actions and reaction and astronautic activities

The experiment in space education has been applied in an elementary school classroom (fifth grade students), with the purpose of applying and explaining Newton's Third Law, the Principle of Action and Reaction and of establishing a connection with work and life of astronauts in space. It has been adapted from a study topic named *Spinning Chair* which refers to movement in space, as described in the activity NASA book *Suited for Spacewalking* [7] a didactic manual published by NASA which deals with concepts and experiments related to space activities and involving contents in sciences, technology and related fields, based on the activities developed by astronauts in outer space. The experiment has been divided into two activities aiming to reconstruct the Principle of Action and Reaction.
The materials used in the first activity were the following:

a) spinning chair without back;
b) objects for hands (sandbags), about 2 kg each.

Initially, students have been accommodated in a circle with the chair at the centre, with a space left for that the students could move with the chair.
The teacher explained that they should attempt to move in the inner of the circle and in circular movement but without stepping on the floor neither upholding on the wall. For that they should produce with the body movements that could cause

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locomotion. In the sequence students have been asked individually to develop the activity and received two objects two kilograms each to help them achieve some movement. After some attempts they have realized that a certain pendulum movement allowed the circular movement.

Figure 3. Student tosses the bags to move

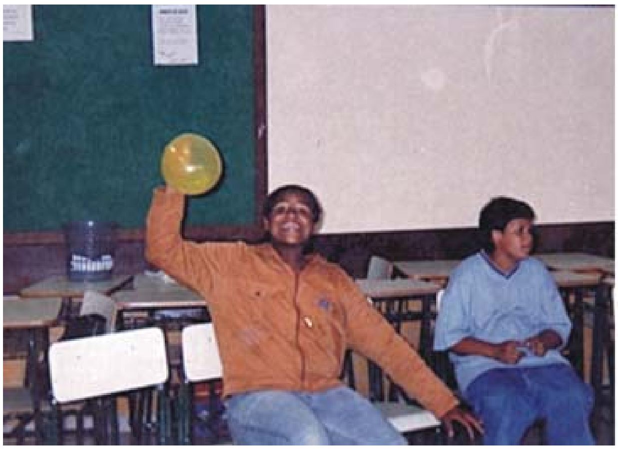

Figure 4. Student doing the balloon activity

Figure 5. Students fill in the questionnaires

The second activity had the purpose of consolidating knowledge explored in the preceding activity and has been realized as follows: students individually received a rubber balloon, filled it with air and after that they had been oriented to release it and notice the movement realized by the balloon and by the air inside of it. In order to illustrate the Principle, the teacher filled one balloon with air and explained that as the air inside the balloon exerts a force against its inner surface this surface also exerts one force that maintains the air compressed inside of it. Hence, when the balloon is released, the air pushes the balloon and it pushed the air, simultaneously. In the sequence it has been conducted explanation on the daily astronaut activities in space, with presentation of pictures allusive to the work of these professionals to better illustrate the theme.

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To conclude and record some of the results of the experiment, each student presented by means of a previously elaborated questionnaire for collecting data their impression about the activities: comprehension, facility, meaning, satisfaction, interest, and so on. Besides it has been realized and recorded an interview with two persons involved in the experiment: one teacher and one student.

Results

Considering classroom observation and the collected answers, generally speaking, it has been realized that the participating students felt difficulty during the prescribed and experimented locomotion. Furthermore, although they had received some notion about the Principle of Action and Reaction they thought it a little strange the fact that as they were pushing the wall, it would be pushing them too; that as they jump on the floor, so that exerting a force in direction of the centre of Earth, the planet would be pushing them in the opposite direction, with a force of the same intensity.

It has been also verified that the majority of the students involved in the experiment were not familiarized with space thematic, since according to students' reports, such subjects have not been presented in any scholar subject. In the fifth grade students studied some concepts and theories in astronomy but the thematic of space exploration was not discussed.

Considering the twelve questionnaires answered by the students and the two interviews realized it has been possible to infer that students had satisfaction in realizing the experiments and they could establish relation among them and the space activity, demonstrating understanding in various levels of the physical concepts involved. From the sample researched, half the students supplied reasonable explanation for the Principle of Action and Reaction, that is, spontaneous deductive explanation related to sensorial perception and to visualization as in the case of the balloon activity. Additionally, it has been evidenced that for these students it has been more difficult to understand the fact that as one jumps on the floor, Earth exerts a force of the same intensity but opposite direction.

Additionally, 75% of the students stated that the activity was viable and easy to realize. Some student's reports:

"Is has been good"; "Because you just needed to give the impulse";

"You just need to toss the objects back and then you have the impulse".

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Items	Answers (%)			
	Yes	No	No answer	Other
Facility	84	8	8	0
Comprehension of the principle of action and reaction	75	8	17	0
Importance	67	0	25	8

Table 1. Student's answers to the questionnaire. Source: Table elaborated from questionnaires applied in Paraná State public school (Brazil)

About the utility, 75% stated that the experiment has helped in the understanding of the principle under study and from this number, 16% gave a justification for their answer. It has been asked that students related what they liked the most in the experiment.
Some answers:

"To push the chair"; "To move backward and forward the objects";
"To release the balloon and explode it".

When asked about what they did not appreciate in the activity, they referred to the moments of pushing the objects. According to the teacher interviewed, Brazil has much yet to do about space matters in classroom and students do not have the opportunity of thinking beyond their immediate world. One of the difficulties pointed out by the teacher on the completion of the experiment by the students has been motor coordination question.
The report of the student interviewed has confirmed that her greatest difficulty has been to move by the impulse of the objects. She stated she had never studied space exploration in some school discipline but considered the subject important and interesting.

Conclusions
Activities in space education can be characterized as experiences rich in meaning and which contribute to the process of learning and teaching of contents in science, technology and related subjects. The experiment developed has privileged the ludicity and interactivity, to that motivating the study and active students' participation along the activity, possibilitating that the Principle of Action and Reaction could be experimented and would have good receptivity by the involved people.

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The option to realize one experiment related to Astronautics, besides facilitating the assimilation of the Principle of Action and Reaction, has allowed the realization of a discussion on subjects correlated to space exploration such as the astronaut career and the Brazilian space activities. It has been realized that the space thematic although seemed strange at first glance fascinates students who, among other factors, find out that there are people living and working outside the Planet in reduced scale ecosystems that are spaceships or space stations.
Finally, this hands-on experiment contributed indirectly in the demystification of space careers such as the ones of astronauts, scientists and other professionals of space field opening up the possibility of awareness about the activities of the Brazilian space program.

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References

[1] Azevedo R, Na Era da Astronáutica. São Paulo: Editora do Brasil, 1969.
[2] Haggerty JJ, Washington: NASA, Office of Space and Access and Technology, Spinoff, 1995.
[3] Oliveira F, O Brasil chega ao Espaço: SCD-1 - Satélite de coleta de dados. São Paulo: Proposta Editorial, 1996.
[4] Reis NTO and Garcia NMD, O Princípio de Ação e Reação em uma Abordagem Astronáutica: Uma Proposta de Trabalho em Educação Espacial. In: Nardi R, Borges ON, (Eds.), Atas do V Encontro Nacional de Pesquisa em Educação em Ciências; 2005 Nov 28 Dez 3; Bauru, Brasil. Bauru: ABRAPEC, 2005.
[5] NASA. Education Division. NASA's Education Program. Washington: NASA, Education Division, 1993.
[6] United Nations. Education and Training in Space Science and Technology. In: III United Nations Conference on the Exploration and Peaceful Uses of Outer Space; 1999 Jul 19-30; Vienna, Austria. Vienna: Austria Center, 1999.
[7] NASA. Education Division. Suited for Spacewalking: a teacher's guide with activities. Washington: NASA-Education Division, 1992.

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On the Feasibility to Include Contemporary Science Concepts in the Primary School Curricula. A Retrospection into Two Case Studies

Tsigris M and Michaelides PG

Introduction

The contents of the Science syllabus in school curricula have a significant impact on the effectiveness of Science and Technology Literacy which is of paramount importance to the contemporary knowledge conscious societies [1]. For an adequate Science and Technology Literacy knowledge on contemporary Science concepts is necessary [2]. However, concepts like quantum mechanics, relativity of space-time, statistical physics, elementary particles and cosmology, materials science and solid state physics, radioactivity - even more traditional topics like (micro) electronics - and other recent developments are missing from school curricula although many of them are (more than) a century old.

One often quoted reason for this omission is the statement that these concepts are very abstract and difficult to understand, thus they are not appropriate for the Science syllabus in schools. In this work we examine the validity of this statement which is (to our opinion) a widely accepted belief rather than an empirical fact

Methodology

In order to test the feasibility of teaching contemporary Science concepts to students of the compulsory education we proceed as follows:

1. The basic notions from a selected contemporary Science topic were located and analysed. It is understood that the objective, for the compulsory education at least, is to teach the understanding of the basic notions of the selected topics and not the full functioning of the model with all the (complicated) mathematics.
2. A class (grade) from the compulsory education level was chosen as a test case for the teaching of the basic concepts located in the previous step. Grades 5 (age 10 to 11 years) to grade 7 (age 12 to 13 years) were thought appropriate. The reasons are: a/in a Piagetian context the

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students are old enough to be at the stage (or approaching the stage) of formal logic, b/they, usually, have not exposed to a systematic (analytical) Science course consequently they have not any representation related to the concepts to be taught (presumably – see next step).

3. The basic steps for a teaching intervention were planned.
4. Before the teaching intervention was actually delivered, a questionnaire was given to the prospective students. Its purpose was to locate the students' relative (pre) concepts on the subject to be taught and adapt appropriately the details of the teaching intervention. Possible influences of the society (in a Vygotsky's context) could also be traced.
5. The teaching intervention was delivered. This included at least two sessions of 1 or 2 teaching hours each separated by an interval of one or more weeks. At the last session a questionnaire was again given to the students.
6. For every one of the Science topics selected at the first step, a report with the outcomes from the questionnaires together with the comments of the teacher who delivered the teaching intervention (action research) was prepared.
7. The reports prepared at the previous step were analyzed by the authors of this work who had also been involved during the planning of the teaching intervention as 'councillors' on the didactics and on the subject matter of the topics selected.

Implementation

The whole work was organized within the degree dissertation course of the Department for Primary Education of The University of Crete. The choice of Grades 5 and 6 (ages 10 to 12 – primary school in Greece) as the classes for the test cases was a consequence. The reports prepared became (part of) the graduate dissertation of the students involved. Two specific topics were selected, their selection influenced by the students – researchers who actually delivered the teaching.

Systems and Systemic thinking

The 1st topic selected was on the concept of 'system'. The student researcher was already a teacher in primary education schools with a diploma from academy attending further education courses at the Department for Primary Education of The University of Crete in order to obtain a primary teacher's University degree. The basic concepts located for this topic were the system as a complex concept consisting of entities (subsystems) with direct links (dependencies) between them. The skill to recognize a system with its various constituents and the deduction by the school students of indirect links (dependencies) of the type ***constituent a*** *is linked to (depends on)* ***constituent b****,* ***constituent b*** *is linked to (depends on)* ***constituent c*** *consequently* ***constituent a*** *is linked to (depends on)* ***constituent c*** were among the aims of the teaching intervention [3]. Characteristics of systems,

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e.g. relations between different parts of a system, are included as factual knowledge in the school syllabus, for example (some) relations between constituents of an ecosystem. Consequently the students, who, in a Piagetian context, are entering or approaching the stage of formal logic, are not faced with a concept totally abstract to them. However, these basic concepts are mentioned in a fragmented way mostly as (direct) dependencies between parts of an ecosystem and although the word system with its everyday meaning is mentioned quite often in the textbooks, the concept of '*system*' as a technical term of systemic theory is missing [4]. The planned teaching was delivered to students of the 5th and 6th grade (ages 10 to 12) of the classes the student researcher was teaching. It should be noted that the word system is a commonly used word in many expressions of everyday life and many preconceptions from the students are expected. As a result, a successful teaching intervention will show clearly, even with a relatively small sample.
Some of the results obtained from the experimental teaching of the topics selected are [6]:

1. The pre-test indicated that students perceived 'system' as something repetitive (e.g. clock) or something planned (e.g. homework reading) or something involving human action (e.g. irrigation) or humans themselves (e.g. the human body). Even 'system' as a complex or corporate notion (e.g. a tree or a tree wood) was not perceived clearly as a system. The post-test carried out one month after the teaching intervention showed a remarkable improvement on the perception of system. Not only they exhibit a working knowledge definition of 'system' but they can also justify it by indicating interrelations between its parts.
2. The pre-test indicated that all students stayed within the direct one to one relations. At the post-test 5 out of the 20 students were able to immediately indicate also indirect relations (dependencies). Although this number is rather low it is very encouraging in view of [3]. This is further supported by the observation that during the discussion following the post-test [7] almost all the students were able, in a two step process, to perceive also indirect relations which they had not indicated at first so that a more thoroughly planned teaching intervention may have had better results. The fact that of the 5 students who showed a clear evidence of advance towards a systemic thinking the 4 were girls (who mature earlier) combined with Vygotsky's context of the Zone of Proximal Development reinforces our statement.

Einstein's Theory of Relativity

The 2nd topic selected was on Einstein's theory of relativity. The student researcher was a final year student at the Department for Primary Education of The University of Crete whose most of the graduates of the Department work as primary school teachers. The basic concepts located for this topic were the meaning of simultaneity

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and the time – space dependence on the state of motion of the observer (relativity of space and time). As it was discovered that *speed of light*, *black holes*, etc are words familiar to school students through comics, science fiction, mass media, etc their meaning were also included to the teaching plan. On this topic nothing is explicitly included in the school curricula although the phrasing of the textbooks suggests an absolute (Galilean) space-time continuum [5]. This is in dissimilarity to the previous 1st topic selected and should be taken into account in comparing the results. The planned teaching was delivered in a 6th grade class (age 11to 12) of a primary school where the student researcher was doing his 4th level school practice undergraduate course.
For this 2nd topic selected the implementation was done using a primary school class of 6th grade (ages 11-12 years) [8]. There were 16 students in the class 12 of which attended all 5 meetings. The student researcher had 5 meetings with the class. The 1st meeting was to familiarize with the students and collect the pre-test questionnaire. In the 2nd, 3rd and 4th meeting the teaching intervention was made in 3 separate days about one week after the 1st meeting. At the end of every teaching a questionnaire was completed on formative assessment purposes. The final (5th) meeting was done about one week after the last teaching took place and the post-test questionnaire was collected. The main results are:

1. The pre-test indicated that the students knew that distance time and mass are measured in (kilo)meters, hours (seconds), (kilo)grams, that an object weight is due to earth's gravity and it would be less in the moon. They also had heard about galaxies and black holes, presumably an influence of (science) fiction through TV, comics and DVD's.
2. In the 1st teaching hour the concepts of motion, of the speed of light and of the dependence of the weight of an object upon the gravitational attraction of the earth were introduced. Clarifications on the students' understandings on galaxies and stars were also provided. At the end of this teaching, the students were able to infer that an object in moon should appear lighter and, if left to fall, it will need more time to reach the ground than the time needed in a similar situation on earth.
3. In the 2nd teaching hour the students were introduced to the concepts of the speed of light (as constant in all frames and as an upper limit for any material body), of the dependency between the speed and the mass of an object and of the relativity of space (time dilatation-space contraction) within the context of Einstein's theory of relativity. At the end of this teaching, the majority (>60%) of the students answered correctly the questions on the speed of light as an upper limit and on time dilatation. On the other issues the correct answers were: for the speed of light constancy 4/10, for space contraction 3/10 and for the mass dependency 4/10 with another 2/10 answering 'do not know' [9].
4. In the 3rd teaching students were exposed to a presentation on the shapes of galaxies, the expansion of the Universe and the evolution of stars [10]. Their attention was also drawn on the observable perception that 'their

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weight seems to change in accelerating (decelerating) situations, e.g. at the start (stop) of an elevator on the take off (landing) on an aeroplane, cornering (braking) of a car, etc.' as an introduction to the concept of equivalence between the inertia and the gravitational mass. At the end of this teaching, all the students answered correctly the questions about the shape of the galaxy and those relating acceleration to gravity. Again, about 1/3 of the students answered correctly the question of a more advanced character.

5. One week after the last teaching a 'post-test' questionnaire was collected. In this the majority of the students (>70%) answered correctly. Although the time elapsed is short, the questionnaire indicates an effective teaching of the corresponding subjects. The increase of the correct answers in comparison with the questionnaires completed at the end of the teachings is under investigation. Possibly this is due: a/to a better phrasing of the questions of the final questionnaire, b/to an informal peer discussion between the students after the teachings and the completion of the questionnaires. The fact that the 'do not know' answers have diminished may support this view.

Commentary

From the previous two (small scale) test-cases it is evident that 5th and 6th grade (ages 10-12 years) primary school students:

- are capable to conceive the basic concepts of '*system*' and of the relativity of space and time.
- are, to a significant percentage at least, capable to comprehend more advanced notions like '*systemic thinking*' or the relation of weight to acceleration.
- the difficulties on some advanced concepts may be considered as similar to the difficulties in understanding other topics and, with a more carefully planned teaching (e.g. based on individual teaching approaches) may improve the situation.

We may, consequently, expect reasonably that the same results will show up also with other topics as mentioned earlier in **Introduction**. Thus, the issue of updating the school Science syllabus acquires a new perspective. Towards this end we briefly indicate some remarks based on our experience from these test cases and, also, from discussions with other colleagues, teachers (including the students – researchers) and students.

a) For every topic the basic concepts should be located and an appropriate teaching strategy should be adopted. This teaching

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should focus not on the detailed processes and functioning (a scope outside the objectives of the compulsory education) but on the conceptual modelling (representation) of the natural world. The teaching should also try to relate the (new) concepts to other topics and, also, to everyday phenomena.

b) The topics selected should be presented in a coherent way and not as separate unrelated add on modules.
c) There are no previous experiences on the preconceptions of the students and this implies more effort from the teacher.
d) The previous teaching implies a similar mode of initial education for the Science teacher. Science teacher education is usually along two extreme lines, as a specialist training and as a general teacher. The first is usually the case for the secondary and for the technical vocational education. These teachers usually tend to occupy their students with details on data, processes, mathematical formulas etc paying little attention to the general model for the natural world. The second is usually the case for primary education. These teachers usually tend to repeat the textbooks and teach Science as a collection of (unrelated) data and observations. Neither of these seems appropriate for the context under discussion where the teacher should possess and be able to teach e.g. scientific inquiry skills. Further study towards the development of complex cognitive skills and reasoning should always accompany even declarative teaching, which sometimes seems unavoidable. Only this way the ‘dogmatic approach’ of an ‘absolute scientific truth’ (similar to indoctrination in a religious class) will be avoided. Otherwise, confusion between science advances and the religious dogma will appear as has repeatedly been observed [11].
e) In both cases the students-researchers observed that the students were approaching the (new) ideas with a ‘fresh and innovative’ way they had not anticipated. This helped them (the teachers) to clarify their understanding of the subject they were teaching. It unearthed however the real problem, according to us, on the introduction of contemporary Science concepts to the school curricula, i.e. the teachers’ competence and their lack of a conceptual understanding of Science. In these two test cases the students researchers did not had a specialist’s training in Science [12]. This resulted in extensive consultancy with the authors of this work. As they commented later, they used this experience of theirs to anticipate children’s’ behaviour and adapt the teaching strategy adopted although in many occasions children surprised them with the (usually simpler) interpretations they assigned to the new concepts taught.

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Epilogue

Our basic objective that we should put under the test of empirical evidence the general belief that 'children are not able to understand new concepts which scientists have spent a lot of time to understand' has been validated. Children are capable of assimilating contemporary Science concepts. Consequently, a total reform of the school Science curriculum must be done. In view of the comments made in **Commentary** this reform should be tested on its different parameters to ensure an efficient contemporary Science literacy, the most critical parameter being the Science teacher (initial) training.

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References

[1] Michaelides PG, State of the Art in Science Teaching, in Divjak S (Ed.) Proceedings of the International Conference on Hands on Science; 2004 Jul 5-9; Ljubljana, Slovenia. Ljubljana: University of Ljubljana, pp.: 11-17, 2004.

[2] For the necessity on the modernisation of the Science curriculum see George Kalkanis 'Which (and How) Science and Technology Education for Future Citizens?', pp.: 199-214 of Vol. II of the proceedings of the University of Cyprus, '1st IOSTE Symposium in Southern Europe – Science and Technology Education: Preparing Future Citizens', Paralimni-Cyprus, 2001.

[3] It should be noted that in a Piagetian context, the students in this age are mostly in the concrete (and towards the formal) operational stage able (mostly) to one parameter (direct, one to one) relations. Consequently, the expectations here should be limited.

[4] In systemic theory the term 'system' is used to denote a way of organizing our thoughts about reality. It may refer to (material) things (e.g. a machine) or a corporate organization. Although related concepts may be traced back to the works of Norbert Wiener on Cybernetics and of Edward Lorenz (a meteorologist) on Chaos systemic theory, especially applied to understanding and solve complex problems has only recently emerged as a, more or less distinct, scientific branch. See Daniel Aronson, Overview of Systems Thinking (in http://www.thinking.net/Systems_Thinking/OverviewSTarticle.pdf.

[5] This is true also for the textbooks in middle and high schools. In most of the University level textbooks the same attitude is also observed.

[6] Kountourakis N and Michaelides PG, 'Contemporary Scientific Concepts in Primary Schools: A Test Case on the concept of Systems', Proceedings of the 2nd International Conference on Hands on Science Hsci2005 – Science in a Changing Education, July 13-16, 2005 – Greece, The University of Crete

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campus at Rethimno, pp.: 307-310 (http://www.clab.edc.uoc.gr/2nd/). A more detailed report may be found in; N. Kountourakis, 'Teaching the concept of system in primary school – introduction to systemic thinking', Rethimno 2005, degree dissertation, Department for Primary Education, The University of Crete (in Greek).

[7] The pre- and post- test questionnaires were complimented by discussions with the students in order to ascertain the validity of their answers. This was triggered by the observation that the students understood the meaning of relation as one sided. For example they understood the word influence as having the meaning of diminishing (in numbers) or of a negative (on values) notion.

[8] Tsalapakis A, 'The Theory of Relativity in Primary Education', Proceedings of the 2nd International Conference on Hands on Science Hsci2005 – Science in a Changing Education, July 13-16, 2005 – Greece, The University of Crete campus at Rethimno, pp. 408-410 (http://www.clab.edc.uoc.gr/2nd/). A more detailed report may be found in; Antonis Tsalapakis, 'The Theory of Relativity in Primary Education', Rethimno 2006, degree dissertation, Department for Primary Education, The University of Crete (in Greek).

[9] Although these figures seem low, in view of the comments made in point 2 of Systems and Systemic thinking, they rather encouraging.

[10] This was done mainly following (provoked?) students questions on the subject. The inexperienced zest of the student researcher played also a role.

[11] It was also observed by the student researcher of the second test case when, answering students questions he entered to recite current views on the origin and evolution of the universe. Many students reacted intensely on reason that it was contrary to what they had learned in the religious class (the bible in this case).

[12] This was rather an advantage because: a/ they were willing to learn without any second thoughts about their image as 'Knowledge sources', b/based on our teaching -training experience, secondary education Science teachers (specialist's training) usually have strong conceptions on what Science is and how it should be taught and very rarely they endeavour to try a different teaching style.

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Introduction to Fiber Optics and Telecommunications

Costa MFM

Introduction and principles

The evolution of technology and the development of new solutions that directly affects our everyday life demand the establishment of a sound scientific and technological literacy in our societies. From early ages our youngsters and pupils should have an enduring and efficient knowledge update especially in what concerns key proficiency and aptitudes. It is so important to promote the pedagogical conception development and production of new materials and equipment that may allow the introduction, in-school but also in informal learning environments, to basic concepts of recently developed high-tech including the underlying scientific theories.

In our days, in our Information (or better Knowledge based) Society, telecommunications play a fundamental, crucial, role. With the massive increase of the amount of information that needs to be exchange, virtually in real time, between all the points of the globe, all the telecommunications system had to be redesigned and renewed in the last decades. At present, optical fibers are at the foundation of all modern telecommunications system. It was its sprouting and development which allowed telecommunications development to the level that we now observe and to what is already foreseen in a near future. Thus optical fibers and waveguides are surely our day's one of the most important domains of physics and of Science and Technology in general.

The light propagation phenomenon in optic fibers, or waveguides in general, apart from being amply inquisitive and intriguing for the layperson (and the young are especially receptive to the solving of such strange and vanguard type "enigmas"), can be explained, on a first approach, with the use of some basic and fundamental rules of geometric optic. Hence, its study may not only serve as a way to motivate and stimulate pupils for the study of Physics and Sciences in general but also to contribute to the learning process of some concepts and basic competencies of the higher importance in physics in general and optics in particular, that are often even included in the natural sciences and physics curriculum of most of our primary and secondary EU schools.

In this perspective, the development of an introductory kit intended to the experimental study of wave guidance optical fibers and telecommunications, was

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considered essential to the scenery of almost total absence, as far as we know, of this type of pedagogical materials in Portugal.
The kit which consists on an integrated and coherent set of materials, equipment and introductory activities' manuals to Optical Fibers and Telecommunications, was developed in the frames of the Hands-on Science Network based on the authors' previous work supported by the former Instituto de Inovação Educacional.
This experimental kit to Optic Fibers and Telecommunications introduction enrols itself in the hands-on experimental approach to Science and Technology teaching/learning process that we advocate [1-3]. The use of this sort of material in the different levels of education, to whom it is intended to, will contribute to a more effective prosecution of the established specific objectives of learning in terms of acquired knowledge, but also on what concerns the development of critical spirit, observation capability, creativity and on pupils active and autonomous engagement in the critical analysis of problems and situations. Furthermore it may become an important motivational factor for the study of physics and natural sciences.
In a systematic way we could enumerate the pursuing set of objectives [1-9] with this type of activities: to establish a basic knowledge in the field and make it possible for pupils to acquire aptitudes and elementary competencies in a modern top importance domain as optical fibers and telecommunications is by hands-on experimental practice; to contribute to the development of the active study of sciences by means of hands-on experimentation; to contribute for teachers knowledge update concerning wave guidance optical fibers and telecommunications but also on essential aspects of optics; to enhance pupils commitment on physics and natural sciences study as earlier as at elementary school up to secondary vocational training and even higher education level; to encourage the use of experiments execution as essential science learning tool; to familiarize (/introduce) pupils to the scientific method, developing critical spirit and observation abilities as tools essential to all science related activities; to stimulate creativity; to stimulate pupils active and autonomous engagement on critical analysis of problems and simple situations in science and technology fields; ultimately inducing the recognition of the usefulness of physics and science in general in the everyday life [8].

Brief introduction to optical fibers and its use on telecommunications

Light (electromagnetic radiation) propagation in waveguides and optical fibers [10, 11] is a process indubitably fascinating however of complex explanation. Yet, the basic process is simple and well-known for a long time. It is all about total reflection or, if you prefer, total internal reflection of light. When light in its path finds a surface of separation (dioptre) between two mediums of different optical properties, part of the light is transmitted (refracted) and part of it is reflected. When the transition occurs from a more optically dense material to one with lower refractive index the transmitted light is shifted away from the normal to the dioptre in the light' incidence point. Increasing the inclination of the incident light impinging onto the dioptre, at a certain point, the light will "go out" perpendicularly to the dioptres' normal not being

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transmitted. Above a certain angle limit of incidence only reflection will occur: the total reflection. The process is easily envisioned in a transparent recipient with water. As well also the process of successive multiple total reflections where light bounces inside a material, as it happens in optic fibers, in a pipe or glass plate, or, simply … in a block of gelatine!

The properties and characteristics of different types of optical fibers readily available allow the replacement of conventional materials in wide range of situations such as in illumination and decoration, on several medical applications, artwork cleaning, in different types of sensors and … in telecommunications.

In this domain (of outstanding importance in nowadays life) the importance of optical fibers became unsurpassable and was the introduction of fiber optics that leads to the current level of development in the telecommunications area. As an example: a 5 mm diameter optic fiber cable can replace a 7,5cm diameter copper cable employed some years ago. It is 25 times lighter and lasts 2 to 4 times more. The cables can be longer - 20 km (even 40km) - than copper cables which demand repeaters from 1 to 1km. The major drawback is still the costs involved. Fiber optics are made of a rather pure glass - 1km of this glass is as or more transparent than a normal window' glass (5mm thick). But... while a normal telephone line (2 copper wires) allows the transmission of 24 simultaneous calls, with a pair of fibers 24,000 or even 100,000 to 150,000 simultaneous communications can be established. The profits in transmission capacity will be still more noticeable in the transmission of TV signals. While with UHF modulation it is allowed the transmission of 10 channels, with an optical-fiber cable system this number raises to 100,000 channels. Digital signals transmission capacities superior to 200 superior Tbit/s.km are commonly obtained.

The market' demand for optical fibers is ever increasing been the telecommunications area responsible for almost half of it. Application on long distance communications (transoceanic submarine cables) increased significantly in the 90's. Cable television (CATV) is now one of the main applications of optical fibers. Annually the world-wide optic fiber market puts into motion over 10.000 million Euros with a steady growth.

Among the advantages of optical fibers uses we can summarize the following: low loss in transmission; immunity to noise and electromagnetic interference; high broadband width (nowadays massive amounts of information need to be transmitted between distant places all over the world); information transmission security; is made of insulator material; small dimension and low weight; high flexibility (when coated) and resistance to temperature and chemical agents; and low cost. The disadvantages are: fragility of non-coated fibers; difficulty to execute derivations; delicate connection between fibers and other components; and sensitivity to cosmic radiation.

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Fiber optics and telecommunications introductory kit

So as to reach the proposed objectives, it was planned and established an integrated and logical set of experiments' guides materials and equipments (as simple and low-priced as possible) which allows the accomplishment of simple and attractive experimental hands-on activities of introduction to Optical Fibers and Telecommunications.

A set of 15 experimental works was prepared, with increasingly complexity in order to promote the improvement of our youngsters critical and autonomous engagement along this learning process. First it starts with light guidance' observation in solids (glass blocks, prisms...) and liquids (tap water flow...) and, eventually, light guides made of eatable gelatine (for pupils of elementary and pre-school). Thereafter we move forward to the observation and study of different types of optical fibers (always plastic ones or strongly protected in order to prevent accidents) including fibers for ionizing radiation detection, the concept and use of remote illumination and image manipulation, fiber cables use on monitors and on rudimentary scanners. The preparation of fibers and cables as well as with its connections will be followed by the study of light propagation on different types of fibers and with diverse constraints. Light sources and detectors will be studied and a direct voice communication system (energy conversion: sound-electric-luminous-electric-sound) is to be set-up and used. Finally it will be assembled an elementary telecommunication system using optical fibers introducing also a first approach to the information codification problem.

In what concern the manuals/guides, it was intended to cover all sorts of doubts and questions that pupils may have, with an intuitive structure and simple and direct explanations as complete as possible, always appealing to the student's critical active intervention.

The protocols are simple and formative just pointing the student/group towards the execution of their work'. Frequent appeal is made towards critical reasoning and careful observation. Attention is drawn to some situations that should be observed and critically analyzed in a more diligent manner. In general, the teacher or monitor will be responsible for this task and will also have to raise some questions (whenever possible making use of comments, questions or commentaries pupils will make along the process) of informative and formative nature leading the student to raise questions and open new insights. Whenever possible it is suggested that pupils should be allowed to establish the way and steps of execution of their experiments and also project new, their own, experiences.

The carrying out of all experiments, in the proposed order, will be relatively time consuming and require the learning process to be consolidated. Thus the kit may be used in succeeding years from the first to the last years of school.

Conclusion

The goal of the physicist is to discover understand and explain the physical world which surrounds us.

To observe (seeing critically) is the first and essential step in this process. Then doubts and problems should be raised and critically analyzed. New situations and

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sceneries are to be foreseen and constructed. Always in an active and engaged way.
The students should observe discuss convey and criticize their own conclusions and, as possible as it can be, establish/decide what to do next… constructing their own knowledge. Making Science...
The enhancement of student's specific knowledge is important but Science demands work responsibility and Method. It is precisely in this direction that the teacher/educator first efforts must focus.
The exposure to knowledge or the access to its sources is not a sufficient condition so that the learning occurs!

References

[1] Costa MFM, Hands-on Science, in Teaching and learning Science in the XXI Century", Sasa Divjak (Ed.), Ljubljana: Faculty of Computer and Information Science, pp.: 1-9, 2004.
[2] Costa MFM, Learning by research, Proc. Soc. Photo-Opt. Instrum. Eng., 4172: 152-159, 1999.
[3] Costa MFM, Teaching Applied Optics at the University of Minho, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 357-361, 1995.
[4] Prasanis AS, Teaching Optics in the Optics Age, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 318-330, 1995.
[5] Schuch JH and Wu ZL, Getting students to see the light, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 309-315, 1995.
[6] Nofziger MJ, Optics curriculum for middle school students, Proc. Soc. Photo-Opt. Instrum. Eng., 2525:213-224, 1995.
[7] Williams G, Laser experiments for the secondary school classroom, Proc. Soc. Photo-Opt. Instrum. Eng., 2525: 230-246, 1995.
[8] Narayana PS, Put the real world in the physics curriculum, Physics Today, 48: 15, 1995.
[9] Wilder C, Elementary laser optics? Yes!, Proc. Soc. Photo-Opt. Instrum. Eng. 2525: 193-197, 1995.
[10] Hoss RJ and Lacy EA, Fiber Optics, Prentice Hall: New York, 1993.
[11] Keiser G, Optical fibers communications, McGraw Hill: London, Borghoff V and Paresi R (Eds.), Information Technology for Knowledge Management. New York: Springer Verlag, 1998.

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A Cycle-Ergonometer

Costa MFM

Introduction

The ability to integrate, to reason and to operate in situations involving diverse and varied types of knowledge from typically “not related” fields – physics, biology, maths, chemistry, ergonomics…- in our education system it might surely be of utmost importance in a sound effective science education [1].
The hands-on activity herein proposed intends to tackle this need of interdisciplinary through activities directly related and significant to our everyday life [2, 3]. We propose the study setting up and use of a digital cycle-ergometer.
A cycle-ergonometer can be defined as bicycle that, in general, is kept stationary and to which are adapted instruments that allow measuring the physical effort developed during the pedalling process [4].

Physics, ergonomics and life…

The measurement of the physical effort developed by an individual in the course of a certain physical activity, may give relevant information allowing doctors and health technicians (mainly of sports and rehabilitation medicine) and also ergonomists to assess the patient or athlete condition or physical state. Overall physical condition can be characterized but also different medical situations can be detected even in early stages of evolution, i.e. hearth diseases [5, 6].
Ergonomics can be succinctly defined as the scientific discipline concerned with the study of the interaction between man and the physical or technical environment where he lives in, studying different human activities - at work, in sports, leisure, etc. - and the influence of certain environmental conditions on individuals [6,7].
There are various ways to accomplish this measurement. One of them is the employment of the ergonometric bicycle or ergonomic cycle frequently used for instance in sports to assess the athletes’ physical conditions [5-8].

A homemade cycle-ergonometer

In the cycle-ergonometer we assembled (Figure 1.) the energy spent by the user while cycling is registered through electromechanical energy conversion using an alternator or a dynamo.

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Figure 1. The homemade cycle-ergonometer

Figure 2. Details of the coupling of the electromagnetic energy conversion units to the *stand-still* bicycle

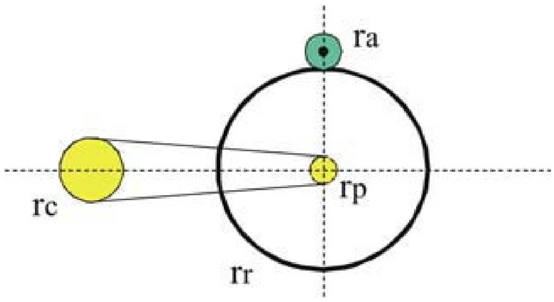

Figure 3. Simple mathematical relations of elementary mechanics should be sorted out

The DC generator shaft will be connected to the back wheel of a fixed bicycle in such a way that when the user pedals the generator' rotor rotation (in the case of the alternator an excitation current allow us to control the amount of mechanical resistance to cycling) will generate an induced electrical current (Figure 2.). The output electrical signal, proportional to the pedalling rotation speed (Figure 3.), is digitalized processed registered and presented in real time to the user himself at the monitor of a microcomputer attached to the bicycle' wheel [9,10].

The energy spent by the user while pedalling can be calculated from the dissipated electric power in a load resistor at the DC generator. However, it has been verified that only about 25% of the user's spent energy (the acquired energy from the "transformation" of ingested foods) is effectively used to make the bicycle pedals movement (from the remain most will be freed as heat - the average body temperature during intense sport activities can surpass the 39/40 ºC). As well a certain amount of energy is lost in the mechanical parts and in the direct-current generating machine [11, 12].

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Study and using the cycle-ergonometer

Cycling can be a rather demanding activity in physical terms [12]. Before using the cycle-ergonometer it is very important to guarantee that the users do not suffer from significant health problems. Besides being necessary to verify if the users know of any health problems they might have - cardiac diseases, respiratory problems, renal or hepatic insufficiency, hypertension, ... - it will be necessary to carry out a short test. The user should pedal at moderate speed and mechanical resistance during a couple minutes. The cardiac rhythm should be read (during 30s) before the exercise and 30 seconds, 1min30s and 2min30s after its conclusion. Users can be considered "apt" if they present a deceleration rate of the cardiac rhythm higher than 10 pulsations per minute.

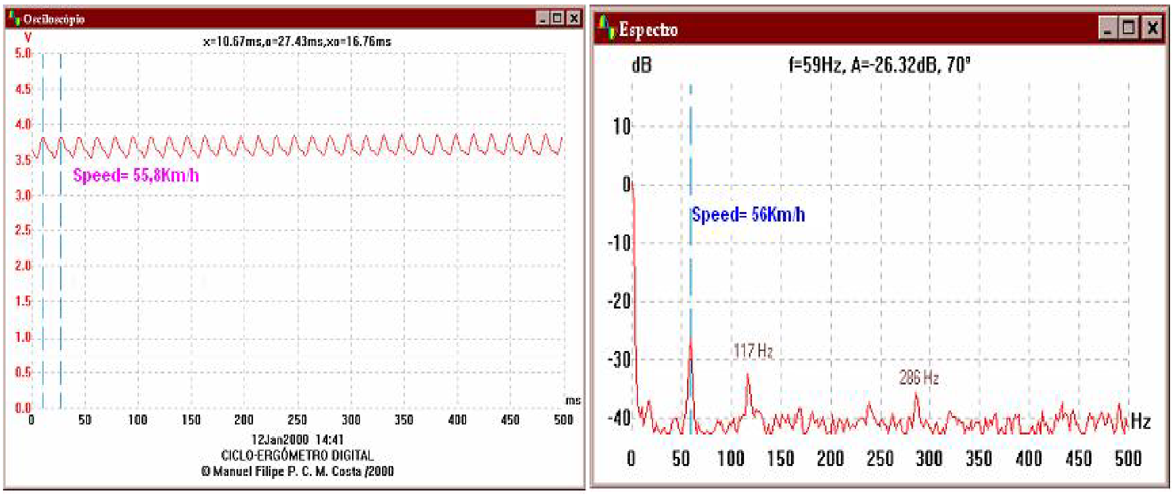

Figure 4. The voltage generated with an alternator at a certain excitation current during a pedalling process

Several questions may be raised along the study and use of this cycle-ergonometer. Let us just draw your attention on the way the paddling process unrolls. A careful observation of the registered graphs, like the one presented in Figure 4, may indicate that the cycling effort is developed alternately through the two legs, on the two pedals, and that when, for example, the right pedal goes down "pushed" by the respective leg, the left one goes up "dragging" the left leg. When the right pedal reaches the lower level, the left pedal will start "to be pushed" by the left leg (entering the right leg in "rest"), but not in a homogeneous way: until the horizontal position (roughly) the force developed by the leg will be higher and from this point on it will probably be more difficult to push the pedal down to the lower level (when the left leg almost does not have to make effort), "recommencing" then the action of the muscles of the other leg. On Figure 5 we intend to illustrate this process.

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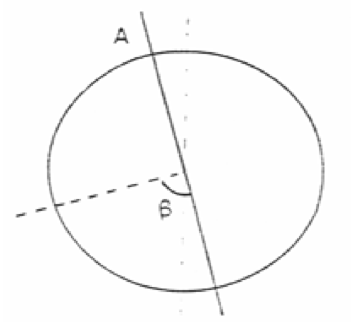

Figure 5. The pedalling process presents a particular sequence that is rendered evident on the graphs representing the evolution of the *effort* spent during the process (Figure 4)

References

[1] Costa MFM, Learning by research, Proc. Soc. Photo-Opt. Instrum. Eng., 3527: 173-181, 1998.
[2] Swany PN, Put the real world in the physics curriculum, Physics Today, 48: 15, 1995.
[3] Meiners H, Physics demonstration experiments, Ronald Press Company, 1970.
[4] Ghista D, Perspectives in biomechanics, Harwood Publishers, 1978.
[5] Edholm OG, A biologia do trabalho, Bibiloteca Universitária Inova, 1968.
[6] Konz S, Work Design, Grid Publishing, 1979.
[7] Grandjean E, Fitting the task to the man, Taylor & Francis, 1979.
[8] McCormick E, Human Factors in Engineering and Design, McGraw Hill, 1976.
[9] Fitzgerald R, Grabel H and Higginbothan S, Engenharia eléctrica, McGraw Hill, 1981.
[10] DeFrance J, Electrical Fundamental, Prentice Hall Publishing, 1969.
[11] Brouha L, Psychologie et industrie, Gauthier-Villars Editeurs, 1963.
[12] Durnim J and Passmore R, Energy, work and leisure, Heinneman Books, 1994.

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The Subject SATELLITES on Portuguese Primary School Development of a Pedagogical Model

Carvalheiro L, Amasaki Y and Manso M D

Introduction

Following several discussions about the main objectives of education, quite often statements in the literature claim that education systems can be adapted and developed to deliver the basic skills and competences to everyone's needs in the knowledge society; to make lifelong learning attractive and rewarding and to reach out to everyone in society, however far from education and training they may consider themselves, with ways of developing their skills and making the best use of them [2]. In what concerns science education, it is quite well established that the goals for school science are to educate students who are able to: i) experience the richness and excitement of knowing about and understanding the natural world; ii) use appropriate scientific processes and principles in making personal decisions; iii) engage intelligently in public discourse and debate about matters of scientific and technological concern and iv) increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers [9]. This way, some views [6] recognised that the science curriculum for 5-16 should be seen primarily as a course to enhance scientific literacy. On the other hand, the importance of science education is acknowledged taking into account that Science involves using the knowledge that has been generated through process skills to create and continually refine testable models of nature that helps one to describe, explain, predict, and to conceptualise observable phenomena of nature.

More particularly, several authors emphasize the exposure to science in primary school in order to develop the notion that knowledge is based on evidence and that evidence is critical for sensible community decision making. This way, science in primary school tries to develop skills to make informed decisions on issues of science, technology, the environment and one's health and well-being. Moreover, it has been shown that science in the primary school is one of the most exciting parts of children's and teachers' work [5].

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Low resolution satellite imagery reception systems in primary education

With the overwhelmingly accelerated growth of the satellite remote sensing community, data from satellite-based Earth observations is, nowadays, very simple and easy to obtain. With just a few mouse clicks, it is possible to have access to satellite images. Among others, it may be worth to mention products like Google Earth [4], or websites like [3], or [10]. However, the authors' conviction is that low-resolution satellite imagery reception systems can be operated in a classroom environment, enabling pupils to capture real-time satellite signal, processing it and obtaining their own satellite pictures.

Figure 1. NOAA-17 satellite image received by the Universidade de Aveiro APT reception station on July 6, 2005, at 11:57 (local time)

A simple satellite receiving station can be assembled, relying on the Automatic Picture Transmission (APT) mode of the Advanced Very High Resolution Radiometer (AVHRR), onboard the National Oceanic and Atmospheric Administration NOAA Polar-orbiting satellites. Historically, APT was initiated with the TIROS-8 satellite, launched in December 1963.The APT is a low-resolution analog transmission of AVHRR data. Two channels of reduced-resolution (4 km) data are continuously transmitted using analog Very High Frequency (VHF) signals (137-138 MHz) at reduced rates (120 lines per minute).[9]
The APT reception system comprises a VHF receiver (one can be bought for nearly €200), a 137 MHz antenna (a turnstile antenna can be bought for less than €100), a 137 MHz pre-amplifier (cheaper than €60) and a personal computer.
The processing system makes use of the computer's soundcard, and the demodulation of the satellite signal can be made with free software, like WxtoImg (free of charge, for personal, non-commercial purposes). With this system is possible to receive very interesting satellite images, like the one depicted on Figure 1.
A closer look at Figure 1 reveals all the marvels of the implementation of satellite receiving stations in the primary education classroom: the possibility of acquiring

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real-time satellite images establish a pedagogically rich experience, that contributes to the enrichment of the curricula, and can be viewed as an important pedagogical resource for promoting scientific literacy [7] and scientific culture.

Portuguese primary school curriculum and Methodological suggestions

The programme for the curricular area “Estudo do Meio” (Environmental Study) of Portuguese primary education gathers a few subjects on which several activities may be developed, in an innovative way.
Having in mind that the Portuguese curriculum points out to the fact that the learning experiences should emphasize the direct observation of reality, the use of instruments, the interpretation of data, the formulation of problems and hypothesis, the research planning, the prediction and assessment of results, the establishment of comparisons and the use of inference, generalization and deduction, the proposed activities aim to develop specific competences, in an interdisciplinary and unified perspective, such as:

- understanding current weather (2nd grade);
- recognising several weather conditions (windy, warm, rainy, cold) (2nd grade);
- relating the seasons with weather conditions (2nd grade);
- distinguishing different landscapes (3rd grade);
- finding locations in maps (3rd grade);
- using the directions (N, S, E, W) (3rd grade);
- observing aspects of Portuguese shore (Ria de Aveiro, Cape Carvoeiro, Cape da Roca, etc.) (4th grade);
- identifying and locating cities on a map (4th grade);
- using maps of different scales to locate Portugal in the Iberian Peninsula, in Europe and in the World (4th grade).

Thus, the activities with APT satellite receiving stations may begin on the 2nd grade in an evolutionary perspective along primary education to explore curricular subjects, integrating low-resolution satellite images, and all the underlying technology.
The methodology of these activities, in concordance with the Portuguese curriculum for primary education, intends to focus science education on investigations, in order to achieve the activation of several processes related to learning. It may be worth to mention, however, that the activities should consider all areas of the Portuguese primary education, not only just Science, Mathematics, or Geography.
This work relies on hands-on activities that should be implemented as problem-solving in order to attain possible answers for the central questions, in which the activities are based upon. Exchanging ideas in small groups or class group

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discussion promotes the use of language and social skills. This way, the contribution of each pupil will depend on his/her knowledge, but also on his/her language level, enhancing, thus, the importance of group work, even when pupils come from different linguistic and cultural contexts. Also, it should be considered as a proposed objective the effective implementation of satellite APT stations in the primary school environment as well as the establishment of a satellite reception schools network.

Some suggested activities

The proposed activities develop different topics explored horizontally in the Portuguese Curriculum, in an interdisciplinary and unified perspective, promoting the integration of scientific interrelated concepts in diversified contexts.
Five proposed activities for the integration of APT satellite receiving stations in primary education are shown above, according to [1].

Satellites: what are they? Where are they? What can they do for us?

This first, introductory-level activity intends to present pupils to this subject and some associated concepts, as well as creating the space for discussing the importance of satellites, nowadays. Thus, this activity can lead pupils to:

- understand the meaning of the word satellite, recognizing differences between natural satellites (like the Moon) and man-made satellites;
- distinguish polar-orbiting satellites from geostationary satellites;
- acknowledge the importance of using satellites in several fields of study;
- distinguish different uses of satellites, along different fields of study.

What and how does a satellite “see”?

In this activity, pupils would investigate, in order to attain a possible answer for this question. As a final goal, pupils should be capable, at the end of this activity, of:

- recognise that satellites with different orbits have different fields-of-view;
- understand de predictability of satellite orbits;
- distinguish, in a satellite tracking program, geostationary satellites and polar-orbiting satellites, in terms of the path followed;
- identify the most suitable satellite pass, in order to capture a satellite image over Portugal.

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Where are we?
With this activity, satellite images and maps are used in order to develop, in pupils, competences related to map interpretation and critical analysis. It is intended that pupils, through group work, discuss ideas, produce conclusions and make use of geographical skills in order to:

- identify their location in maps and satellite images;
- identify neighbouring countries and their capitals;
- identify neighbouring cities;
- identify national boundaries.

What is a satellite image made of? How is a satellite image obtained?
The main purpose of this activity is to lead pupils to the comprehension of the nature of a digital image. Thus, the concept of pixel as the smaller element of a digital image, and the concept of resolution are introduced.
At the same time, pupils are put in contact with a satellite image reception station, understanding how the satellite APT signal can be recorded and processed, to obtain an image.

Clouds in satellite images
In this last proposed activity, pupils will use their knowledge about cloud formation in order to compare several representations of clouds in satellite images. Then, they would be asked to group clouds, in a satellite image, according to a personal classification scheme. Infrared images and their temperature-related properties will be presented, so that pupils can distinguish low clouds from high clouds, based on its brightness temperature. Additionally, pupils can be lead to correlate the rainfall occurrence with the fraction of high clouds in a satellite image, developing, thus, a rainfall map.

Preliminary results
In order to test the suitability of the proposed activities, a case-study was performed with an urban fourth-grade class, from Viseu, composed of 21 pupils: 16 boys and 5 girls. In terms of their performance, it is an average class.
The activity on which this case-study was based consisted on the elicitation of pupils' ideas about satellites, followed by the data analysis. Thus, "what is, in your opinion, a satellite?" was the main question of this preliminary study.
Pupils were asked to draw something related to their knowledge about this subject, without any previous explanations. This strategy gave pupils the sufficient concentration time, in order to represent their previous knowledge. There were no impositions for the drawing, so the limit of the activity was conditioned by pupils' creativity.

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After this task, the drawings were gathered and pupils were asked for writing a few lines of text, stating what a satellite is, in their opinion. Additionally, pupils were invited to include in their texts some aspects of the theme "satellites" that they would like to learn. When the activity came to its end, all the pupil-produced materials were collected, and subsequently analysed. Extracted ideas from the written texts were independently coded by a Senior lecturer of the School of Education of Viseu. The analysis of the collected data was organized and represented according to systemic networks, revealing answers: i) scientifically correct answers (subdivided in partial and totally correct answers), ii) scientifically incorrect answers and iii) non-coded answers. In order to guarantee the anonymity of the children, their names were changed, being respected only their gender.
As for the representation of pupils' knowledge revealed in their drawings, the following figures show some of the results.

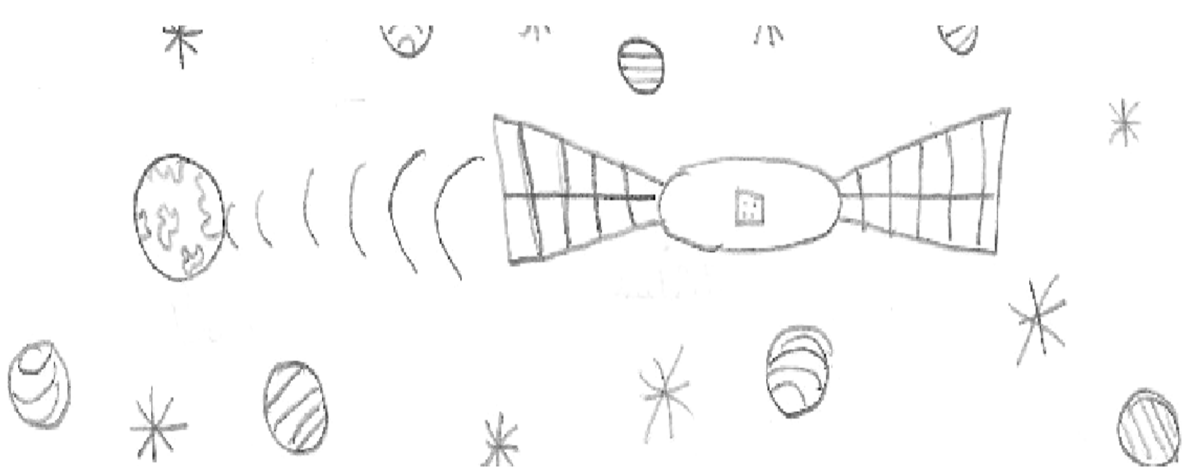

Figure 2. Ana's representation of a satellite

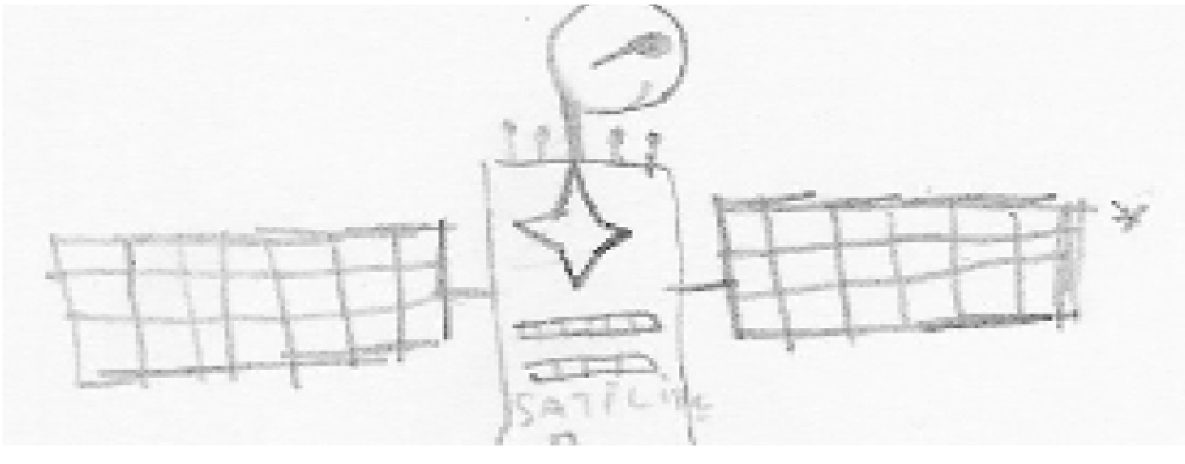

Figure 3. Bruno's representation of a satellite

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From a first analysis of these drawings, it is utterly visible that pupils possess some previous knowledge about satellites, namely in what concerns to the satellite structure (in particular, the existence of solar panels, presented in the majority of the drawings). Taking into account the previously described analysis of the texts written by the pupils, totally correct answers were considered the ideas which indicate a satellite as a receiver (R) and a transmitter (T) of information. Therefore, answers evincing the information transmission or receiving role of satellites were considered partially correct. According to Figure 4, from the 21 analysed texts, 11 totally correct answers were found, 6 partially correct, and 3 pupils gave answers not accepted (O), from the scientific point of view. Only one answer could not be coded (NC) according to the network classification parameters.

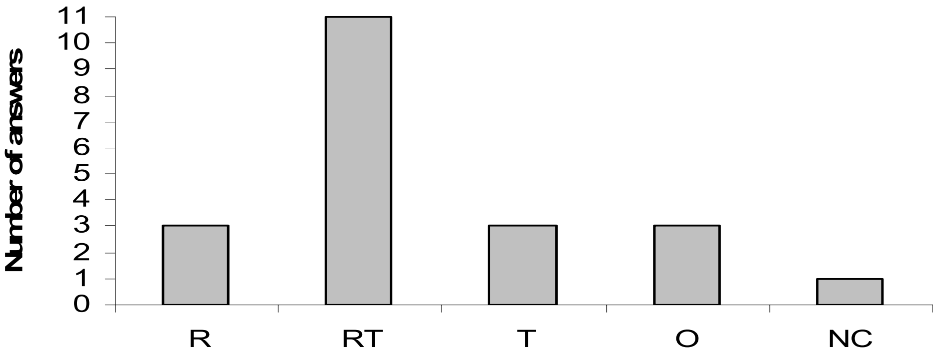

Figure 4. Distribution of pupils' answers

Having a detailed view of these answers, it is worth to mention a pupil's idea about the functions of data acquisition and transmission by satellites for meteorological purposes (Figure 5) and another text, that evinces the important role of satellites in communications relay (Figure 6).

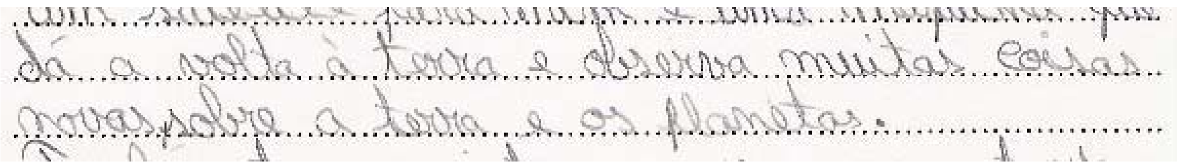

Figure 5. Carlos' answer: "to me, a satellite is a machine that goes around the Earth and observes many new things about Earth and the other Planets. It also transmits what the weather is going to be like"

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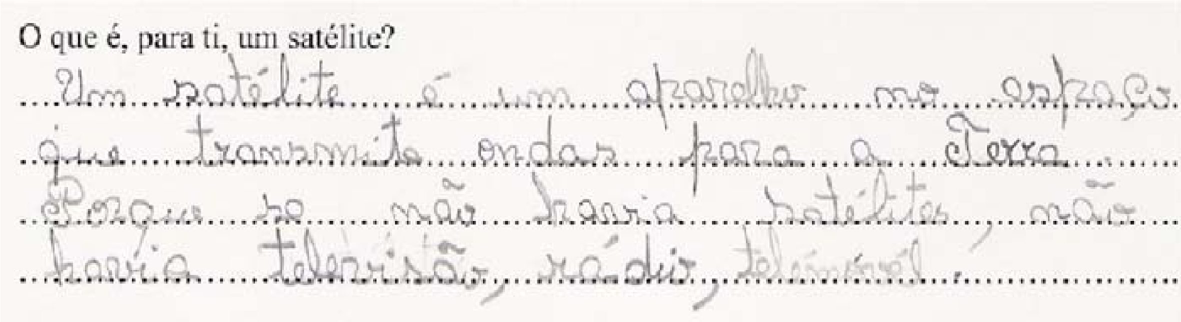

Figure 6. Diana's answer: "a satellite is a device in space that transmits waves to Earth. If satellites didn't exist, it wouldn't exist television, radio or mobile phone"

The pupils also point out several questions that they would like to discuss, showing their motivation for future or further learning on this subject, as Figure 7 depicts.

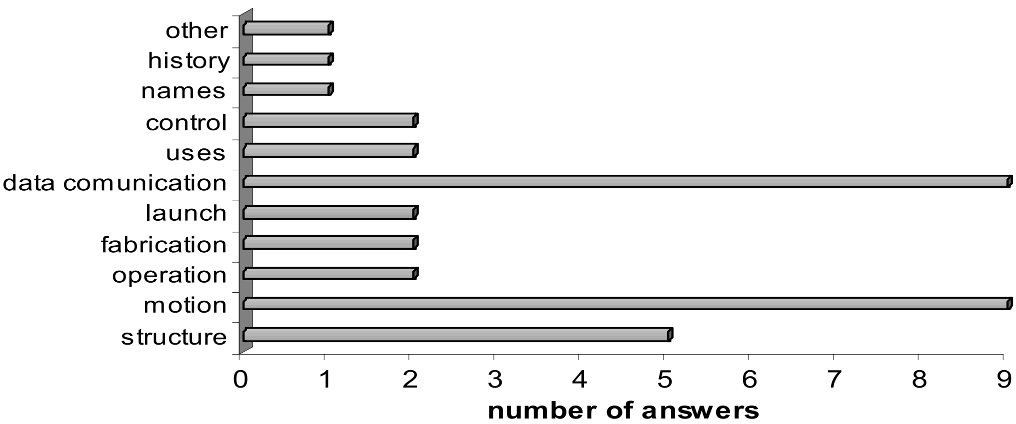

Figure 7. Pupils' interests about satellites

As a final remark, it should be noted the interest of pupils about the history of satellites and satellite communications, as well as satellite orbital motion.

Conclusions

This study reveals, as a main conclusion, the existence of a set of scientifically correct pupils' ideas about satellites. Therefore, the results shown justify per se, the suitability of the proposed activities in the classroom environment.

These results can, inclusively, constitute a vow of hope to teachers and to science education investigators: 4th grade Portuguese pupils have, in their majority, scientifically correct ideas about satellites, and their motivation is shown by the large quantity of questions that they desire to investigate.

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References

[1] Carvalheiro L, Satellite Image Reception Systems: Development and Applications. (in Portuguese). Unpublished master's thesis; Universidade de Aveiro, 2006.
[2] http://europa.eu/scadplus/leg/en/cha/c11049.htm
[3] http://www.eumetsat.int
[4] http://earth.google.com/
[5] Harlen W, Primary teachers' understandings in science and its impact in the classroom. Research in Science Education, 27: 323-337, 1997.
[6] Millar R and Osborne J (Eds.) Beyond 2000: Science Education for the Future, King's College: London, 1998.
[7] Moxey L, Tucker C, Sloan J and Chadwick J, Introducing Real-Time AVHRR-APT Satellite Imagery in the Classroom Environment, Journal of Science Education and Technology, 13: 387-394, 2004.
[8] http://www2.ncdc.noaa.gov/docs/klm/
[9] National Research Council: National Science Education Standards. National Academy Press, 1996.
[10] http://www.nnvl.noaa.gov/

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Interdisciplinary and Interactive Learning Environments in the Science Teaching-Learning Process in Secondary Schools

Libardi H, Coulon Grisa A M, Reis Pacheco M A, Rochefort O I, Villas-Boas V, Tomazzoni Gonçalves S F, Brinker J M and Cemin C

Introduction

Lately university professors and instructors have become increasingly concerned with the quality of the students arriving from secondary schools. This concern has stimulated reflection on the preparation and formation of secondary school teachers as well as on how to give them a chance to use educational tools related to experimentation. Learning how to learn, to create, to administer and to manage information are some of the abilities expected of citizens in contemporary society. Knowledge of science has been indicated by technological researchers as one of the determinative factors in the formation of professionals who are capable of recognizing and caring for scientific and technological dynamics. Interdisciplinary became a mandatory element in the discussion of methodological aspects of the science learning-teaching process, aiming at a broad and integral formation of the educator. It is necessary to prepare the secondary school teachers so that they will have a strong theoretical and experimental background that favours a broad and clear vision of the interdisciplinary context in science. So, the role of interdisciplinary in the context of secondary and education, due to its dynamic nature, must be the subject of permanent discussion.

The improvement of secondary school teachers is necessary since the opportunities for recycling them are scarce. The acquisition of knowledge, the active and significant learning, the participation in the teaching-learning process and the relationship with his/her environment come together for the formation of the professional. In this process arises the necessity of a continuous professional improvement, with reflections on his/her pedagogical practices. The teacher must participate in discussions of epistemological and pedagogical content that give basis to what, how and why to teach a certain subject, make possible knowledge and reflections, carry out conceptual reworks, transform the knowledge in science, and aim at an active and significant learning. The formation of scientific attitudes

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and the logical structuring of the teachers thought will gain new directions when the scientific methods are employed related by means of observation, organization of ideas and the comprehension of scientific principles aiming at using knowledge in the solution of day-to-day problems. For this to occur, teaching must be prioritized, promoting learning with the other teachers, aiming at changes of pedagogical practices, by means of research on the teacher's role, sharing his/her inquiries, the production of his/her work and committing him/ herself to the construction of knowledge.

An interdisciplinary vision of course content must be guided by a theoretical foundation and scientific procedures that seek the resolution of problems in the interaction of the citizen with his/her environment on a daily basis. This vision emphasizes the role of the different areas, in the interaction of the environment and in the broadening of the understanding of the concepts as a whole, providing the development of abilities and the preparation of useful materials and instruments for learning in the consolidation of the reconstruction of the knowledge.

Many schools use commercial didactic material, i.e., experiment kits. This material has the objective of stimulating the student to try and to test physical laws and principles, mathematical relations etc., and can be an excellent support. However, for a creative teacher, the commercial experiment kit is only one starting point, since it will never substitute his/her own experimental assembly, his/her own text, his/her own experiment, etc.… The main idea is in the alternative dynamics that the search for materials can motivate, mainly in terms of making the lecture a collective initiative, of all students, including the teacher. Instead of the traditional teaching ritual (i.e., traditional lecture, chalk and talk lectures) and of the learning passivity, one tries to create a space and a moment of joint work in which all are collaborating for a common objective. The University, as an integral part of the community and considering its responsibility in relation to education, must be active in teacher's qualification, arranging systematically relevant information in the innumerable readings of the world as a whole, proposing alternative actions for the teacher's role towards the reality.

At the Universidade de Caxias do Sul (UCS), a project is being developed with the objective of better qualifying secondary school teachers in the science teaching–learning process. This project is being carried out by UCS faculty members in the areas of physics, chemistry, mathematics, biology and computer science jointly with UCS´s Museum of Natural Science. Within this project, that takes into account the new curricular guidelines of the Ministry of Education and Culture, workshops have been created using an interdisciplinary, interactive and experimental approach. For these workshops, support material has been elaborated to be used in science classes of the secondary schools. In this paper, we discuss the subjects developed in the workshops, the participation of the secondary school teachers in the workshops, the activities developed, the support material conceived and the results obtained up to this moment.

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Methodology

Science education cannot continue to give priority to the teacher's lecturing, the presentation of contents and the fulfilment of the program. This sentiment is constantly being exchanged between in science educators, emphasizing the importance of informal learning environments, such as science and technology museums, for the construction of scientific meaning for the students.

The methodological proposal of this project considers the experience of the teacher and the knowledge that he/she possesses. Within this project, that takes into account the new curricular guidelines of the Ministry of Education and Culture, workshops have been created using an interdisciplinary, interactive and experimental approach. The subjects to be developed in the workshops were chosen by the participating teachers of the secondary schools and the UCS faculty members in the areas of physics, chemistry, mathematics, biology and computer science. For the first set of the workshops, twelve participating teachers were chosen: five from the area of sciences and biology, four from physics, three from mathematics and two from chemistry. The subjects chosen took into account their attractiveness and the scarcity of available material in these areas. These subjects are: the five senses (vision, touch, hearing, smell and taste) and electromagnetic waves.

Figure 1. Reproduction of a tongue and its tastes buds

Figure 2. Material developed for the workshop on quantum jumps

UCS faculty members worked so that in interactive and interdisciplinary learning environments the teachers interacted with playful materials, potentially significant objects that could generate discussions at theoretical, practical and interdisciplinary levels. Once the subjects were chosen, UCS faculty members and their monitors developed texts, materials and interactive and interdisciplinary activities. In Figure1 part of the material developed for one of the workshops on the five senses is presented, where one explores the sense of taste.

In Figure 2 the material developed for the workshop on quantum jumps is presented. The quantum jumps experiment is one of the workshops on

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electromagnetic waves, where one explores the visible part of the electromagnetic spectrum.
The texts and the activities were developed based on the methodology of active learning. According to the active learning methodology students will discover new phenomena and concepts on their own, link them to previous knowledge, reflect and generalize to acquire conceptual and significant understanding [1-3]. Traditional teaching through lectures can be successful in knowledge transfer, but do not necessarily permit the acquisition of competencies that require the active participation of the learner. In contrast, active learning is an inductive bottom-up approach. It transfers the onus from the teacher to the student and makes the student the prime actor in the learning process.

Workshops

Once concluded the development of the material (texts, experimental material, support material, computational infrastructure, etc...), the workshops were prepared and applied to the secondary school teachers. A total of 60 hours of activities was developed in the workshops. Of these 60 hours, 36 hours were on the five senses and 24 hours were on electromagnetic waves.
Short expositive lectures (i.e., 15 to 20 minutes), with the largest possible amount of demonstrations and audiovisual resources, were used for the introduction of the subject. Among the audiovisual resources used with the participating teachers, one can list: demonstrations using the computer (applets), videos commercially produced for use on DVD players or computer, overhead projector and data show for better exposition of figures and complex images.
The videos presented are never longer than 5 minutes, to guarantee that the participant teachers will not have their attention dispersed. At this point, it is important to mention that the majority of the planned activities tend to be of short duration, in order to respect and to dribble the well-known lack of concentration that grows every day among the majority of children and teenagers due to an overexposure to television in first infancy [4].
In the sequence, the participating teachers developed the experimental activities in group (see Figure 3 and Figure 4). Stimulating group work is also one of the goals of the proposed activities. Results obtained with students working in group have shown that the active exchange of ideas between the components of the group not only increases interest among the participants, also promotes more critical reasoning [5, 6]. According to Johnson and Johnson [7], there is persuasive evidence that students that work in groups reach more complex levels of reasoning and retain information for a longer time than students who work individually. Shared learning gives the students a chance to engage in discussions, taking more responsibility for their own learning process and thus becoming more critical [8]. In this context, with the group activities developed in the workshops, an objective was to stimulate the participant teachers to increase significantly the group activities in their own lectures in secondary schools. Besides carrying out group activities, the analysis of the results is also carried out in group, as well as a critical analysis of

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the activities of each workshop, where the participant teachers give a first opinion on the work that was developed.

Figure 3. Workshop on the sense of taste

Figure 4. Workshop on spectroscopy

Figure 5. Students developing the quantum jumps experimental activity at EEEM Danton Corrêa da Silva in Canela, RS, Brazil

The participating teachers were constantly stimulated in the direction of interdisciplinary education. For all activities they were questioned on new ideas and suggestions. As workshop activities, the participating teachers were asked to propose interdisciplinary and interactive activities that could be developed in the context of their secondary schools. These activities were evaluated and developed in the workshops with their colleagues or directly with their students.
The participating teachers were also allowed to deal with environments on the internet, identifying ways to program learning environments for their students, to demystify the use of computer to assist students in their learning process, and to

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reflect on the possibilities of the internet as a source of information and interaction to further the learning.

The application of the material in the secondary schools

The activities, texts and support material developed in this project are already being applied by the participating teachers with students in their schools of origin. Some workshops already had their support material produced in great quantity and are available for the participating teachers. In the particular case of the workshop on quantum jumps, the participating teachers had already applied the activities to their students and had made the reports of their experiences, as well as an analysis and evaluation of them. In the case of this workshop, modifications of some points of the experimental activity had been proposed and incorporated in the search for more significant teaching-learning methods. In Figure 5, we present a group of students from a secondary school developing the quantum jumps experimental activity at their school.
The application of the activities developed in this project to secondary school students has led to the conclusion that the physical conditions of the school environment do not matter much, but the methodology adopted and the learning environments created are very important since. The activities had been applied in schools with quite different financial resources. In all schools, the participating teachers had observed that these activities had made the classroom environment less formal, meaning that the students had felt more relaxed, more confident, participating more actively and asking many more questions. The students were more satisfied also as they understood why they were learning that content and how useful that content was. The students from schools with less contact with modern technologies (i.e., internet, chat rooms, MSN; cell phones; electronic games as PS2, X-Box, World of Craft, Tibia; parties in LAN Houses, etc...) had shown results as good as the students from the “technologically” more “rich” schools.

Conclusions

The main objective of this project is to enable and empower teachers of secondary education in the area of science, through an interdisciplinary, active and significant methodology. The results obtained up to now shows that it is having reasonable success. A collection of support materials to be used in courses and workshops for secondary school students and teachers, another collection that will be available to the secondary school teachers, as well as support material with bibliographical references, and material for use on the internet, has been produced. The creation of a group of interdisciplinary courses in other subjects of interest has been proposed with the objective of capacitating science teachers from secondary schools on a regular base. The activities developed in this project are in tune with the projects developed for the itinerant museum from the UCS Museum of Natural Science, whose first stage deals with phenomena involving light. The methodological proposals, interdisciplinary activities and the instructional material developed by the UCS faculty members and the teachers participating in this project will be made

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available on the homepage of the project [9]. In this context, one expects that the participating teachers realize the advantage of learning and teaching by means of situations and/or subjects that give more meaning to the concepts and to the ideas. One expects also that the teachers will be encouraged to use other educational methodologies in sciences, based on the discussions and illustrations proposed during the activities programmed during the workshops.

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References

[1] McGrew R, Saul J and Teague C, Instructor's Manual to Accompany Physics for Scientists and Engineers 5th edition, Serway & Beichner, Harcourt: New York, 2000.
[2] Sokoloff DR and Thornton RK, Using interactive lecture demonstrations to create an active learning environment. In: Redish EF, Rigden JS, editors. Proceedings of International Conference on Undergraduate Physics Education; 1997 March 10, College Park, Maryland. New York: American Institute of Physics; 399: 1061-1074, 1997.
[3] Ebert-May D, Brewer C and Allred S, Innovation in Large Lectures: Teaching for Active Learning, Bioscience 47: 601-07, 1997.
[4] Christakis DA, Zimmerman FJ, DiGiuseppe DL and McCarty CA, Early Television Exposure and Subsequent Attentional Problems in Children, Pediatrics, 113: 708-13, 2004.
[5] Webb N, Student interaction and learning in small groups: A research summary, In: Slavin R, Sharan S, Kagan S, Lazarowitz RH, Webb C, Schmuck R, editors. Learning to Cooperate, Cooperating to Learn, Plenum Press: New York & London, pp.: 148-172, 1985.
[6] Gokhale AA, Collaborative Learning enhances critical thinking, Journal of Technology Education, 7: 22-30, 1995.
[7] Johnson RT and Johnson DW, Action research: Cooperative learning in the science classroom, Science and Children, 24, 31-2, 1986.
[8] Totten S, Sills T, Digby A and Russ P, Cooperative learning: A guide to research, Garland: New York, 1991.
[9] http://www.ccet.ucs.br/pesquisa/projetos/cienciadetodos

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Formation of Young Scientists. The Educative Mission of the Senior Scientists

Timus C

Introduction

The scientific research is a field of activity in which there are special conditions to be fulfilled by those who decide to devote to it: first of all, it is a creative activity and to develop such an activity it is necessary some natural gift and also, let say passion, since there is a long way to obtain the satisfaction of some “grains of truth”, any humble contribution to the world scientific patrimony. There is not a spectacular career as concerns the material income, but for sure there are different other satisfactions mostly at the moral level. To reach the level of a true scientist there is no more the condition of the scientist isolated in the “ivory tower” but the open friendly relationships, since to the scientific activity is added the activity of formation of young scientists.

The mission of a senior scientist is that of transmission the scientific information but also of building a scientific personality, which means to discover the natural gift, or not, to advice towards a different other career. The process of formation of a young scientist is a long one in which the senior scientist could be, or not, a model for the young people, taking into account the very strong personality of the new generation, much earlier matured, because of the larger information system.

To be a model for the young scientists means to be a professional, to impose professional authority, but in the same time to know to collaborate, to encourage to stimulate the creativity of each member of the team, according own gifts. The formation can’t be proper, if there is not an appropriate atmosphere of fair cooperation, confidence, respect and stimulation.

Jean Piaget[13] showed that the transmission of the information is just one of the meaning of the school, since there are, as well, many other important tasks to achieve in order to prepare the young people to be integrated in the society, such as:1) to have the habit to a daily working program, useful later when integrated in the activity field, 2) the responsibility feeling; since the specific school procedures: marks, control works, examinations, periodical evaluations, even the score at the

Jean Piaget (1896 – 1980) psychologist, professor at Geneva and Paris Universities founded the genetic epistemology

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end of each scholar year will prepare the future employee to accomplish the duty at the working place and accept the criteria and steps of the promotion in the professional hierarchic scale.

Romania experience in the last years

The quality of the society depends on the quality of the education and a high level education is obtained in a serious school with professional teachers and professors. Unfortunately, now in our society towards a democratic system we could notice the consequences of the communist education, when politics based criteria have been promoted.

The qualification of the scholars is different: for gifted scholars there is a special training, in which there are involved even the university professors and such scholars are able to participate in the international contexts and obtain good results, since they are highly motivated. I'd like to mention that last year 2005 at the International Physics Olympiad held at Salamanca the Romania team scored the 4-th place after China, Taiwan and Russia. It is worth to notice, that all the teams provide from countries with a high motivation of the young people to be accepted for study abroad. All Romanian laureates have been invited by the US universities to continue their professional accomplishment.

The other scholars less gifted receive in the school a level of information that has to be improved by private activities paid by parents in order scholars to be accepted in better universities. The education in the school is no more so severe, since the teachers are not motivated by attractive salaries, the authority of them is much decreased by a false understanding of the democracy and to be frank because these teachers are produced in the ex communist system. There are plenty of private universities, but the competition with public universities is not in the favour of the first.

The graduates in physics are no tall absorbed by the education - generally the graduates in physics are absorbed by IT. The schooling is not attractive since of unmotivated earnings and the often reforms, the lack of authority of the teachers.

Our research institute [1] absorbs yearly a number of graduates in physics and engineering, since the policy of the government is favourable in this respect (half of the salary was paid by the government and only half by the institute).

Unfortunately Romania did not adopted the Timberger model[14] (the planning of the education in respect to the economical development) probably because of the huge transformations of the economy after the collapse of the communist time and the long time planned economy in the ex totalitarian system. In the last years the quality of the graduates decreased very much as compared with about 8-10 years ago. In this respect those students selected to work in a scientific institute have to continue to improve the professional level; generally, they follow MS and PhD. Some of the students prepared their thesis in our laboratories and continue their activity. The MS topics are related to the activity in the laboratories of the institute, where they are

[14]Jan Timberger scientist from the Economic Institute from Rotterdam Denmark

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selected to work. The benefit of these PhD students consists in the opportunity to be integrated in complex working team with people already specialized in the field. Due to the international projects, in which the senior scientists are already involved, the cooperation with scientists from other countries, there are activities in progress and the new graduates could easily be useful and accomplish their practical gift. The common work with experts in the field is a privilege for young scientists to be promoted, since they have to face different steps of the professional promotion: present the results of their activity in seminars, attend national and international conferences, work together with students from other laboratories belonging to the same network This is an impressive opportunity to start the career in a specialized team, which task is the scientific progress in optics and photonics.
The topics of the projects are ever up-dated according the last results in the world. This is a very stimulating and favourable environment for a young scientist [2].To develop experiments all together, to find solutions, to project new set-ups, to comment and discuss the results this means not only get expertise but it is an opportunity to take responsibility, to manage in unpredictable situations to improve the working style, to be more motivated to face new situations, to be able to report upon the contribution in a complex team work.

Figure 1 Students working in the international project LASERACT

Fig 2. The SPIE President James Bilbro with Romania SPIE Student Chapter in Bucharest July 2004

There are many different other opportunities students have to rise their professional profile: The “Module Franco-Phone” had been organized during 1993-1996 between Ecole Normale Supérieure des Arts et Inginiérie de Strasbourg, France and the University Bucharest with the National Institute for Laser, Plasma and Radiation Physics and between 1996-1999 with ”Politehnica“ University Bucharest MS. In the frame of this bilateral cooperation French professors held intensive courses, prepared questionnaires for evaluation, interviews with students to know the level of knowledge the motivation and the best students had the opportunity to develop six months working stages at Strasbourg. These stages had been determinative for the

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career of all the students. It was the beginning of the next co-tutelle PhD to be defended in France and Romania, as well.
It could be say that it was an important experience not only for the students but for Romanian professors and scientists, as well because of the opportunity to discuss upon the methods to work with students, to compare the level of French and Romanian students. The French professors found Romanian students better than French students, because the last ones had a higher motivation.
Romanian scientists held courses in French for Romanian students and each time a meeting at France Embassy in Bucharest with the cultural attaché took place in order to strength the cooperation. Some of the students after defending their PhD in France and post doctoral stages left for Canada.

Romania SPIE Student Chapter

In April 2001 the board of Society for Photo-Optical Engineering (SPIE) approved the first SPIE Student Chapter. To be member of a professional society is a pride and a sign of professional recognition.
Besides this moral benefit the contacts with this society opened new privileges for young scientists: to be able to attend international conferences sponsored by SPIE having some facilities as travel and accommodation, to apply for grants, to receive books and journals donations, to pay reduced membership fees, to attend the SPIE Annual Meeting and establish contacts with students from other countries.
In July 2004 on the occasion of the visit of SPIE President James Bilbro and Executive Director Eugene Arthur in Romania a meeting with Student Chapter was organized in NILPRP. It was the opportunity of SPIE staff to present the strategy of the society to promote the interest for optics and photonics, to encourage student to take profit from all the opportunities offered.
Two Romanian students attended the SPIE Annual Meeting a special occasion to attend a large conference and many members from different countries.
There is not an easy task the formation of a young scientist and very often due to the large opportunities the young people has to develop motilities, many of the young scientists once defended the PhD prefer to be employed abroad. The fluctuation of the personnel in the last 15 years is very high and the activity of formation of new scientists never ends.
The national and international conferences are other opportunities for training the young scientists, the occasion to present their results in front of a specialized audience, to select and process the scientific information, to elaborate a scientific paper. The young scientists have to be encouraged to work on the problem of “how to attend a conference”? This could be improved by presentations in the seminars and all kind of scientific events.
In our institute an international conference on optics and photonics is organized at every 3 years since 1982. As young scientists we had the opportunity to meet Nobel Prize winners Charles H. Townes, Alexander Mihailovici Prohorov, and many scientists, who attended the conference in a time, when Romania was a bridge between east and west. The schools, the conferences have been an opportunity to learn the secrets of the profession: how to make an attractive presentation, to

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organize the material to be presented, how to select the most important information, how to be attractive for the audience, how to react at critique, which is, or which are not a good presentation and many other things. The organization of a conference is another step in the training of a scientist, which belong to the art to establish scientific relationships, to preserve contacts, to change the information, to learn to be useful in any occasion. Everything is important and more disposals you are the higher is the gain in the profession of a scientist- it is impossible to be a good scientist without having a large culture. In the education of young scientists it is important to involve them in the different events for science promotion: consisting in conferences, exhibitions, demonstrations, visits in the laboratories, "open doors" days, etc. This activity is a form to strength the pride and respect for profession transmitting the right scientific information toward the civil society.

Figure 3. Program of "Science Week" held in April 2005 in Bucharest coordinated by the French Institute

Conclusions

There are some suggestions about the mission of a senior scientist that accomplish even its personality. Of course this is not an easy mission since the relationship between senior and young scientist is different from the conventional didactic one, but rather a close friendly one. Probable the most important thing for a senior

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scientist, in order to be able to create a new generation of young scientists is to be generous, open to ever learn and receive information.
Serban Titeica a famous Romania physicist said: “There is no education, what there is… just to be a model”. We had some models of real scientists, gentlemen in the science, in the culture and education. Shall we be a day the same? Will be the new generation content about what kind of scientists have we been?

References

[1] Fara L and Timus C, Romania reveals its research. EOS Newsletter, June 2004.
[2] Timus C, Flexible training in Optics and Photonics–an open window towards a modern society. Invited paper at ETOP 2005, Marseille 23-26, October 2005.

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Slovenia Experience Using Videoconference Technologies in Long Life Learning

Divjak S

Introduction

One of the projects of the Slovenian Ministry of Science and Education is dedicated to the computer literacy in Slovenian schools. Part of the project is focused to the problems of continuing education of the teachers. Every year they should participate to various seminars and workshops.
Faculty of computer and information science, University of Ljubljana plays as a specific role as an educational and R&D institution that follows the trends of the information technologies. It acts as a disseminator of the acquired knowledge to other members of the educational community and also to the teachers of elementary and secondary schools that should implement computer supported solutions in their everyday activities.
The obvious way for such dissemination is seminars and workshops that are organized in a classical way with regular presentations in classrooms. In the last years some other more advanced ways of such education were investigated.
Every year the members of the faculty organize on behalf of the Slovenian Ministry of Education so called Summer school for teachers and some selected scholars. This event is mainly dedicated to new Information technologies in education. The participants are mostly Slovenian teachers. The summer school is organized as a workshop consisting of interesting presentations and practical hands-on work in computer supported classrooms.
In the past years the attention was focused into Internet compliant technologies and into the conceptual learning of sciences, supported by these technologies. The participants gained the first experience in using and creating hypertext materials supported by advanced Java, 3d graphics and video examples. The first steps into videoconferencing technology were also accomplished. In the first years the summer school was limited to several 10 participants
In the Year 1999 we introduced a decentralized approach supported by means of ISDN multipoint videoconferencing technology. 11 different Slovenian cities were interconnected into a single virtual classroom. More than 230 participants could follow the lectures without travelling to a common location. The basic idea was to interconnect the involved locations, to have common videoconference lectures given by some experts and to combine these lectures with accompanied hands-on

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experience within the computer supported classrooms that were allocated at the involved locations. The whole system is represented on Figure 1.
Considering spatially distributed community the effective interaction between all the participants had to be implemented. According to this requirement several technological and organisational problems have to be solved before and during such events.

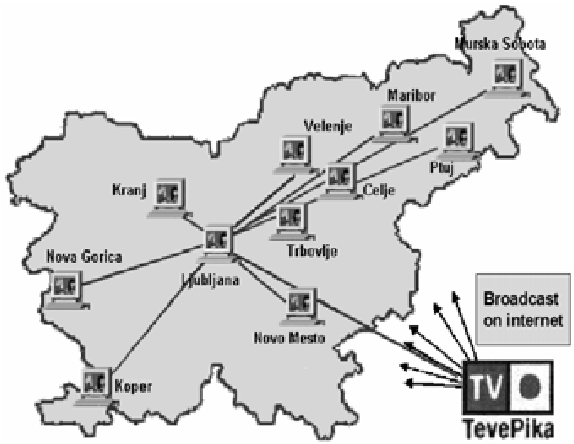

Figure 1. The interconnected virtual classroom in Slovenia

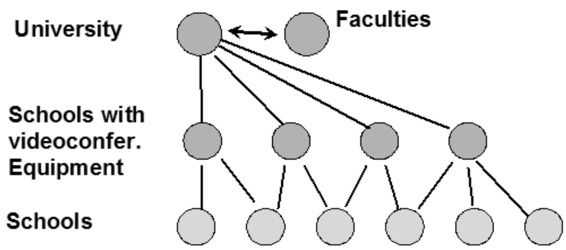

Figure 2. Model of the learning community

Technological details

First of all several computer classrooms in the involved Slovenian schools were equipped with videoconference computers that permitted the interconnection through ISDN. Every videoconference computer was equipped with particular hardware and software that permitted 2 video inputs and ISDN or IP connection towards the central Multipoint Communication unit (MCU). One video input was connected to the required video camera; the second video input was used for the connection to a presenter's computer (usually a notebook). The multilateral cooperation of these videoconference points was enabled through the multipoint communication unit located in the capital city of Slovenia- Ljubljana. All classrooms were also equipped with usual computer projectors.
A particular attention was paid to the videoconference point at the Faculty of Computer and Information Science which was organized according to its central role. In the first years practically all lectures were given from this point. The lecturers have had the possibility to connect their personal notebooks to the videoconference system by means of appropriate SVGA to video converters. At the time of the first the summer school only the central location at the faculty had such facility. In the following years every location was equipped with such converters and therefore the lecturing was enabled from other locations according to the scheduled time-table.
The guidelines from more experienced sites suggested involving not more than 4 videoconference points. In our case we decided to connect first 8 and later 11

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locations. This represented a risk in the case of the communication problems. Therefore we decided to double the technology with the support of the local TV station. A parallel videoconference point–to-point interconnection with this station was established. The whole event was broadcasted on the local cable TV and also as streaming video on Internet. Such approach gives us the needed backup link in the case of communication problems and enables also an individual follow of the tutorials on domestic computers by means of usual browsers and with Real player plug-in.
The complexity of the technological infrastructure and the crucial role of the faculty required also more staff involved in the support. At each moment at least 4 people were active in the videoconference. Besides the lecturer the second important function was the moderator who supervised the timing of the presentations and monitored the feedback from other sites.
The additional interaction possibilities were achieved by the establishment of an internet portal dedicated to the summer school. The participants had the possibility to send to the lecturers their remarks, questions and links to the accomplished assignments by e-mail.

Organizational details

The implemented technological infrastructure permitted multipoint collaboration between the involved videoconference points. However the first experiments leaded to the conclusion that a more structured approach should be used. Every lecture had 2 distinct phases: presentation and discussion. In the first phase every lecturer had 40 minutes for his presentation. After that the discussion phase was started and up to 3-4 remote locations had the possibility to ask questions. The technology of multipoint permitted even more active locations but in order to avoid chaotic discussion on one side and too long turnaround the number of interacting videoconference points was limited to 3-4.
From the logistic point of view each videoconference site a local administrator supervised its infrastructure. All administrators were prepared through several preliminary technical videoconference sessions before the official opening of the school. They also received a CD with instructional materials that permitted them the establishment of the same working environment in their local computer classrooms.
From the organizational point of view one of the problems is immediate, real-time interaction between administrators of the involved videoconference points. In the first year the cellular phones were used for such interaction. In addition to this, in the following summer schools we established a parallel communication system that was used by videoconference administrators but it was transparent to the regular participants. We implemented classical simple internet chat between the administrators. They had in such a way the possibility of immediate reports concerning the technological problems (mostly with bad sound).
In order to give to the participants the feeling of a well organized school a WEB portal was established with all data concerning the organization of the school and links to instructional materials.

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A particular care was paid to the quality of presentation materials since the quality of streamed video image requires bright and large fonts on possibly dark background. Unfortunately not all lectures followed the prepared PowerPoint templates and guidelines.
Considering the problem of the possible communication failure some lectures were prepared in advance with the technology of interactive video on demand. In such a way a complete tutorial dedicated to the 3Dgraphics was prepared. Typically each lecture was composed by a PowerPoint presentation with various video clips and combined by lecturer's talk and video. The characteristics of such lectures are that they are much more intensive and personalized since each participant can stop, step back, and skip parts of the interactive streamed materials according to his own previous experience and knowledge. The advantage of such tutorials is also high resolution of presentations, much better than with videoconferencing, combined with video clips. However according to the guidelines each lecture should be no longer than 10-15 minutes.
Remarks were that this technology can act as a complement to the regular lectures but it cannot be a good substitution for live presentations because there is missing immediate live feedback from the instructor's side.

Engagement of the participants

The participants had the possibility to follow the videoconference lectures and to put the questions to the instructor in various ways:

- Giving the questions by regular e-mail. In fact the moderator located near the lecturer continuously monitored the incoming e-mail and forwarded it to the lecturer. The lecturer could decide to answer immediately or to postpone the answer after his presentation.
- Asking for attention: The moderator annotated the requests for questions and enabled the connection with the corresponding remote locations immediately after the presentation.

Part of the participants' activities was the accomplishment of their individual assignments. At the beginning of the summer school every participant received a CD with the corresponding courseware. The contents mainly consisted of the additional didactic stuff and some software tools that were required to solve the assignments. They were able to do this in the local computer equipped classrooms and had the support given by local administrators. Besides this they were motivated to ask some additional questions to the experts by means of regular e-mail. The experts had also the possibility to see and assess the assignments accomplished by the individual participants.
For this purpose, each involved location established a local WEB page, which was linked to the central portal of the school. The basic idea of these local WEB pages

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was decentralized broadcasting of the solutions of the "domestic" assignments, prepared by the participants.
At the end of the every summer school the expectations and the reality of this event were analyzed and suggestions for further improvement were given. The best solutions of the assignments, prepared by the participants were also presented by means of the videoconference.

Analysis and remarks

After the first summer school one of the observations was that there were too many lectures (one week, at least 5 hours per day) and the participants did not have enough time for their assignments. But such intensity of videoconference lecturing was also problematic from the lecturers' and organisational point of view. We concluded that in the future we should limit the lecturing to 3, in any case not more than 4 hours per day and give more time to hands-on experience.
One conclusion of this event was also that the technological infrastructure was too complex. One reason was also doubling of the communication technology. In fact more than 30 people worked on background of the summer school. We concluded that it should be simplified. However a communication backup is needed in any case because of the possible communication problems and of the large number of participants, sparsed in different cities. In the worst case the local administrators should be able to activate some substituting activities in the local classrooms.
Another remark was that only the central point (faculty) had the possibility of giving lectures accompanied with didactic materials from personal computers (notebooks). According to this observation now all videoconference sites are equipped with converters which permit the connection of a separate teacher’s computer to the videoconference computer.
Another conclusion was that the multipoint concept is maybe attractive with its interaction possibilities but is not adequate since it could lead to chaotic problems because of too many locations involved. In any case the experience show that the lectures should not be interrupted at any moment and it was better to give to participants the permission for questions only on request, approved by the conference moderator. This means that instead of multipoint is better to use multicast or sometimes even broadcast concept.
Certainly the success of the summer school was represented by the involvement of more than 230 participants from different cities without the need of their travel and accommodation. Despite the distance between them they really acted as a virtual classroom. The technology also permitted the remote involvement of experts without the need of their travel to the central location.

Experience with continuous distance learning

The learning community participating in the experimental phase of mentioned summer school consisted of secondary and elementary school teachers who should get or refresh the basic knowledge of computer literacy and multimedia technologies. In the teaching and learning process also several experienced

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teachers of computer engineering were included. At least one such teacher was present at each location. Their role was to help their colleagues on particular sites during the practical hand-on workshops that followed the lectures.
The success of the first videoconference summer school encouraged the involved partners to activate one experimental school organized on distance learning concepts. Instead of a single, one-week long seminar, the planned school had to last several months and had to be more focused to particular topics. The idea was to try a new concept of continuing distance learning. The already mentioned communication technologies were used for distance lecturing and for additional explanations during the additionally introduced domestic assignments. The first experimental course was dedicated to the Java programming language.
In order to permit better interaction and to give more time for domestic assignments the following didactic scenario was used:
The lectures were limited to 30 minutes per week and were broadcasted through local cable TV and through Internet. The broadcast of each lecture was repeated 3 times, once in the afternoon and 2 times in the late evening.
Again, a WEB portal was dedicated to the experimental school, which contained links to the tutorial used during the lecturing. Some links were pointed to the additional didactic materials. The "Program" page contained the structure and schedule of the course. The "Videoconference points" page contained useful contact information concerning all involved locations (e-mail addresses of local administrators, links to local WEB servers.) The "Assignment” page was dynamically updated every week. It contained the definition of the particular exercises for the participants and (with the delay interval of 1 week) the possible solutions of these exercises. The "Didactic materials" page contained the link to the hypertext lessons used by the lecturer, links to some interesting WEB pages on Internet and links to some useful downloadable software tools.
Every week a new domestic assignment compliant with the current lecture was published on WEB. The next week the solution of the exercise was also published and explained.
Once per month a virtual, videoconference supported workshop was organized. The participants obtained a new assignment that integrated the already acquired knowledge. They could also ask the lecturer for any additional information. The basic idea was again that they could use the computer facilities at their classrooms during such workshop and share their experience between them. In addition they could interact with lecturer by means of usual Internet services.
In order to permit as much as possible the same working conditions for all participants regardless of their location a separate working meeting of all local administrators and the lecturer was organized before each videoconference workshop. All administrators obtained a CD with instructors' didactic material. This enabled them to prepare each local computer classroom with the same didactic tools. This approach permitted them to act locally in the case of communication problems.
A separate CD was prepared for each registered participant. This CD contained the hypertext lessons which were used by the lecturer during his performance. The CD contained also some accompanying useful didactic material.

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Conclusions

Both experiments, the first videoconference supported summer school and the experimental introduction of continuing education supported by such communication technologies had some common characteristics. First of all the habitude of the participants is just to follow the lectures and not to use the combined videoconferencing and Internet communication technologies for one immediate feedback with the lecturer. Therefore such lectures had more broadcasting than interacting character. The participants preferred to interact with the teacher in the days following such lecture by means of usual Internet services, mostly e-mail. Most of the participants also preferred to work on their assignments alone at home and to interact with the lecturer after, and not during the periodic videoconference.

Another interesting experience was using the public services of the local TV station. The limit of 30 minutes per lecture opens for the lecturer new challenges because his explanation should be more efficient, compact and at the same time attractive because it is usually followed also by some less experienced listeners. This is even more difficult in the case that the lectures are "on line" and no corrections are possible as this is the case of "playback". From the technological point of view practically all didactic materials had to be adapted considering the guidelines how to use colours and fonts (big and simple fonts, bright and could colours on black background) in order to guarantee a better readability on TV.

One of the side effects of such lecturing are well prepared didactic materials which are recorded and can be published on video-servers for repeated training seminars.

Another positive side effect of this experience was the increased link and communication between participating teachers and professors and other experts at the university. The personal communication between participants and university lecturers often continues also after such events. In fact we obtained the model of the learning community represented on the Figure 2. At the top of this community are involved faculties, on the second level are the schools equipped with videoconference technology. Their personnel can also act as co-organizers and multiplicators in the case of repeated seminars and workshops. On the third level are the elementary and secondary school teachers from various schools, interested in the continuous refinement of their knowledge and skills.

The achieved experience and the followed analysis lead to the conclusion that such kind of education should remain traditional. One of the primary reasons is that the participants do not have to spend money and time for travelling. In fact they can join one of the nearest videoconference points which are established overall the country on the basis of the regional level. This approach is also appropriate for short lectures or presentations lasting just a couple of hours. This is particular useful for knowledge-refreshment seminars that are a never ending story in the field of information and communication technologies and their application. In the near future this type of education will continue with periodic videoconference seminars accompanied with hands-on workshops. Further development of this activity will be in a more structured and focused organization of videoconference based seminars which should consider the preliminary knowledge of the involved participants and their personal skills and interest.

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References

[1] Divjak S, Distance learning supported by videoconferencing technologies. EUNIS 2000: towards virtual universities: Conference Proceedings. Poznań: Instytut Informatyki, Politechnika Poznańska, pp.: 31-37, 2000.
[2] Kavcic A, Privosnik M, Marolt M and Divjak S, Educational hypermedia: an evaluation study. V: 11th IEEE Mediterranean Electrotechnical Conference, MELECON 2002, May 7-9 2002, Cairo, Egypt. Communications and information technology for development: proceedings. Piscataway: The Institute of Electrical and Electronics Engineers, pp.: 80-84, 2002.
[3] Divjak S, Multimedia supported approaches to computer graphics teaching. RACHEV, B., (ur.), SMRIKAROV, A. (Ed.). Proceedings of the International Conference on Computer Systems and Technologies (e-Learning): CompSys Tech'2002. [S. l.]: Bulgarian Chapter of ACM, 2002.
[4] Walker S, Videoconference Classroom Environment Perception: Developing the Videoconference Learning Environment Survey, http://www.eaglenest.com/~swalker/smec/smec702/Scott_Walker_SMEC_702_Assignment_2.PDF
[5] Ekeblad E, Lindstroem B and Wass K, Learning by Videoconference in the Workplace: http://www.ped.gu.se/users/berner/pdfarkiv/dyrk_ea.pdf
[6] http://sunsite.fri.uni-lj.si/~colos/SUMMER_SCHOOL
[7] A Teacher's Guide to Videoconferencing: http://www.netc.org/digitalbridges/teachersguide/introduction.html

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Foldable Slewing Crane

Pedrosa D, Teixeira P, Crespo J, Costa D and Sena Esteves J

Introduction

A slewing crane equipped with an electromagnet is a very useful tool to move ferromagnetic pieces from a place to another. This paper describes such a crane, built for science fair events. Its first public appearance took place in the activity *Oficinas de Electricidade* (Electricity Workshops), integrating part of *Robótica 2006* festival[15] (Figure 1). Building this kind of equipment improves construction skills and promotes the study of Electromagnetism fundamentals, such as Biot-Savart's law [1, 2].

Crane dimensions and operating details

The crane has a weight of 395 kg, a height of 3m and a length of 2,5m. The base is a 1,20m x 1,20m square. More detailed dimensions are shown in Figure 2.
Three three-phase induction motors, each one equipped with a reduction gear, produce the crane movements. A switchboard located at the rear of the crane (Figure3) receives command signals from a control panel (Figure 4) and two limit switches. According to these signals, it switches the electromagnet (Figure 5) on or off and controls the motors. One of the motors enables the crane to slew right or left. The other two enable the electromagnet to move up, down, forward or backward (Figure 6). The control panel is located on the front part of the crane, where the operator – from its comfortable seat (Figure 7) – has a good view of the pieces to handle. For safety reasons, the crane is only allowed to slew within a 180º angle. This result in a working space whose top view has the shape depicted in Figure 8.
The electromagnet (Figure 9) and the structure of the crane are strong enough to elevate a weight of 80kg to a height of 2m from the ground.
Pressing an emergency button switches off all command circuits. However, the electromagnet cannot be switched off while being on a high position, not even if the emergency button is pressed.

[15] *Robótica 2006 – Festival Nacional de Robótica* (National Robotics Festival), Guimarães, Portugal, April 28 – May 1, 2006.

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The crane is foldable (Figure 10, 11 and 12), which is very convenient for transportation and storing.

Figure 1. Slewing crane at *Oficinas de Electricidade* (Electricity Workshops)

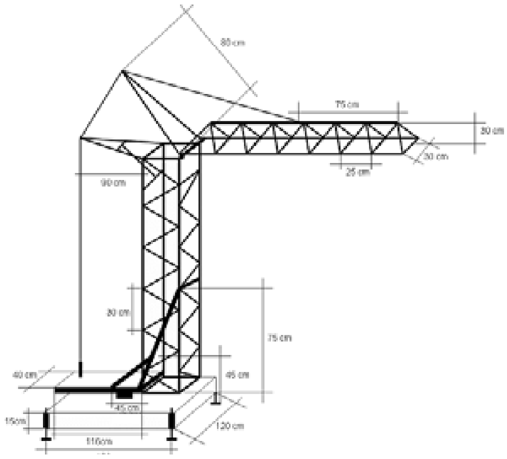

Figure 2. Dimensions of the crane

Materials used to build the crane, the switchboard, the control panel and the electromagnet

The crane was built with:

- 10m of 30mm x 30mm angle iron;
- 24m of 16mm x 5mm iron bar;
- 6m of 25mm x 25mm iron tube;
- 2m of 30mm x 30mm iron tube;
- 5m of 150mm U-shape iron bar;
- 4m of 50mm U-shape iron bar;
- 2m of 65mm U-shape iron bar;
- a 1,7m x 1,2m iron sheet;
- 4 medium pulleys for steel cable;
- 8m of 4mm steel cable;
- 5m of 8mm steel cable;
- a truck hub;
- a seat;
- 4m of steel chain;
- 3 three-phase induction motors equipped with a reduction gear.

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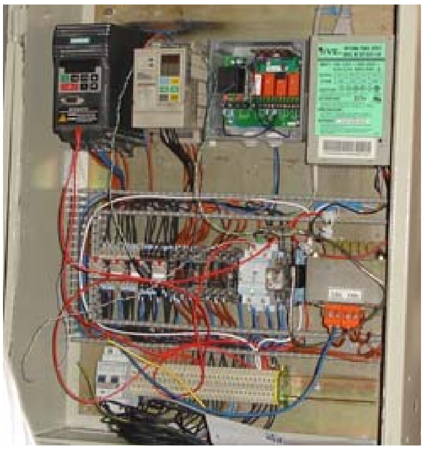

Figure 3. The switchboard

Figure 4. Operating the crane via the control panel (the switchboard is behind the operator's seat)

The following materials were used to build the switchboard and the control panel:

- 2 inverters;
- 1 power source;
- 1 remote control;
- 10 relays;
- 2 contactors;
- 1 transformer;
- 2 circuit breakers;
- 33 connectors;
- 1 roll of $0.75mm^2$ cable;
- 1 roll of $2.5mm^2$ cable;
- 1 switchboard case;
- 1 emergency switch;
- 1 two-position joystick;
- 1 four-position joystick;
- 1 pushbutton;
- 4 limit switches.

The following materials were used to build the electromagnet:

- Varnished $0,25mm^2$ copper wire.
- Cylindrical piece of iron with a diameter of 15cm and a height of 4cm.

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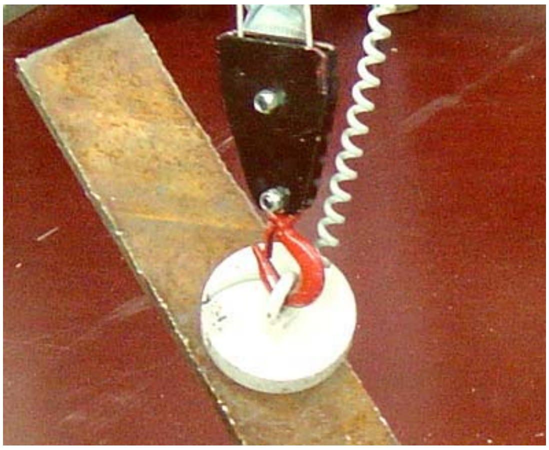

Figure 5. The electromagnet

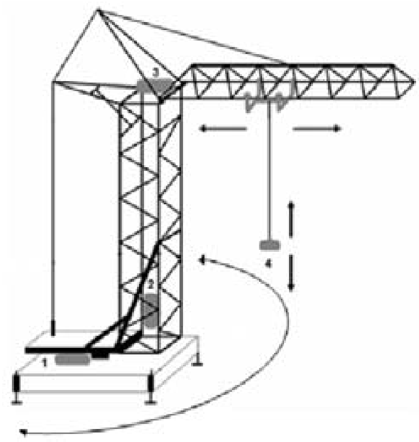

Figure 6. Crane and electromagnet movements

Figure 7. The crane has a comfortable seat

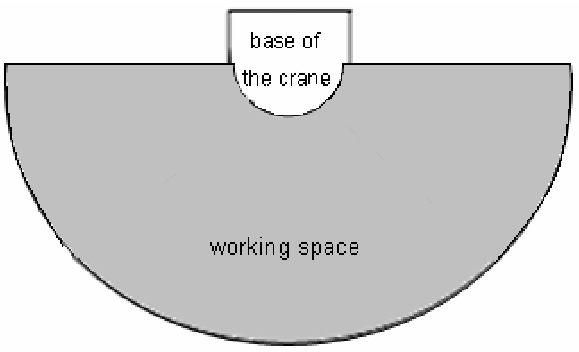

Figure 8. Top view of the working space of the crane

Switchboard operation

The switchboard contains several command circuits [3] that are active as long as Relay 6 (Figure 13) is active. The control panel has an emergency button s1 (Figure 13). Pressing this button switches off Relay 6. It is also possible to switch on or off Relay 6 using a remote control (Figure 13).

In order to keep 230V mains voltage as the only power source of the crane, inverters were used to drive the three-phase motors. Figure 14 depicts the command circuit of inverter 1, which drives the motor that moves the electromagnet up or down. The sense of motion is done according to the position of a two-position joystick s2, placed in the control panel. Pressing the emergency button stops the electromagnet movement.

Figure 15 shows the command circuit of the relays used to command the inverters and to switch on and off the electromagnet. Two limit switches were used to ensure that the electromagnet stops when its forward or backward movements limits are

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reached. Two more limit switches were used to ensure that the crane only slews within a 180º angle.

Figure 9. Electromagnet elevating an iron piece

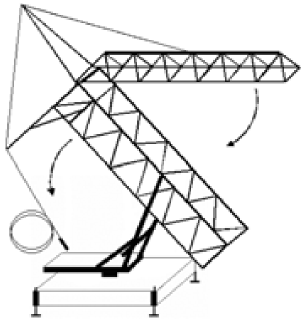

Figure 10. Folding the crane

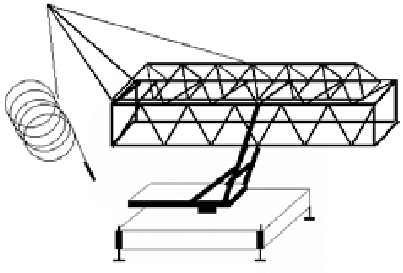

Figure 11. Folded crane

Figure 12. Folded crane being transported

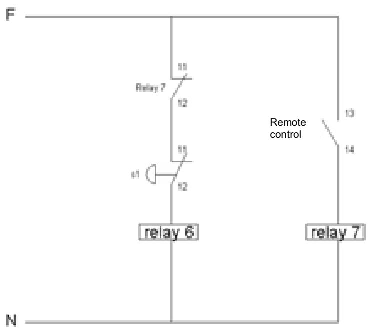

Figure 13. Emergency button and remote control function

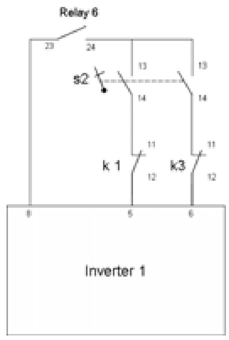

Figure 14. Command circuit of inverter 1

It is not possible to use limit switches to determine the vertical position of the electromagnet. So, a system based on an 8051 microcontroller (Figure16) was developed [4, 5, 6, 7, 8]. An inductive sensor (Figure 17) is placed near the reel of the cable that holds the electromagnet. For each reel turn, the sensor sends one signal to the microcontroller. Electromagnet height is determined by counting these turns.

The electromagnet can be raised to a height of up to 2m from the ground. For safety reasons, an operator is not be able to switch off the electromagnet if it is above 0,50m level from the ground, not even if the emergency button is pressed.

Two contactors (Figure 18) were used to switch the motors on and off. The command of the contactors is done by a four-position joystick, which allows the operator to slew the crane right or left and move the electromagnet forward or backward. Since an operator is not able to select two different positions of the joystick at the same time, it is not possible to activate both motors at the same time. Auxiliary relays were used to control inverter 2 (Figure 19). This inverter drives both the motor that slews the crane and the motor that moves the electromagnet forward

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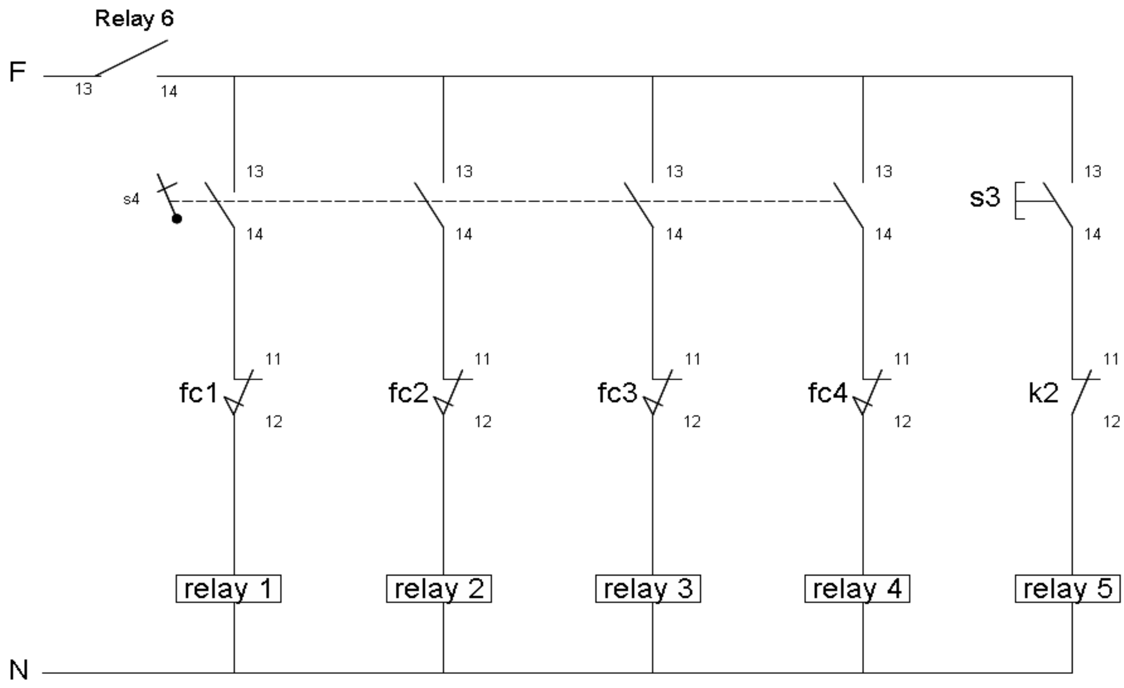
and backward. The two movements cannot occur at the same time. So, only one inverter was used, instead of two.



s3 – pushbutton that switches the electromagnet on or off
s4 – four-position joystick, which allows the operator to slew the crane right or left and move the electromagnet forward or backward
fc1 – left slewing limit switch
fc2 – right slewing limit switch
fc3 – forward movement limit switch
fc4 – backward movement limit switch

Figure 15. Command circuit of the relays used to command the inverters and to switch on and off the electromagnet

Each signal received from the four-position joystick activates a specific relay, which switches on one of the contactors. At the same time, the relay tells inverter 2 which motor should start and which is the sense of rotation of the rotor. Figure 20 shows the power circuit, which includes a transformer that powers the electromagnet. Whenever the emergency button is pressed, all command circuits stop functioning. However, if the electromagnet is switched on at that time, it will not be turned off.

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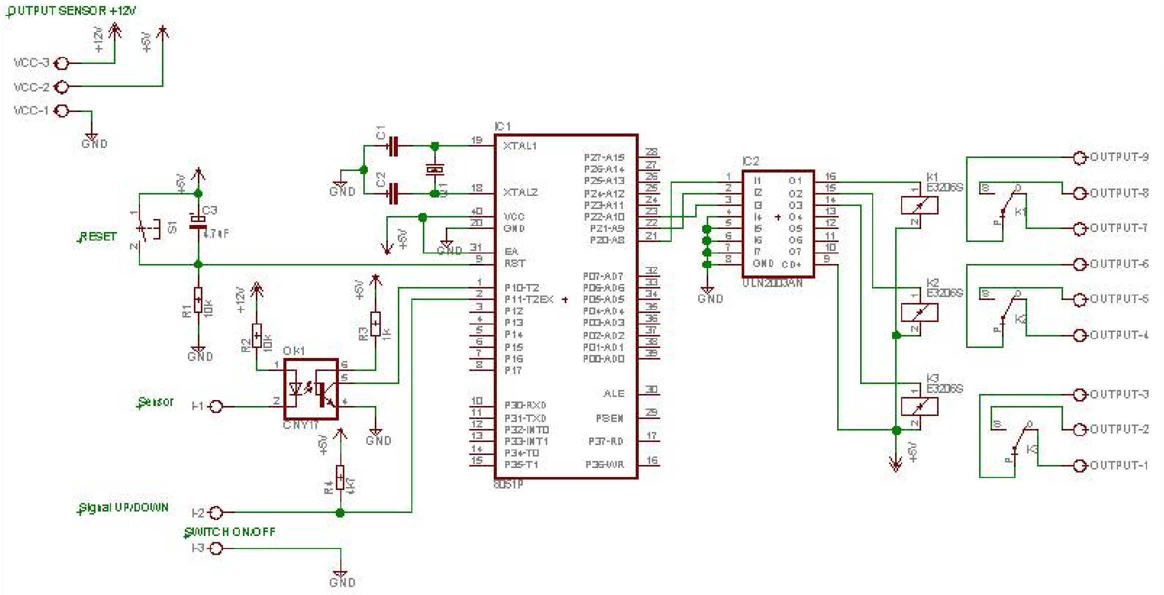

Figure 16. 8051 microcontroller circuit

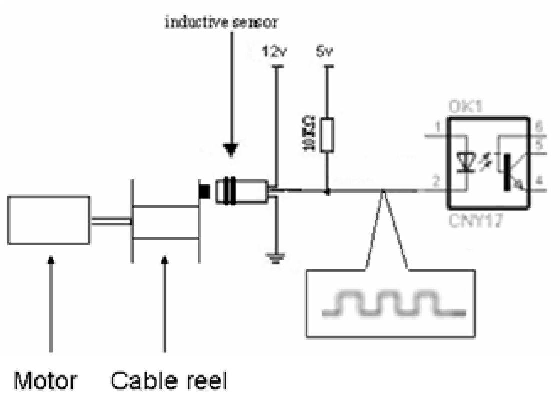

Figure 17. Connection of the inductive sensor to the microcontroller

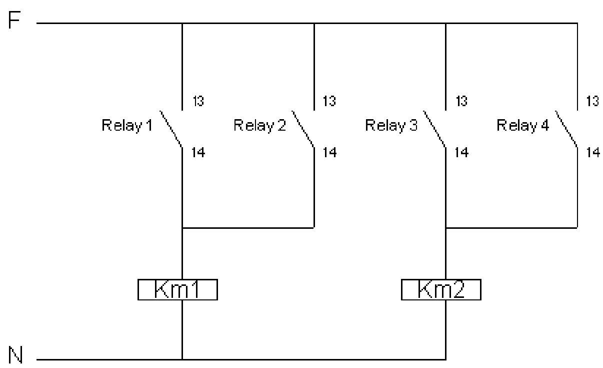

Figure 18. Command circuit of the contactors

Source code of the program installed in the 8051 microcontroller

This is the source code of the program used by the 8051 microcontroller to determine the vertical position of the electromagnet:

```
#include <REG51.H>
#include <portas.h>
int count=0;
void update(void)
{
    int i;
```


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```
    if(P16==1)
    {
        for(i=0;i<=15000;i++);// To eliminate the bounce effect
        if(P16==1)
        count=count+1;// If gate P1.6=1 increases the count
    }
    if(P16==0)
    {
        for(i=0;i<=15000;i++);// To eliminate the bounce effect
        if(P16==0)
        count=count-1;// If gate P16=0 decreases the count
    }
}
// The function verifies the counter state and acts according the //conditions....
void verification(void)
{
    if(count<=14&&count>=10||count==0)
    {
        if(count==0)// If the counter goes " 0 " it turns off the //ascent command
            P20=1;
        if(count>=10)// When the counter is in the middle sends //a sign
            P21=1;
        if(count==14)// If the counter goes " 0 " it turns off the //descent command
            P22=1;
    }
    else
    {
        P20=0; P21=0; P22=0;
    }
}
//.........................................................................//
int main()
{
    int i;
    while(1)
    {
        if(P14==1)
        {
            for(i=0;i<=15000;i++);//To eliminate the bounce //effect
        if(P14==1)
        {
            update();
            verification();
        }
    }
    while(P14==1){}
```


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```
    }
    return 0;
}
```

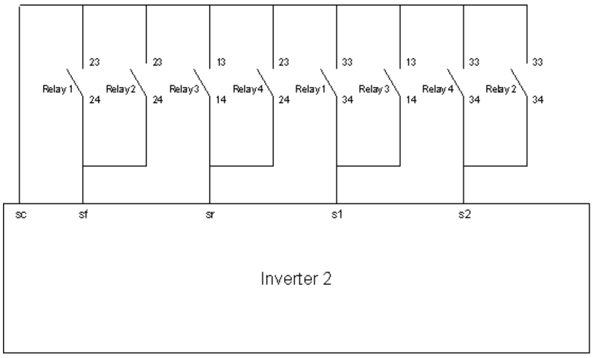
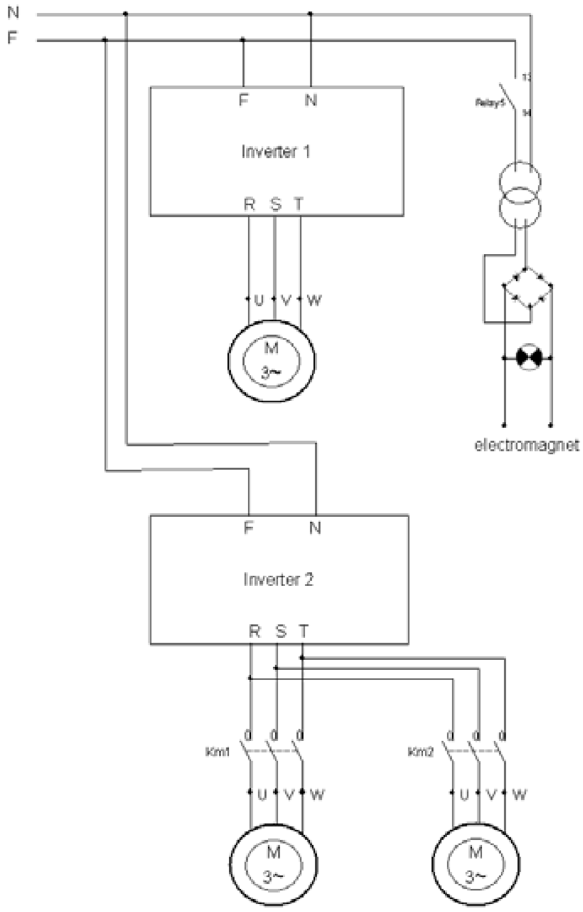


Figure 19. Command circuit of inverter 2



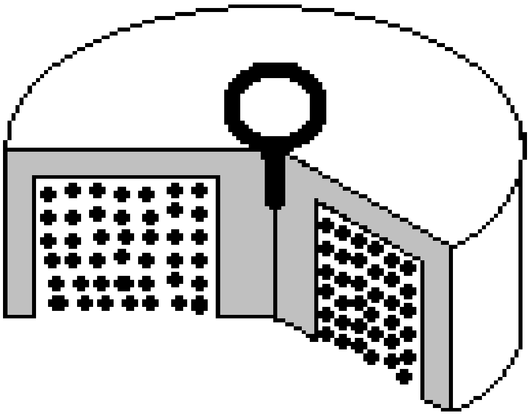


Figure 21. Electromagnet

Figure 20. Power circuit

Remarks:

- Whenever gate P14 (Figure 16) has a logical level 1 the program executes the *update* instruction, which updates the *count* variable. This updating depends on the logical level of gate P16 (Figure 16).

- The *verification* instruction has the purpose of verifying the state of the *count* variable.

  ─If *count*=0 then gate P20=1 (Figure 16). This disables the electrical circuit through the relay K1 (Figure 16), which turns off the ascent circuit.

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–If the value of *count* is between 10 and 14, gate P21 (Figure 16) has a logical level 1. That will switch on relay K2 (Figure 16).

–If the value of *count* is 14, that means the electromagnet is at the ground level. Gate P22 (Figure 16) stays at logical level 1. This activates relay K3 (Figure 16), which shuts down the electrical circuit, allowing the electromagnet to go down.

Electromagnet construction and operation

The core of the electromagnet was made with a 15cm diameter cylindrical iron piece with a cavity. A coil with 3500 turns of 0,25mm^2 varnished copper wire was placed inside this cavity. Figure 21 shows an inside view of the device.
To activate the electromagnet, an 110V DC voltage is applied to the coil terminals. Then, a continuous current flows in the coil, producing a constant magnetic field [1, 2]. The electromagnet can lift 80kg loads.

Conclusions

A slewing crane equipped with an electromagnet has been presented. The device, built for science fair events, is capable of elevating ferromagnetic pieces of 80kg to a height of 2m from the ground.
Three three-phase induction motors produce the crane movements. The crane switchboard contains relays, contactors and inverters that allow the operation of these motors using a single-phase power supply. The switchboard also includes a transformer that powers the electromagnet.
On the crane control panel, a two-position joystick allows the operator to move the electromagnet up or down. A four-position joystick allows the operator to slew the crane right or left and move the electromagnet forward or backward. The operator can make the crane slew left or right within a 180º angle. Pressing an emergency button switches off all command circuits. It is also possible to switch on or off these circuits using a remote control
An 8051 microcontroller-based system was developed to determine the vertical position of the electromagnet, which cannot be switched off while being on a high position, not even if the emergency button is pressed.
This kind of project develops the construction skills of the builders and promotes the investigation of Electromagnetism fundamentals.

Acknowledgements

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References

[1] Plonus MA, Applied Electromagnetism. McGraw-Hill, 1986.
[2] Mendiratta SK, Introdução ao Electromagnetismo. Fundação Calouste Gulbenkian, 1984.
[3] Matias JVC, Tecnologias da Electricidade – Vol. II. Didáctica Editora, 2005.
[4] Rogercom. Controle de Motor de Passo Através da Porta Paralela. www.rogercom.com/pparalela/IntroMotorPasso.htm
[5] Sá MC, Programação C para Microcontrodadores 8051, Érica, 2005.
[6] Gonçalves VMS, Sistemas Electrónicos com Microcontroladores, LIDEL, 2005.
[7] micro8051. http://micro8051.com.sapo.pt/
[8] mikroElektronika. www.mikroelektronika.co.yu

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Hands-on Science Network. Improving Science Education towards a Sustainable Development

Costa MFM

Improving Science Education towards a Sustainable Development

Established in October 2003 in the frames of the Comenius 3 action of the Socrates program of the European Commission, the European Network “Hands-on Science” developed since then a vast range of activities towards a better Science Education in European Schools [1].

Our main goal is the promotion and development of Science Education and scientific literacy in Europe. We aim to generalise innovate and improve Science & Technology teaching at basic vocational training and secondary schools by hands-on experimental practice in the classroom. Bringing hands-on active learning of Science into the classroom and into the soul and spirit of the school.

The network, established now as an International Association, enrols as institutional or individual members, over two hundreds schools, several universities, national and international associations, governmental bodies, science centres and museums, NGO’s and companies of practically all countries of the European Union and from all over the world.

About a thousand teachers and educators from kindergarten to high and vocational training schools including special education institutions and well over 20000 pupils are or had been directly and actively involved in our activities.

Several dozens of lectures, countless experimental activities in the classroom, experiments demonstrations plays festivals and science fairs were organised. Several science clubs were established are working actively and passionately… discovering Science.

Training seminars and courses for teachers and pupils had been developed at national and European level. Over four hundred pedagogical and scientific papers were published in conference proceedings and journals. Several books and experiments guides and support texts had been published in different languages. Multimedia CDROMs and DVDs were produced as well as fourteen websites in different languages:

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http://www.hsci.info,
http://hsci.no.sapo.pt,
http://www.hsci-pt.com,
http://colos.fcu.um.es/comenius/,
http://webs.uvigo.es/eventos/h-sci/,
http://ptcl.chem.ox.ac.uk/%7Ehmc/hsci/,
http://www.emg-huerth.de/comenius/index1.htm,
http://www.hsci.info/hsci_si/,
http://education.inflpr.ro/ro/hsci.htm,
http://users.skynet.be/fb738062/,
http://micro-kosmos.uoa.gr/Hands-on-Science/
http://www.hsci.info/hsci_mt/,
http://www.clab.edc.uoc.gr/hsci/,
http://lsg.ucy.ac.cy/other/hsci/.

Most of the websites establish links to many other websites offering an enormous amount of resources (including remote laboratories like the site http://colos.fcu.um.es/rlab/) that can be used freely by teachers, students, and all interested persons in general.
Various press-conferences news and reports were organised disseminating the results of our work in our communities.
A major public relations campaign stating and illustrating the importance and the absolute need of a generalized use of practical hands-on experiments at the classroom as basis the education in Science at all school levels was developed aiming EU' schools, decision makers governments and politicians, universities, networks and national and transnational associations, science museums and other institutions involved with non-formal or informal education, the industry, local communities and the citizens in general.
Several successful Comenius 1 and Comenius 2 cooperation projects between dozens European schools and other institutions had been promoted in different subjects: robotics, renewable energies, optics, in-service science' teachers training, sociology and European identity, arts and science, and sustainable development. Other types of cooperation resulted also from the three Socrates/Comenius Contact Seminars we organized as part of our annual conferences in Ljubljana, Slovenia in 2004, in Crete in 2005 and in Braga in September 2006. The 2007' conference in Ponta Delgada, Azores, in this European year for "Equality" will focus on "Developed Diversity and Inclusion in Science Education.
Three international workshops were organized in Cologne, Malta and Bucharest to discuss issues of utmost importance as the Access of Women to Science, Scientific Literacy the Development of Europe and the Challenges of EU' Enlargement, and the increasing importance of Life Long Learning and Scientific Literacy in our Societies.
The "1st International Conference on Hands-on Science. Teaching and Learning Science in the XXI Century" held in 2004 in Ljubljana, was an excellent forum where 120 participants from 13 EU' countries presented 52 works and discussed the main

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aspects of modern Science Education establishing the basis for the work the network developed thereafter towards the generalization of hands-on experimental work in science education at our schools.
In Crete, July 2005, the HSCI2005 conference, "2nd International Conference on "Hands-on Science. Science in changing Education", gathered nearly 200 participants from 27 countries of the five continents that presented 81 communications discussing the changes education is facing these days in our schools. An interesting science fair was the preferred meeting point for informal contacts and friendly exchange of experiences and good practices.
In September 2006, 4 to 9, at the University of Minho in Braga, Portugal, our "3rd International Conference on Hands-on Science. Science Education and Sustainable Development", HSCI2006, proved the importance and prestige our organizations reached among the EU', and world's, educational and scientific community (a web search for the phrase 'Hands-on Science International Conference' gave more than 1 million hits most of them referring to our annual conferences and over 1/3 of all hits on hands-on science refer to activities of our network [2]).
Over 450 persons registered to the conference and the 314 effective participants from 41 countries presented 270 works, involving 432 co-authors, apart of 137 hands-on experiments presentations (many including several different experiments) at the 1st European Science Fair we organised from the 5 to the 8 of September that was visited, apart from the conference participants, by more than 500 students teachers and interested citizens in the most active and enthusiastic way.
In the overall over 790 scientists teachers students heads of school politicians ministers and other national and local governments representatives, NGO and media from 43 country (mostly from the EU) actively participated in our six major meetings presenting their ideas in 403 works, published and freely available in our websites in electronic format, and established a set of major recommendations and work' support material that, we truly believe, will positively influence the way Science Education is approached in our schools.

The Future of Hands-on Science

With the active contribution of all network members and individuals and institutions committed to the improvement of science education, the Hands-on Science network will continue growing and contributing to the improvement of scientific literacy and to the quality of science education and thus to a sustainable development of our societies.
The Hands-on Science Network [4] will be maintained in the form of an International Association (www.hsci.info) and will keep growing enlarging its membership and the impact of its activities and proposals in our schools and societies...

inducing a better science education ...
in favour of a sustainable development ...
… towards a brighter future of humankind ...

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Conclusion

World' sustainable development both in economical and social terms strengthening the democracy and social cohesion in our societies with high levels of human development in respect to the United Nations chart of human rights should be a goal of all countries and of each one of us.
The importance of Science, both the pursuit of knowledge and the search for practical uses of scientific knowledge, is widely recognised at all levels in modern societies. A strong and enlarged scientific literacy is fundamental to the development of science and technology but also to a democratic citizenship.

Acknowledgements

As coordinator and chair of the Hands-on Science Network, the author would like to acknowledge the enthusiastic participation of all member of H-Sci in this effort of improvement of Science and Science Education.

References

[1] Costa MFM, Hands-on Science, Proceedings of the 1st International Conference on Hands-on Science en Teaching and learning Science in the XXI Century, pp.: 1-9, 2004.
[2] Michaelides PG, The Hands-on Science Project: Perspectives of an Adventure, Proceedings of the 3rd International Conference on Hands-on Science. Science Education and Sustainable Development, pp.: 4-7, 2006.
[3] http: //www.hsci.info

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Results from an Undergraduate Test Teaching Course on Robotics to Primary Education Teacher – Students

Anagnostakis S and Michaelides PG

Introduction

It is increasingly accepted that an effective Science and Technology Education may be achieved by an interdisciplinary teaching approach within a constructionismic context. In this sense, Educational Robotics is especially useful. On this basis we have presented in a previous work the design of an undergraduate course with the title 'Laboratory of Educational Robotics' [1]. Its syllabus includes the assembly and (simple) programming of different modules towards the construction of a robot performing specified (simple) tasks. The course objectives include the familiarization with the notion of robots and the development of cognitive skills. The course was designed within the general context of increasing the Science and Technology Literacy, a crucial factor for the modern, technology based societies. Pursuing the objective to construct (or assemble) a robot, students may develop complex cognitive and problem solving skills. They are also presented with real problem situations in which, trying e.g. to chose and manipulate the appropriate sensors or to incorporate movement to the robot, they are helped to a better understanding of basic concepts in Physics. In this work we present results from a first time test teaching of this designed course to the undergraduate students of the Department for Primary Education of The University of Crete.

Course Delivery

The course was included within the undergraduate program of courses at the spring semester of 2007 as an optional choice in the area of Informatics in Education of the Department for Primary Education of The University of Crete. Graduates of this Department are qualified to be appointed as teachers in the primary school. The course was delivered by the authors of this work. It addressed students on the 5th or greater semester. Most of the students addressed have already completed their basic courses in Science and in Methodology of Teaching. In their majority they are computer literate. In the announcement of the course it was stated that no formal prerequisite knowledge was demanded from those choosing to attend the course,

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although computer literacy extending to familiarization with simple computer programming would be an advantage. Due to its experimental teaching as a laboratory course and taking into account the available equipment (number of robot kits) the course was planned for 16 students at a maximum in one class. The course was chosen by 26 students. Instead of selecting between them, it was decided to enrol all the students, forming two separate classes in groups of 3 to 4 students instead of the 2 persons per group planned initially. This arrangement was made partly in order to compensate for possible drop-out that is significant in the Mathematics, Science and Technology area of the curriculum partly as a limitation imposed by the number of available robot kits. The drop-out rate was zero a fact we comment on later.

Figure 1. Some of the equipment used

Figure 2. Overview of the workbench during a break of students' study

The course was delivered in intervals of three teaching hours per week for 13 weeks. Students however were free to use the laboratory for more hours, if they wanted to prepare or study for their assigned tasks. The equipment used was the LEGO© Mindstorms (Figure 1) because their purchase was easier. They had the added advantage that the LEGO parts are familiar to most (almost all) of the students. There were two different versions of the robot processor units. The programming was made on PC's with Windows XP or Mac's with OS X using the Robolab© Software supplied by LEGO, an icon based programming language. The program was then transferred through the infrared link to the robot units.
The teaching was organized as follows:

- During the first 3 weeks students were introduced to the concepts related to the robots and the robot programming. Examples of robots used already in different applications were given and students were encouraged to propose possible applications of robots in other areas also. During these same weeks the available equipment was available to the students. They

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were taught its use so as to become familiar with common techniques of robot programming.

- During these first 3 weeks all the students were in one class. During the next weeks, students were working in groups formed by them. Every group had its own Lego Mindstorms set to use throughout the course. Students were advised to assign between the members of every group the responsibilities for the design, for the assembly, for the programming, etc.
- During the next 4 weeks students were assigned the task of constructing a specific robot from the examples given on the manuals. The manuals were in English, a factor causing difficulties to the students. A clarifying explanation of the logic of the respective robot programs was demanded from the student as an indication of their understanding. Alternatively they could make their own programming to perform the same (or more) tasks. In parallel, students were introduced to design and assemble a robot of their own for a specific task, i.e. to construct a robot that could transfer objects from a place to another one. To make it more interesting a contest was setup where the student made robots will compete, in pairs, to clear their area of a number of ping-pong balls transferring them to the opponent's area.
- The next 3 weeks were dedicated to the construction and testing of the robot. At the end the contest was made. During the same period, students were introduced to the concept of 'smart home' with the objective of study, design and implement, in a model way, a specific component of a 'smart home' The students were asked to identify such components and possible ways of introducing appropriately made robots. Students were encouraged to identify components of their own although, as a help, the following components were indicated and analyzed to some extend:

  - the operation of water heater and of central heating,
  - the interior – exterior house illumination in relation with the presence – absence of the residence or with other conditions,
  - the operation of the garage gate,

- The next 2 weeks were dedicated to the implementation and the presentation of the 'smart home' components that every group of the students had chosen.
- During all times of laboratory work a supervisor was always present to guide, during the first weeks, or to help and provide advice if asked, afterwards. Specific parts of the manuals. Referring to the assembly and some techniques on achieving specific results, were also translated into Greek and made available to the students.
- Students were also requested to submit a short weekly report (one per group) on their work.
- During the last week, through an anonymous questionnaire with open type questions students were asked to express their opinion on specific aspects of the course [2]. The remaining time after the completion of the

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questionnaire, was dedicated to a free brain storming type discussion commenting on the course experience.

Teachers' Observations

All the students attended the course without any drop-out. This is a rather remarkable outcome for this type of course at the specific Department where the majority of students have a rather negative attitude towards Mathematics, Science and Technology. In previous courses, when the actual practice work (constructions, experimentation, field research …) commenced there was a significant drop-out rate (up to 50%). The remaining students however, all were achieving high marks. High marks, on the upper 25% range, were also achieved in this course.
None of the students had any previous experience with computer programming but they managed quite well using the supplied software with the (intuitive) icon based robot programming language. Quite often, however, the students had to work in the laboratory outside the teaching hours in order to get experience with the programming, a fact that added to their workload significantly. A rather worth noticing observation was that, mostly, students were trying to correct their programming or their assembling without resorting to the manuals (even if they were translated into Greek) but by trial and error techniques. This may be perceived as an indication of increased interest and self-esteem about their abilities to succeed on the subject. If their attempts failed, students were asking advice from the instructors quite often with humorous comments an indication of a friendly teaching environment.
The zero drop-out rate for this course despite the increased students' workload together with the high marks achieved may be perceived as a positive change of the students' attitudes towards Science and Technology. This explanation is further supported by the fact that the teaching proceedings of the course were known widely arousing the curiosity of other people (students, technicians, even outsiders) and many times there were outside observers during the teaching.
Work within the groups was mostly on an equal basis with peer discussions. Even at the 2 groups where there was an evident domination of activities by one of its members, all members were active. Sometimes discussions on what to do were lengthy and lead to disputes, especially during the first weeks. In three groups, the advice to assign responsibilities was taken literally and it seemed to be another source of dispute.
There was no apparent differentiation in task responsibilities between girls and boys. Girls were equally involved in constructions with gears, wheels, etc although this is considered, to some extent at least, a male occupation.
Judging from the results obtained at the end of the 7th, 9th and 11th weeks, students had attained the objectives of the course at least at the group level. They assembled successfully and put into an efficient operation the robot under guidance (end of the 7th week). They all succeeded to construct a robot of their own (with very little guidance) and participate to the contest (end of the 9th week). On the final task requested, namely that of a component of a 'smart home', all groups made a rough analysis of one of the components indicated to them but at the end all groups

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choose to construct a rather simple household item – accessory (automatic light equipment, a toy activated when light or movement was detected, …) [3]. It seems that the time allotted to this activity was not sufficient, one or two more weeks were missing. However the main objective to detect application areas for a robot work and ‘invent’ an implementation was achieved by all groups more or less successfully. Their self esteem towards Science and Technology seems to have increased – all were keen to have their pictures and small videos from the contest published on the web site of the Department.
A ‘by product’ of the course was the experience from the attempt to form a Greek – English dictionary of terms related to robots and robot programming where someone was uploading a term and others (or the same person) were proposing translation and explanation. Links to relevant web sites was also indicated.

Students’ Questionnaire

From the 24 students (8 boys, 16 girls) registered to the course 22 (7 boys, 15 girls) answered questionnaires were received. The percentages boys – girls is the same to the percentages of male – female primary school teachers.
In the following we present the answers we received from the students. The answers are grouped. With the exceptions indicated, answers in the open type questions occurred more than once. Students included, mostly, more than one characteristic in their answers. The answers are still being analysed.

1. **Write briefly your impressions from the course.** Students found the course: interesting (very interesting, most interesting), creative, different from the courses they were used to, a nice experience, useful.
2. **What you think you will remember from this course 5 years from now.** Team work, a pleasant course, the construction, our efforts and time devoted to solve construction – programming problems, the contest, the new ideas (1 answer), nothing (1 answer).
3. **Write up to 2 of the best characteristics of the course.** Teamwork, useful, creative – intelligence – originality (in 18 out of the 22 questionnaires), pleasant, practice work
4. **Write the worst characteristics of the course.** A lot time (10 out of 22), not enough materials, no manuals in Greek, not detailed guidance (4 out of 22), sending reports every week was tiresome, ‘no bad or worst characteristic, it simply requires more time than other courses’ (1 answer).
5. **The guidance was sufficient?** (Yes/No). 22 out of 22 Yes.
6. **Write up to two of the best characteristics of the guidance.** Helpful remarks, always present, patience and Socratic Method, ideas.
7. **Write the worst characteristics of the guidance.** No detailed guidance (we had to complete the task ourselves), no praise on our efforts, left to follow wrong threads.
8. **Was there cooperation in the group?** (Yes/No). 20 Yes – 2 No.

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9. Write up to two of the best characteristic in your group. Effectiveness, enthusiasm, teamwork, mutual assistance, understanding, none (in the 2 that said No to the previous question).
10. **Write the worst characteristics in your group.** None (7 out of the 22), disputes, trying to impose decisions, fixed responsibilities (in one case), many persons (in one case). No reply from one of the students who answered no cooperation while the second mentioned 'no teamwork-disputes-trying to impose decisions-no respect to other opinions'.
11. **What was missing from this course?** More detailed guidance, manuals in Greek, shortage for some materials, a more spacious laboratory, links with other departments teaching this course to exchange ideas (in 1 out of the 22).
12. **What was surplus in this course?** Nothing (in 9 out of the 22), the weekly reports, the demands to improve our artefacts, the theory (in 2 out of the 22).
13. **What issues should also cover this course.** None (in 7 out of the 22), more theory including the context and its role in pedagogy, use of other equipment also, smart home should be a common project for the whole class (in 2 out of the 22), 'Coffee, snacks (!)' (in 1 out of the 22).
14. **Would you recommend this course to your fellow-students?** (Yes/No). 22 Yes, 0 No
15. **Would you choose another course of a similar type?** (Yes/No). 21 Yes, 0 No, 1 no reply.
16. **Do you think you could teach such a subject in school?** (Yes/No). 15 Yes, 7 No
17. **Justify your previous answer.** Yes because: it is not so difficult – it is within the abilities of the students and mine (in 12 of the 15 yes). Yes provided there exist the infrastructure i.e. parts, equipment, computers, laboratory and time (in 3 of the 15 yes), Yes provided that there is adequate preparation and more training (in 1 of the 15 yes). No because: with the current situation in (Greek) schools there is no infrastructure, it is outside the culture, it is very demanding, it is time consuming, it is very difficult, I do not learned the programming.
18. **Add any other relevant comments you think appropriate.** (10 replies)

    - amusing, interesting,
    - I think you should have encouraged us more as it was totally unknown to us,
    - at the beginning I was afraid but I do not regret choosing it – it was hard work but worthy,
    - it was the most amusing course we had – in its negative are your criticism giving the impression you did not value our efforts,
    - I liked the teaching approach, the friendly within the group and with the teachers – in general the nicer and most interesting seminar,
    - it should have only two persons per group,
    - next time more parts (in 3 of the 10 replies),
    - constructive, original. Good to be introduced in schools,
    - constructive and creative for school students who could learn in parallel Science, Mathematics and Information Technology.

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Some Comments

We are still analyzing the test teaching of the course. However from the data already presented we may conclude:

- The course objectives have been met successfully. More specifically:
  - Students became familiar with the concept of robot and its possible uses.
  - Students learned the basic principles of assembling and programming a robot.
  - Students learned to locate areas where a robot may be used and plan appropriately such an implementation.
- Students had the opportunity to develop problem solving skills. This is supported also from the, negative for some students, comments of them, that they missed detailed guidance or that they were left to follow wrong threads.
- On the management and delivery of the course problems were located. Although most of the problems were expected due to the initially planned test teaching on a small scale, they are taken into account. The problem of the limited number of parts has been already solved with the purchase of more kits on a variety of component parts. This will also solve the problem of group size limiting it to two students per group (or three, in exceptional circumstances). However, this will mean an increased teachers' workload and more laboratory work space. The manuals in Greek is also taken into account although we do not think it as serious problem – our observations showed that, even when there was a Greek translation of the manuals, the students preferred a trial and error approach or the teachers' advice. The problem of time needs some more thought. It may mean that students workload for the course is high, as the students have already indicated. However, we did not notice any group working in the Laboratory for more than three hours in excess of the three teaching hours per week. On the assumption that a couple of hours of home study per actual teaching hour is a normal situation for a University course this comment of the students may simply mean that they can do the homework necessary for the course only in the Laboratory [4]. This aspect needs more study as the obvious solution to lend the whole kit to the group may pose administration and logistics problems as is evident from Figure 2. This point is still under study.
- Another point from the students' comments is to find the appropriate balance between the theoretical context and the possible use of educational robotics within the school curricula and the level of detail for the guidance on the actual practice work. Our observations indicate also that a closer connection between the techniques used to assemble the robot they plan and the underlying Science concepts would also help. The demands on the students' artefacts should also be considered to be appropriate to the time available.

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- Students liked the course. They judged it as interesting, creative, different (with a positive meaning) from other courses and as one student explicitly wrote ‘it took us a lot of time but it was worthy’. Even some of the negative aspects they were provoked by the questionnaire’s structure to write may be considered as positive remarks.
- From the data we have so far there is no indication of any differentiation between girls and boys, neither to their achievements or the marks obtained nor to their involvement as ‘programmers’ or constructors’ or otherwise. The groups the students themselves had formed were included all girls or all boys as well as mixed groups with no apparent evidence of sex differentiation.
- The self-esteem of the students towards Science and Technology has increased, for example they feel confident that they could manage a similar teaching in school with themselves as teachers. This was also an explicit objective of the course and may explain, to some extent, the origin of the (negatively perceived) comment ‘no praise on our efforts’.
- Another significant outcome is the students’ comments that this course could be incorporated within the school activities. Even the negative answers (with three exceptions) accept this possibility on the fulfilment of some conditions. Although this cannot be considered as ‘experts’ opinion’ it is noticeable moreover as the students who had attended the course had some school experience through their school practice courses.

In conclusion, we think that the test teaching was successful and we plan to include this course into the undergraduate curriculum on a regular basis.

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References

[1] Anagnostakis S and Michaelides PG, Laboratory of Educational Robotics - An undergraduate course for Primary Education Teacher - Students, HSCI 2006: 3rd International Conference on Hands-on Science, 4 - 9 September, 2006, Braga, Portugal, University of Minho, pp.: 329-335, 2006.

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[2] The questionnaire was formally anonymous but due to the small number of students, an analysis of their answers could reveal the student (naturally, it was not made). However we believe that the students have responded sincerely. This is based to the good teachers - students' relations and mutual confidence developed and the continuous encouragement of the students during the course to express their opinion, which they did, sometimes criticizing openly aspects of the course they considered as negative. Indirect similar evidence is from the fact that on similar other test teaching courses where a more thorough study was made there no indication of any bias was found.

[3] The constructed implementations included: a mechanism counting entries and exits to be used as a Gate counting persons in a place or as a post-box indicating new mail, a solar device following the sun to be used on household solar devices used in Greece to increase their efficiency, a toy producing soap bubbles activated by light or movement to be used with children, automatic irrigation control system to be used in watering flowers on the owners absence, a lighting device activated by detection of sound or movement to be used in corridors, outside of the house areas, etc.

[4] Another possible explanation is that because of the course structure and the active students' involvement, necessary for a course aiming at the development of problem solving skills, the homework has actually to be done in time for the next teaching session, while in other courses this may be left at the end of the semester.

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Vision: An Interdisciplinary View

Catelli F and Libardi H

Introduction

Inside an interdisciplinary, active and hand-on perspective, we present a boarding on the sense of vision. Our activities were developed to use with continued education of teachers and teacher education undergraduate students. This new boarding contemplates necessity to move paradigms in current academic education, once the process of making pedagogical decisions is focused. In the Cartesian-Newtonian paradigm that favoured materialism, rationalism and a fragmented vision of the world and of the sciences [1, 2]. Education/learning cannot be treated just like a transmission of scientific knowledge, in a broken way, through activities whose learning neither stay nor represents a constructed knowledge. Education must stimulate the student to search, going far beyond the four walls of the classroom. The research is necessary. Mainly, because the world changes very quickly and, the people who lives in it, must be prepared for these changes.
The majority of the graduation courses do not prioritize a reflexive and consistent formation. The courses are disarticulated, there are not exchanges between the diverse areas of the knowledge. We must show to the student how the reality around them is and which relations exist between them, the other creatures, the work and the world. It is necessary to show in the classes that there is a net of relations between all the creatures and the environment. Everything becomes related and everything is in connection.
In this direction, this work considers a boarding where it is considered in special the participation of the student, through questions, suggestions, critical, etc., investing in the holistic vision, by which the academic study is carried out analyzing the whole context, practically being impossible to restrict the scope of the questionings to an only one disciplines, physics, for example.

Methodology

To avoid an education were the teacher presents the contents in order to fulfil the program, we emphasize the construction of scientific meaning for the students by adopting interdisciplinary, active and hands-on activities.
This work is part of an extension project that aims at the continued education of teachers of high school in the sciences area. Our work group is teachers of Physics,

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Chemistry, Biology, Mathematics and Computation. Always working in an interdisciplinary, active and hands-on perspective, workshops in science have been created. In Figure 1 we can observe the work group in a workshop with undergraduate students. Taking into account the new curricular guidelines of the Ministry of Education and Culture, some areas of interest were chosen by the high school teachers who participate of the workshops. To this work we are going to present some activities on vision developed for the five senses workshop.

Figure 1. Our work group working interdisciplinarly with undergraduate students

Figure 2. Material used for a model of the eye construction

The high school teachers interacted with playful materials, potentially significant objects that could generate discussions at theoretical, practical and interdisciplinary levels. The texts and the activities were developed based on the methodology of active learning. According to the active learning methodology students will discover new phenomena and concepts on their own, link them to previous knowledge, reflect and generalize to acquire conceptual and significant understanding [3-5].

The Sense Study

Always working inside of a perspective interdisciplinary, active and hands-on, we choose the study of the sense for this work. In special we choose the study of vision. Some equipment had been mounted by the participants during the course, well to the taste of the hands-on philosophy. The sense activities had been presented as in an interdisciplinary workshop offered in continued education of teachers, as in mini courses offered to graduation students.

The Vision

Inside an interdisciplinary study on the five senses, the sense of vision is presented taking in account aspects not only of the physics.

The study of the sense of vision it is initiated with a holistic activity that consists of mounting an eye with a glass globe a lens of increase and a lantern (Figure 2). The

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students in this stage visualize the formation of an image in the posterior part of the glass globe.

The students start to make analogy with the real eye, observing as the image is formed.

In the follow a model of the human eye is presented, in its morphologic aspect, well to the taste of Biology (Figure 3). The model is compared with the previously mounted globe. The anatomical parts are described and its functions are specified. In this point the eye is perceived not only as an optic system with two “lenses”, but also as a detector. The functions of the retina, blind point, optic nerve, pupil, cones and rods are argued.

After the presentation of the morphologic model, some optic illusions are presented. The paper of our brain in the interpretation of what we see is pointing out. It is possible to find diverse websites (some optics illusions can be seen, for example, in [6, 7]) that explore diverse types of “tricks” to deceive our brain (Figure 4). We can explore, for example, the 3 dimensions vision through images with different colours, showing images in a retro projector and distributing special eyeglasses with lenses of two colours. Defects on vision were explored too. In Figure 5, we can see an image with a test of colour-blindness.

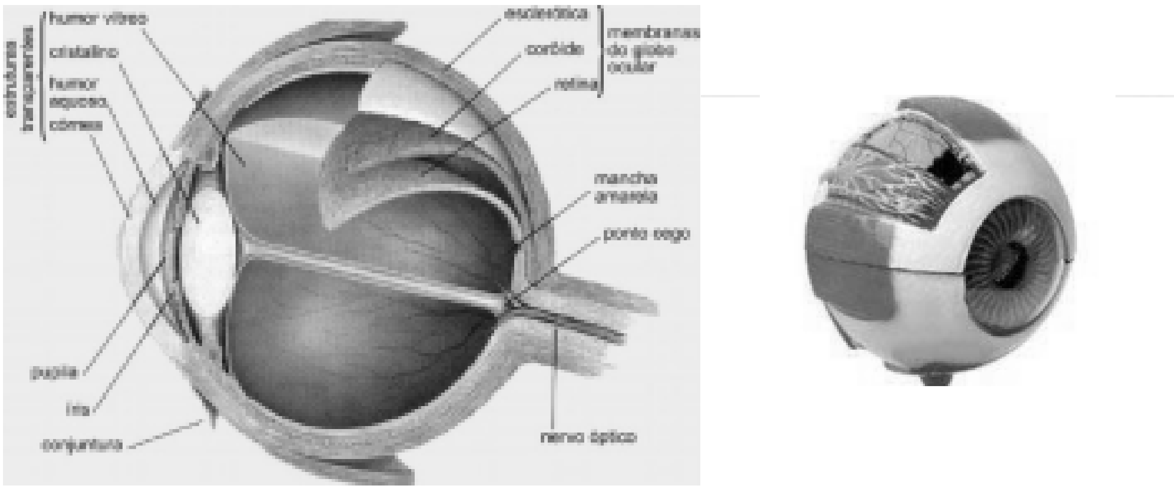

Figure 3. Model of the human eye

In another activity, we made an ocular globe with a sphere of expanded polystyrene, an entrance hole in the place of the iris and another one in the exit, in the retina’s place. In the exit hole the student must place his eye and observe the image formed. We use lenses calculated for a normal vision, hyperaemia and myopia. We can use “corrective glasses” to put in focus the image of a hyperaemic or myopic eye.

In this activity we discuss, in an image’s formation perspective, the focus of the lenses, and the common defects of vision. In Figure 6 we show to some images formed with (a) lens for normal vision, (b) hyperopic vision, (c) position of the

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hyperopic image, moving the plate behind the retina, and (d) image corrected with an adequate lens.

In Figure 7 we can observe the students during the activity. The hyperopic image is being corrected for the lens put in front of the eye and the students can observe it in the posterior part, in the plate placed in the position of the retina. We can see the eye in Figure 8. In this, a second lens is putting in front of the eye to correct hyperaemia.

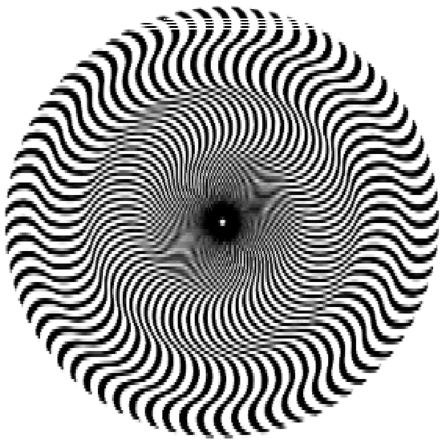

Figure 4. Example of optical illusion. Moving the head, you will have the sensation that the image is moving constantly [6]

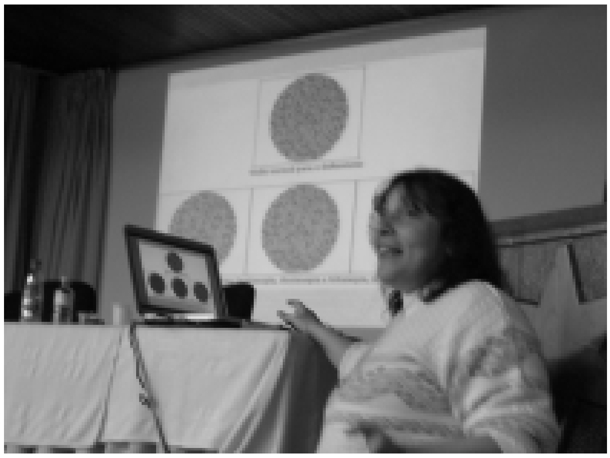

Figure 5. Image with a test of colour-blindness

Coming back again to the morphology of the eye, it is argued the paper of the cones and rods. The Physics reappears, but in a peculiar scene. For example, the perception of the colours for the human eye is investigated, and compared with the perception of some animals.

In the study of colours we use an over head projector with plates to support colour filters and diffraction gratings, as we can see in Figure 9. We can obtain the filters by printing the colours desired in transparencies. The diffraction gratings can be obtained cutting a recordable compact disc without the protection film.

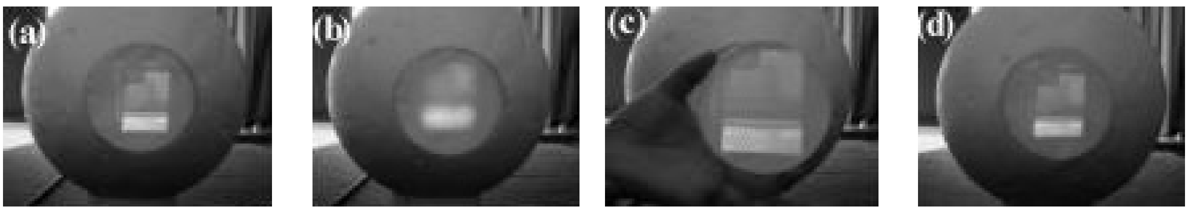

Figure 6. Images formed for (a) the normal eye, (b) hyperopic eye, (c) position of the hyperopic image, behind the retina, and (d) image corrected with an adequate lens

Using this apparatus, that can easily be constructed in classroom of high school, we can explore the electromagnetic spectrum, the function of the colour filters and the

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composition of colours. The detectors of our eyes, rods and cones, are also studied in terms of its sensitivities. The addition of the signal received for each sensor is described. We discuss what happens when one of the sensors presents defect, causing colour-blindness. Also the animals´ vision is presented, comparing it with ours. In Figure 10 we can see the student’s activity using composition of colours.

Figure 7. Students using the eye to observe images and to correct defects of vision with lenses

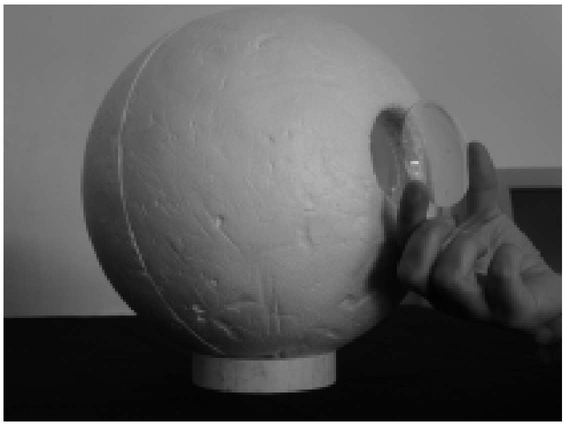

Figure 8. Eye with a correcting lens

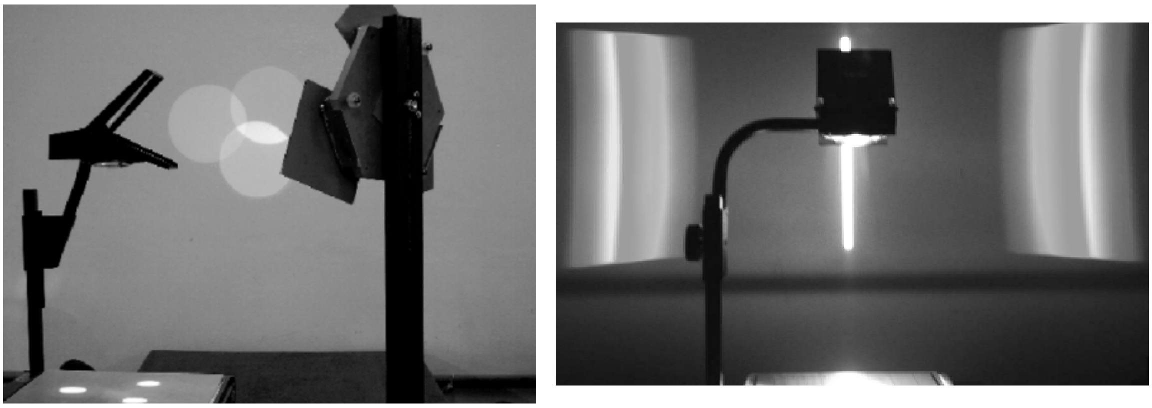

Figure 9. Apparatus used for the study of colours

To explore the electromagnetic spectrum, the students mount a spectrograph, as we can see in Figure 11. Pieces of recordable compact discs without the film mounted in a cardboard box are used. The students mount the box, the slit and the “diffraction grating”.
Some characteristics of the electromagnetic waves are presented. When observing the spectrum obtained with the aid of the over head projector, the students back to analyze the colours. We can see in Figure 12, activities with electromagnetic waves.

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Analysis and Discussion

The philosophy of our work is interdisciplinary, active and hands-on. All proposals activities contemplate this philosophy. When we work with the sense of vision, beyond the physical and biological aspects, we emphasize the existent chemical reactions in the exchanges of information in our biological sensors. The mathematics is present when working with the images and the composition of colours. The use of computer in classroom also is stimulated, with the use of diverse programs in Java.

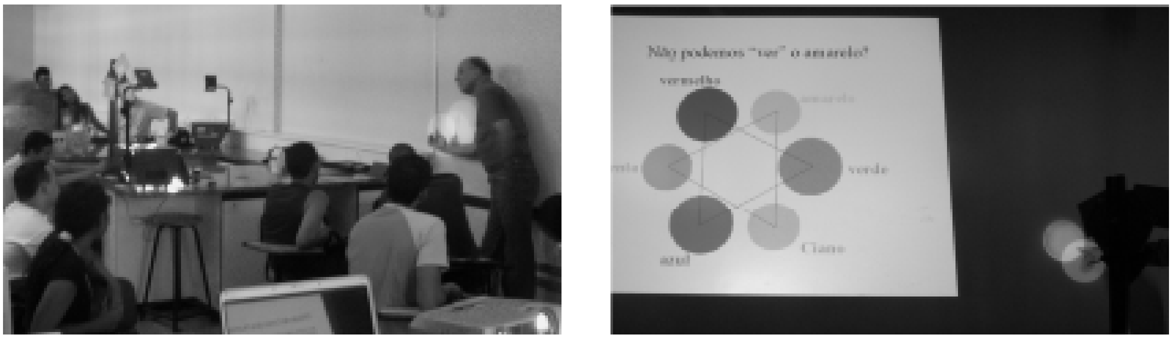

Figure 10. Activity of composition of colours

Figure 11. Activity with the spectrograph

Figure 12. Activity with electromagnetic waves

Conclusion

With ours activities we hope enable students to learn more about science. To obtain success we used an interdisciplinary, active and hands-on methodology. The results observed with the answer of the students were very good. The activities developed for the study of vision is friendly and ease to use. This kind of activities awakes in the high school teacher the creativity and the desire of work in their class in an interdisciplinary, active and hands-on way. In the workshop to continued education of teachers, they presented activities developed in this philosophy.

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References
[1] Kuhn TS, The Structure of Scientific Revolutions, University of Chicago Press: Chicago, 1996.
[2] Capra F, The Tao of Physics, Shambhala: Boulder, 2000.
[3] McGrew R, Saul J and Teague C, Instructor's Manual to Accompany Physics for Scientists and Engineers 5th edition, Serway & Beichner: New York, Harcourt, 2000.
[4] Sokoloff DR and Thornton RK, Using interactive lecture demonstrations to create an active learning environment, Proceedings of International Conference on Undergraduate Physics Education, Redish EF and Rigden JS (Eds.), American Institute of Physics: Maryland, pp.: 1061-1074, 1997.
[5] Ebert-May D, Brewer C and Allred S, Innovation in Large Lectures: Teaching for Active Learning, Bioscience, 47: 601-07, 1997.
[6] http://educar.sc.usp.br/otica/curiosid.htm
[7] http://www.ifi.unicamp.br/~dfigueir/holosite/estereo/estereos.htm

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Informatics in Science and Technology Teaching

Michaelides PG

Introduction

The rapid developments in Science and technology, with their subsequent impacts on society, impose the need of literacy in modern Science and in contemporary Technology, a literacy which should cover the majority, if not all, of the members of Technology Dependent societies. As these advances are new, the contribution from the society (in a Vygotski context) is almost non-existent if not negative (fear of the unknown – alarm for the new'). The only way for a familiarization, moreover for a literacy, on these Science and Technology advances may be achieved only through an effective education and training with innovative approaches to teaching methods, to means, tools, techniques and equipment, to methods of presentation – communication, to the syllabus selection, … . Towards such an effective education and training, the use of New Technologies, especially of Informatics, is a very useful tool. In combination with already existing experience it could produce real breakthroughs in Science and Technology Teaching.

The need for a more effective Science and Technology Teaching has lead to an extensive exploitation of the use of Informatics in Education and Training. It seems that, the initial period of concern on and, in many cases, of negation of the use of Informatics to teaching, has evolved in a dominant trend, mostly unsupported, that the use of Informatics will solve problems of education. In all cases it is overlooked the fact that Informatics, as all technologies, may only enhance the results of a good or a poor instruction design. This dominant trend has resulted in an especially flourishing activity. An ever increasing number of relevant works on the use of Informatics in Science and Technology teaching appears in scientific journal, conferences and symposia with the majority of them appearing also on the web [1].

The development of teaching approaches based on the use of Informatics requires expertise on three fields, namely on the specific subject to be taught, on the teaching techniques specific to the subject and on the use of the appropriate modules, H/W and S/W, of Informatics. This expertise is rather unusual to be encountered in a single person. Consequently, the development of teaching approaches based on Informatics is usually effected through teamwork of experts on the three fields. This teamwork performance is better when the experts in one field are also at least literate on the other fields. This may illustrate the recent trend to include courses on pedagogy (instructional design, teaching approaches …) to

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the undergraduate curricula of technical departments related to Informatics. On the other side, many special S/W applications have been developed facilitating the development of teaching approaches using Informatics by teachers who may be not experts on Informatics. Also, the curricula for the initial education or training of school teachers include now a considerable section on Informatics. In parallel, there is an extensive program of training of teachers on the use of Informatics in Education [2]. As the tools and processes of Informatics fall within the Science and Technology (S&T) sector it is no surprise that initially the vast majority of Informatics in Education contents referred to S&T issues. In this work, information from a previous presentation [3] is used for a short review of past and current uses of Informatics in Science teaching and cases of good practice which are followed by some perspectives and suggestions.

A Brief Review

The first applications of the Technologies of the information and Communication technologies (ICT) in Education were mainly towards the organization and the management of class and of teaching, e.g. preparation of notes, transparencies, etc for teaching, name lists of students with their marks, formation and adaptation of work- and evaluation- sheets, teaching logbooks, etc. An initial significant application was also the adaptive use of general S/W applications as teaching tools. Examples surviving so far are the use of word processors for language spelling and syntax courses, the use of painting or drawing programs in geometry courses, the use of spreadsheets in mathematics, etc. In Science and Technology Teaching (S&Tt), a very significant development to the acquirement of technical dexterities is still the extensive use of spreadsheets to calculate values and functions, to present graphs and tables, to process experimental measurements, etc. The concern that the ‘automation’ of the process of experimental measurements (e.g. calculation of mean values, error estimation, axis and scale choice for graphs, …) deprives students of quantitative feeling (order of magnitude of physical quantities, measurement accuracy and size of experimental errors, etc) may be compensated for by manually carrying out similar exercises focused on the process and rules used (e.g. how to choose appropriate scale and axis in a graph, what are the significant factors in error estimations …). However, when such ‘automatic’ calculations are used in S&Tt, special care should be given to allow the students time for reflection and feedback in order to achieve long term learning.
The use of general purpose S/W has evolved, especially in the area of tertiary education, to the presentation of whole courses in an electronic form. In combination with existing web authoring systems, these may become available through the INTERNET forming a whole sector of electronic books and bookstores. The electronic books very soon were enriched with drawings, pictures, sound, animation, video … and have been evolved to attractive, mostly, multimedia presentations forming the basis for distance e-learning [4], which have the advantage of easy and low cost development with simple means [5]. Combined with their possibility of smooth integration in teaching they can replace other teaching means as the video, the educational TV or the expensive conventional book

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libraries. Examples of electronic bookstores are presented at [6] while the actions of the European Union on e-learning are presented at [7]. May be used as a very effective presentation type teaching, useful in training, initial and continuing, and in education aiming at factual knowledge and data. Combined with their low space requirements (a whole encyclopaedia may be contained in a simple mp3 player) and the easiness of production, adaptation and updating of their content it is no worry their extensive use, especially in Technical Vocational Education and training. Also, most of modern repair workshops (i.e. garages, machinery and other complex equipment repair services) operate using electronic manuals and help.
Although innovative as a teaching mode and useful for factual – technical knowledge or for reference purposes, electronic book and multimedia presentations scarcely may be considered to bring fresh ideas to teaching addressing complex cognitive skills. This may be achieved when they are enriched with links and a modular structure to evolve into hypermedia applications. Hypermedia applications which, if properly designed, may operate (‘run’ or ‘executed’) either locally, on the computer of the user, or on a server being available to anyone connected to the INTERNET, which, due to its increasing promulgation, becomes another powerful teaching mode with S&T education in the lead. The combination of hypermedia with INTERNET presents many new educational possibilities such as:

- on-line immediate help to teachers, a very useful service especially for isolated schools, without the need for transportation of experts,
- the creation of virtual communities of teachers and other educators where specific subjects may be discussed between colleagues living anywhere,
- the use as a worldwide information data bank,
- the use as a powerful teaching mode.

Some concerns (drawbacks) on the use of widely available information and resources at the INTERNET include:

- In simple INTERNET searches a very large number of data is returned resulting in a need of selecting the relevant information (‘where is the knowledge we have lost in information?’ - from ‘The Rock’ by T.S. Eliot, 1934). Even using sophisticated search criteria the returns are still many.
- The validity of information is, in many cases, questionable or biased. Note however that any different viewpoint and any criticism on any issue may appear on the INTERNET without, up to now, any effective ban (censorship) impeding it.
- Possibility of a unilateral presentation of information due to two concurrent causes: a/ the attempts from governments to ban information on the INTERNET on reasons of combating terrorism, pornography or otherwise, and, b/ the intelligence of the search engines trying to guess the more probable type of information wanted. This intelligence although mostly useful, may hide the (rare) type of information actually wanted. It is also prone to malicious exploitation, see for example the ‘Google bombing’.

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An experienced user can minimize or even eliminate these drawbacks leaving all the advantages of hypermedia applications used to education. For Science and Technology education where experimental expertise, modern field advances and examples of good practices are in demand, hypermedias on the INTERNET present good alternatives. Simple such examples may be found in [8].
There are S/W applications addressing specific groups, e.g. educators, or/and specific sectors, e.g. physics, that facilitate the creation of web pages. Most of these applications are of a good quality and low cost while many may be found for free on the INTERNET (just search for 'free software' see also [9]). On the other hand, the technology of web pages has been enriched with active elements that permit the interactive use of hypermedia applications. These elements (e.g. JavaScript©, Java© applets) are lines of computer code that instead of directives on the type and way of presenting information (like e.g. the standard html code) are passed on as commands to the operating system directing it to perform specific tasks, e.g. the execution of another application. Although this possibility has been maliciously exploited for computer cracking, nevertheless it presents many possibilities and, actually, it makes possible high quality teaching approaches, from simple vivid presentations up to complex real self-study teaching applications. The object oriented and modular structure of JavaScript and of Java applets have lead to the creation and availability of specialized modules addressing specific subject areas, e.g. the so called 'physlets', namely Java applets for Physics (see more in [10]). Together with the development of specific Software applications [11] that facilitate the management of providing courses to different groups, they permit realistic distance education e-learning. With these advances in Informatics, an experienced user may develop complete education environments.
Education environment based on Informatics and incorporating the basic principles of constructivism in the form of 'constructions' [12] has been realized in 1967 by the MIT Artificial Intelligence Laboratory with Seymour Papert as a main actor with the Logo© programming environment. Logo, a LISP like programming language, was used, although on an experimental basis, in teaching young pupils aiming to the development of space understanding and movements (with the 'turtle robot') or to the development of complex cognitive skills (with the 'turtle design' on the display of the computer). In simple teaching implementations with Logo none of the school subjects was, in principle, excluded. However the majority of the simple teaching implementations with Logo addressed Mathematics. The structured programming incorporated to Logo with its recursive modules ('routines' and 'subroutines') permitted to complex teaching presentations (including graphics, sound and animations) often with feedback from the user (learner) mainly in the Science and Technology sector, including visualizations of natural phenomena and, sometimes, virtual experiments a trend peaked after Papert published 'Mindstorms' [13] and facilitated by the proliferation of (personal) computers. Complete libraries of routines were developed (check the INTERNET for 'Microworlds') and distributed with specific Logo implementations addressing school subjects, usually from natural sciences. Another following innovation from MIT Media Lab was LEGO-Logo in which computers with the Logo environments were connected to artefacts made by Lego© bricks and including sensors, lights, and motors. With current advances in

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Informatics and microelectronics, this has been evolved having now a computer as one of the Lego (or Lego like) bricks making thus possible the construction of autonomous robots. Courses on 'Educational Robotics' are constantly appearing as a potentially very powerful tool for the Science and Technology teaching. Another advance is the construction of small size sensors and other measuring microelectronic devices with low cost and capability of connection (e.g. through USB port) with computers or with a microcomputer as one of their constituents. The term MicroLab or Microcomputer Based Laboratory (MBL) refers to the use of such devices which permit in a Science experiment or observation the measurement of many quantities concurrently and for long times.

Perspectives

It seems that the trend described previously will continue in an expanding way. More and more teaching approaches will appear either as autonomous applications or on the web addressing broader groups. This Open Distance Learning type of development may answer problems due to the lack of buildings, equipment, expert teachers and other infrastructure observed especially in Science and Technology at all Education levels, a factor that explains partially the increasing appearance of 'Virtual class'. These are classes in which the teacher(s)-student(s) and the student-student communications are done through computer communication in a synchronous (e.g. videoconference or teleconference) or in an asynchronous way in which the information is prepared, studied and exchanged by the virtual class members at their own convenient time [14].
The development of virtual classes The multimedia capabilities offer the possibility of a multitude of presentations of natural phenomena considered difficult and or outside common experience (see examples in [15]) providing thus the possibility of learning at the level (Bloom's taxonomy) of knowledge and facts. The achievement of learning of complex cognitive and psychomotive skills (e.g. experimentation skills or other practical dexterities) and emotional attitudes requires interactivity with the learner, choice of different learning paths depending on the performance and previous achievements of the learner, time for reflection and active learners' participations. These requirements may be achieved by the appropriate incorporation of active and object oriented programming elements to develop simple simulations or more complex virtual reality environments. Simple simulations appear already in increasing numbers on the web with an expanding range in their contents within a Science and Technology teaching context, e.g.:

- Simple calculations of a table of values and graphs referring to physical quantities in natural phenomena. These usually may be repeated on different parameters ('initial conditions') of the choice of the learner e.g. in order to study the importance of the different factors.
- Real time presentation sequel of the evolution of natural phenomena repeatedly and with varying time scales. This permits comparisons and allows time for reflection.

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- Scenario exploitations through the development of representative computer models of natural phenomena. These may be used either to find correlations between observations or to virtual test a scientific theory. This form, initially developed within Science and Technology (see for example the 'Monte Carlo simulations' used in particle physics and in Cosmology) is now used also in Social and Economic sciences e.g. to test an economic theory or to predict the evolution of society characteristics

Virtual reality has been used extensively (but not always effectively) in electronic games and is now entering teaching as education environments with the 'Virtual laboratory' being the most common application (on a more commercial basis electronic representations of known museums 'Virtual museums' have also appeared). In virtual laboratories, the user chooses equipment and devices, arranges them and conducts experiments specifying what quantities is going to process in a virtual computer space within an application simulating the experiment process [16]. Although it remains a simulation representing actual reality, virtual laboratories, if appropriately designed, may become a very effective substitute of actual experimentation [17].

Using special equipment (spectacles, headphones, helmets with sensors …) simulation may be evolved to complete virtual reality situations in which the user (has the feeling that he) lives the intrigues. Although are as yet simulations with multiple pictorial representations, complete virtual reality educational applications will soon appear and, based on past experience, they most probably start from the Science and Technology area.

The advantages of a well designed Virtual Laboratory include:

- Quick familiarization with the experimentation process including the manipulation and presentation of experimental data, with the use of equipment and of the safety rules,
- Reduces the time for preparation and understanding of the basic processes by permitting (virtual) experimentation under different conditions. This especially useful for expensive or for time consuming experiments,
- It reduces the (often high) cost for expensive devices and for operation maintenance, repair and replacement of the equipment.

Virtual Laboratories however do not, in general, advance scientific inquiry skills (unless used in a very specific way) and, as a faithful or not simulation of reality may be not appropriate for small ages where cognitive skills of abstract concepts are still developing (imaging, for example, how a simple electric circuit is represented and how it appears in reality).

Commentary

Informatics in Education will continue to spread out as it provides an affordable and efficient tool. For Science and Technology Teaching, Informatics presents the

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added advantage of facilitating the efficient teaching of issues that are considered difficult either because they are modern, e.g. elements of quantum physics or because they are prone to misunderstandings. Some naïve examples include:

- Simulations for the solar system and of the movements of the Earth in relation to the seasons of the year or the Bohr atomic model. Note that the traditional teaching of the Bohr atomic model is in reference to the solar system (‘the atom is a miniature solar system’) for which however there is no direct observations (it could be taught equally well that ‘the solar system is a magnification of an atom’).
- Pictorial representations of quantum atomic orbitals and comparisons with the simplistic Bohr atomic model.
- Use of Monte Carlo simulations for a visual representations of the thermal motion [18] a subject very prone to misunderstandings. This technique may be evolved to a full and consistent teaching of Heat within a kinetic theory of particles model context. Such approaches may facilitate the transition from the positivist conclusions of classical physics to the probabilistic (statistical) inferences of quantum physics.

It is increasingly accepted that an effective Science and Technology Education may be achieved by an interdisciplinary teaching approach within a constructive context. In this sense, Educational Robotics is especially useful. Pursuing the objective to construct (or assemble) a robot, students may develop complex cognitive and problem solving skills. They are also helped to a better understanding of basic concepts in Physics e.g. through their efforts to chose and manipulate the appropriate sensors or to incorporate movement to the robot. Their creative thinking and scientific interest is excited while they familiarize themselves with modern technology. Such an example of an Educational Robotics course is described in [19].

Epilogue

Although the use of Informatics to improve teaching is very feasible, empirical evidence shows that teachers are reluctant to use but prefer to teach within the lines they were taught as students [21]. They are reluctant to adapt themselves in new situations and prefer their familiar methods [22]. To my opinion this is the main obstacle towards the proliferation of Informatics in teaching for a more effective Science and Technology Education. To bypass this obstacle, the education and training of the teacher, especially of the Science and Technology teacher, should include an extensive use of Informatics with subjects from modern Science [23] preferring teaching approaches that promote a spirit of research and innovation such as a project type approach or the use of self-made apparatus [24] and connecting Science with everyday observations from everyday life [25].

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References and Notes

[1] A simple search with keywords ‘Informatics Education Science Technology’ produced instantly more the 3million pages. The same search with the keywords in Greek produced more than 200 thousand pages [1-Jun-2007].

[2] On a European level see related actions in
http://europa.eu/pol/infso/index_en.htm
http://ec.europa.eu/information_society/index_en.htm.
http://www.cti.gr/epimorfosi/index2.htm
http://www.pi-schools.gr/epim_tpe/

[3] Michaelides PG, New Technologies in the Didactics of Science (in Greek), Proceedings of the 5th Pan-Hellenic Conference on the Didactics of Science and the Application of New Technologies in Education, University of Ioannina, pp.: 15-17, 2007.
http://users.uoi.gr/gtseper/fifth_conf/fifth_praktika.php

[4] The process actually refers to (self) teaching that, hopefully, will induce learning. A better term would be e-teaching (or e-study).

[5] The Software of a medium personal computer with a simple video camera (e.g. a mobile phone) are usually sufficient, on the condition that the user is aware of the capabilities of the software in his-her computer, see more in Plevrakis A, "Creation of Educational Application Systems for Computer Aided Learning ", post-graduate degree dissertation at the Department for Primary Education, University of Crete, Rethimno 1993.

[6] http://books.google.com/books?q=e-learningots=cc12140-_K&sa=X&oi=print&ct=title

[7] http://ec.europa.eu/education/programmes/elearning/index_en.html

[8] http://www.clab.edc.uoc.gr/hsci/, http://aplo.eled.auth.gr/
http://www.clab.edc.uoc.gr/aestit/, http://www.eap.gr/, www.cern.ch, (pages Education), http://www.windows.ucar.edu/windows.html
http://www.uky.edu/Projects/Chemcomics/
http://www.webelements.com/webelements/scholar/index.html

[9] http://www.horde.org/, http://www.apache.org/, http://www.fsf.org/
http://www.gnu.org/

ISBN 978-989-95336-2-2

[10] Wolfgang C and Beloni M, Physlet Physics, Pearson-Prentice Hall, 2004. http://webphysics.davidson.edu/Applets/Applets.htm
http://webphysics.davidson.edu/physlet_resources/
http://www.swgc.mun.ca/physics/physlets.html
http://physics.uwstout.edu/physapplets
[11] http://moodle.org/
[12] Papert S, Situating Construction, Constructionism, Harel I and Papert S (Eds.), Ablex Publishing: Norwood, 1991.
[13] Papert S, Mindstorms: children, computers and powerful ideas, Basic Books: New York, 1980.
Also http://el.media.mit.edu/Logo-foundation/products/books.html#Mindstorms
[14] Communication through the web is often criticized to enhance alienation in times where societies need closer ties between their members. However communication through the web develops new social skills and, if used in parallel or complementary to the face to face communication may improve socializations and common understanding. A search for 'virtual classes in the INTERNET may provide more information.
[15] http://www.arsakeio.gr/inf_links.htm, http://iskp.csd.auth.gr/projects/sep/, http://www.sch.gr/
http://public.web.cern.ch/Public/Welcome
Search the INTERNET for 'Science Teaching'
[16] Virtual laboratories are simulated representations of actual laboratories. In contrast, 'Remote Laboratories' are actual laboratories established in one place with users being able to conduct experiments from another place arranging the experimental equipment and making their observations remotely with the use of computer communications. They might be useful for experiments requiring expensive equipment or posing safety issues, for example radioactive materials.
[17] An example may be found in http://iskp.csd.auth.gr/projects/sep/
[18] Kalkanis G, professor at the University of Athens, private communication.
[19] Anagnostakis S and Michaelides PG, Laboratory of Educational Robotics - An undergraduate course for Primary Education Teacher - Students, in proceedings of HSci 2006 - 3rd International Conference on Hands-on Science, 4 - 9 September, Braga, Portugal, pp.: 329-335, 2006.
http://www.hsci.info/hsci2006/index.html.
[20] Margetousaki A and Michaelides PG, A seminar for Informatics in Schools, Proceedings of Didactics of Informatics, 16-17, University of Thessaly, 2004.
[21] Somekh B, Supporting Information and Communication Technology Innovations in Higher Education, Journal of Information Technology for Teacher Education, 7: 11-33, 1998.
[22] Mumtaz S, Factors affecting teachers' use of information and communications technology: a review of the literature, Journal of Information Technology for Teacher Education, 9: 319-341, 2000.
[23] Michaelides PG and Miltiadis T, On the feasibility to include contemporary Science concepts in the Primary school curricula – a retrospection into two

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case studies, HSci 2006 - 3rd International Conference on Hands-on Science, 4 - 9 September, Braga, Portugal, pp.: 261-266, 2006. http://www.hsci.info/hsci2006/index.html.

[24] Michaelides PG and Miltiadis T, Science Teaching with Self-made Apparatus, 1st International Conference on Hands on Science: Teaching and Learning Science in the XXI Century, 5-9 July 2004, Ljubljana, Slovenia, pp.: 47-52, 2004.

[25] Michaelides PG, Everyday observations in relation to Natural Sciences, in Learning in Mathematics and Science and Educational Technology, University of Cyprus, pp.: 281- 300.

Paper presented at the 4th International Conference on “Hands-on Science. Development Diversity and Inclusion in Science Education",
Açores, Portugal, July 23 27, 2007.

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Safety of the Human Body in Hands-on Science Experiments

Trna J and Trnova E

Safety of the Human Body as an Important Content in Science Education

Every day and safe living is very interesting content used in science education. If we combine everyday and safe living with hands-on experiments, we receive strong source of cognitive motivation [6] and interest of children, students and adults. Students are often not aware of the fact that they are surrounded by science phenomena in their everyday living.
Important information used in science education is the following [7]:

(a) The human organism: Students are acquainted with human body parameters which can be expressed with the aid of quantities, units and laws. Also external conditions are very important for preservation of vital functions of the human organism including health.
(b) Home, entertainment, sports etc: Students can be motivated by explanation of a basis of commonly used domestic equipment such as heat and light sources, means of transport, audiovisual technique, chemical agents, domestic plants and animals etc. Information on economical and ecological behaviour in everyday living attains more and more importance.
(c) Safety risks: Protection against negative extraneous influences on the human organism and information on safe behaviour in transport, at work etc.

For everybody, his human organism is an interesting object. Mainly astonishing information on the human body structure, especially its function, is a strong motivating content, e.g. huge amount of blood pumped by heart, optical illusions etc. can attract everyone's attention.
The main advantage of teaching-learning of the human organism is also a fact that every student's body is constantly at hand, therefore there is no need to obtain special complicate teaching aids.
Currently, measuring quantities are considered to be one of the students´ essential science skills. In science teaching, these skills are often acquired by measuring items that cannot attract neither the interest nor the application attention of

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students, consequently, they are not motivated enough to use these skills. For example, we can give a boring measurement the heat capacity of a metal weight located in a calorimeter. This activity could be replaced by measuring the human body heat capacity in the case of fever. Similarly, it would be appropriate to include learning the principles of human body measuring devices, i.e. blood pressure measurements.

Taking the human body measurement is a very practical skill for prevention and diagnostics of certain diseases or conditions endangering healthy organism functions, i.e. body temperature above normal or high blood pressure. Acquired information and skills can be useful in everyday life as well as in providing first aid, e. g. knowledge of the breath frequency providing artificial respiration.

Connecting the understanding to the human body with the skills and knowledge of surrounding environment could be a way how to reach the educational aims of environmental education. In this area, the important theme is human health and life protection against dangerous extraneous influences and life risks. These safety risks include fast change of atmospheric pressure, rapid change of speed, effects of forces, acoustic fields, meteorological conditions, temperature fluctuations, electric field, magnetic field, ionizing and non-ionizing radiation.

Experiments and measuring the human body parameters must keep following oddities and principles:

- Observation, experiments and taking the human body measurement must be absolutely safe.
- The human body parameters are considered to be personal private information and must be treated as personal data (e.g. body weight).
- Recorded values of quantities of human body appear at limited value intervals (e.g. body temperature).
- Most quantities norms of human body are obtained statistically, that means using the average of measured data collected from many people.
- For measuring we use special and adjusted devices.

The human body anatomy and physiology is an integrated science topic. The human body is a very suitable content for interdisciplinary co-ordination and integration in science education.

Safety of the human body is also useful content for formation of collaboration teaching-learning projects and positive students' cooperation.

Hands-on Experiments and Family Education as Innovative Teaching-Learning Method

Teaching-learning using hands-on experiments are the innovative solution for effective science education, creation of scientific literacy of students and also adults' life-long education. The many-sided use of hands-on experiments is an important psychological and pedagogical research-based innovation in science

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education ([1], [2], [3] etc.). This teaching-learning method is based on cognitive and social constructivism such as psychological keystone.
The important hands-one experiments are experiments with everyday objects. The transparency of phenomenon base observation is supported thanks to the fact that students know these objects from their daily life, so their attention is not taken away from the demonstrated experiment and they can concentrated on it [4]. Undemanding technical realization of hands-on experiments with everyday objects is also an important quality. This brings students a great opportunity to conduct simple experiment by themselves at school as well as at home.
There exist specific target groups which need special educational contents and educational technologies. It especially concerns handicapped people and seniors. Knowledge and skills of the human body and safety risks are needed to be passed not only to students at school but also to all members of the families. We can use "family education" as an appropriate educational method by education of the all family. A base of this educational method is a transfer of knowledge and skills acquired by students at school into families towards adults and small children. Family education by means of school education can bring to families (for parents and grandparents) important information and skills about new technical equipments at home (microwave, mobile phone etc.) and also about risks in everyday living (transport, fire, poison materials etc.).
Family education requires specially prepared teaching-learning materials. Teachers need also new designed teaching methods which include integrated teaching technology for young and adult people. Family education seems to be a challenge for pedagogy research.

Safety of the Human Body in Science Teacher Training

An important task is the good preparation of science teachers in the field of simple experimenting and the use of information from everyday and safe living. Teaching methods of family education have to be involved in teacher training.
The character of science school experimenting results to necessity of acquiring these teachers' experiment skills in three stages [5]:

1. Scientific experiment skill (complex competency to carry out scientific experiments).
2. School experiment skill (complex competency to carry out school experiments).
3. Skill to teach students by experiments (competency to teach students by school experiments).

Creation of these science experiment skills is conditioned by several-year school work experience of the teacher. Therefore acquiring of experiment skill is not possible to acquire alongside pre-gradual teacher training.
For this reason, there is a need to prepare quality courses of school experimenting and insert it into pre-gradual teacher training at universities and particularly into in-service teacher training. Analogously, there is a need to offer enough relevant

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information about science and technology from everyday and safe living to teachers. Present use of ICT allows the creation of e-learning courses and different kinds of databases on the Internet.

Hands-on Experiments on the Human Body and its Safety

Every day and safe living content on the human body can be used in teaching-learning in the form of hands-on experiments. We can arrange strong cognitive students' and their families' motivation by the combination of interesting content and hands-on experimenting.
There is a set of hand-on experiments about the human body with many alternatives. Every alternative is represented by a concrete example of a hands-on experiment and its explanation.

Demonstration of Natural Phenomena by Means of the Human Body

The human body can be used as an effective teaching aid to demonstrate various natural phenomena.

Gravity and blood pressure

The presence of gravity at the Earth's surface can be demonstrated using both hands. Stretch one arm upwards and let the other arm hang freely along the body. After a short time place both arms next to each other and compare their skin coloration. The standing hand is much paler than the hanging one. The discrepancy in skin coloration is caused by the different promoting the blood circulation in both arms thanks to gravitational pulling of circulating blood.

Demonstration of Human Organism Functions

Hand-on experiments using objects from daily life illustrate the function of chosen organs.
A model illustrating the function of the lungs:
The bottle bottom is replaced by a rubber membrane. The rubber inflatable balloons illustrate the lungs function. The rubber membrane deformation effects the changes of air volume in balloons (lungs models). This is simulation of breathing.

Measuring Human Body Parameters

It is possible to measure values of quantities of human body parameters. While taking the body measurement, we apply special measuring devices.

Body Temperature:

Normal body temperature is the temperature of a healthy organism. We measure body temperature in the underarm where the temperature is proximate 36,5^{o}C. In the rectum and in the ear canal this temperature is 37,5^{o}C. If the body temperature is higher than 38,5^{o}C (in the underarm) the organism has a fever. A critical high

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temperature is 42,0 ^{o}C and a critical low temperature is 27,5^{o}C. In these temperatures, the cardiovascular system collapses and the person has a high risk of death. There are many different types of thermometers which are used to measure body temperature. When measuring the body temperature of children it is better to use a digital ear thermometer, which is possible to use while they sleep. An interesting application of body temperature measurement is in the method of the birth control based on the changes of body temperature during the menstrual cycle.

Figure 1. Model of the lungs

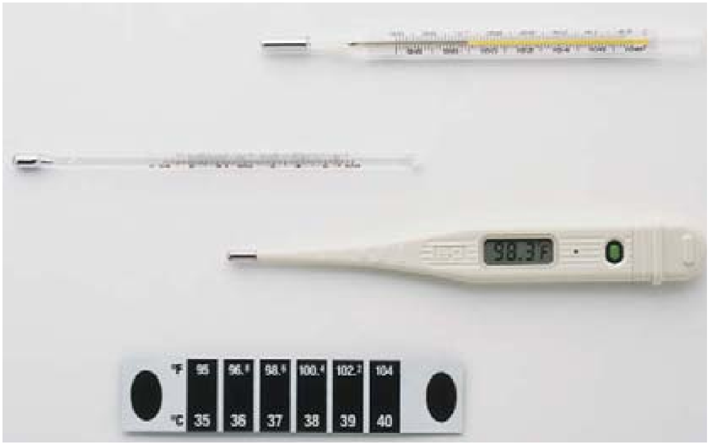

Figure 2. Thermometers

Impacts of Environment on the Human Organism

We can simulate impacts of the environment on the human organism. Hand-on experiments can simulate a function of chosen organs or parts of human body in changing external conditions.

Eardrum during Diving:

Due to the hydrostatic pressure in water, differences in pressure occur in human organism during diving.

(a) Put the test tube with a membrane into a plastic bottle, close the bottle with a cap with valve and overpressure it with a small tyre pump. The rubber membrane buckles. We eliminate the overpressure in the bottle by removing the cap and the membrane straightens back up. This experiment simulates painful squeezing of eardrum during diving.

(b) Fix a thin hermetic plastic wrap onto the test tube tightly. On condition of overpressure as much as necessary, the membrane tears. Similarly to the membrane during the experiment, the eardrum in overpressure caused by water during diving can end up perforated. The water gets to the balanced organ through the ruptured eardrum. The result is sickness, loss of orientation and even drowning.

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Demonstration of the Human Organism at High-Risks

Hand-on experiments can demonstrate the high-risk states for the human organism, which can result in its damage or even death.

Scuba Divers´ Caisson Disease:

Fill approximately a half of a plastic bottle with water. Close the bottle with a cap with valve and overpressure it with a small tyre pump. Shake water and air in the bottle several times intensively and leave it to stand for a while. In a minute, quickly decrease a pressure in the bottle by removing the cap. We can observe a noticeable escaping of gas bubbles in water and later on the bottle side. During diving, air gases dissolve in blood (e.g. at depth of 70 m nitrogen dissolves in blood about 70 times more than above the surface). Rapid loosening of these gases from blood during the diver's fast emergence on the surface is the reason of a gas embolism (so-called Caisson disease), which can cause diver's death.

Simulation of Lifesaving Procedures

Hands-on experiments on the human body support explanation of lifesaving procedures.

Auto-Transfusion:

This experiment proves that blood is influenced by the gravity distribution. If we lift the legs of person lying down the blood gets redistributed into the rest of body, it increases the blood pressure in rest of the body vessels. This blood pressure we can measure. It is used as first aid for people who collapse because of low blood pressure.

Preventative Diagnostics of Human Organism at Risk

With the assistance of hand-on experiments on our body we can diagnose potential health dangers.

Body Mass Index:

Body weight is defined as an essential parameter that helps us to find out the state of health and even predict health complications in the future. The often used parameter for body weight assessing is a body mass index (BMI). It is calculated according to formula:

$$BMI = (\text{body weight in kg}) / (\text{body height in metres})^2$$

A BMI greater than 25 is considered overweight, above 30 obesity (above 40 as morbid obesity) that is valued to be at risk and should be cured. Changes of body weight, especially the fast ones, are regard as an indicator of serious health problems of the human organism.

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Flat Foot:
The diameter of the sole of the foot is measured to diagnose disorders of the foot. The foot structure is very important for the various movement conditions of the body. The most known disorder is flat foot caused by fallen arches. A simple measurement can discover this disorder. Inappropriate footwear is a large contribution to this disorder. That's why the length and width of the foot is important when buying the correct shoes. For the measurement of feet, shoe salesmen use special measuring tools. Measuring procedure:

1. Paint the sole of the foot with oil (ink, paint etc.) and step on suction paper (blotter).
2. Use a ruler to measure widest (w_1) and narrowest part (w_2) of the footprint.
3. Calculate **I** = w_2/ w_1.
4. Evaluate results using the Table 1.

The flat foot diagnosis is a good content example of an effective science family education. We made the research of the effectiveness of family education in 2006. We used the measuring of flat foot described before as the teaching-learning content for our research. We taught 75 students of the fourth grade in primary science lessons. We distributed a questionnaire to their parents after two weeks. All 75 questionnaires we received back. We asked parents of our students to answer the questions:

(1) Do you know a simple method of measuring flat foot? (YES: 68%)
(2) Do you receive this method from your children? (YES: 60%)
(3) Have you measured your foot using this method? (YES: 24%)
(4) Have you found latent flat foot in your family? (YES: 4%)

These results make us sure to input family education into primary science teaching-learning.

I = w_2/ w_1	
normal foot	I = less 0, 45
start to be flat	I= 0, 45
flat foot	I= more 0, 45

Table 1. Result of measuring process

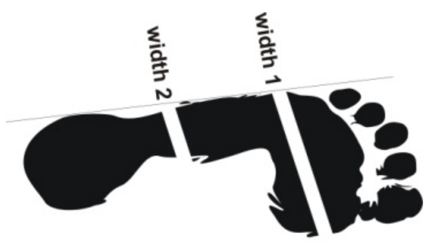

Figure 5. Flat foot

Conclusions
Safety of the human body in hands-on experiments is significant for effective motivational science educational technology. Family education brings to all families

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important information about risks in everyday life (transport, fire, poison materials etc.). The combining of living phenomena on the human body and hands-on science experiments is the source of students' motivation. Hands-on active teaching-learning is the innovative solution for effective science education, creation of scientific literacy of students and also adults' life-long education. The distinctive quality of a hands-on science experiment is the transparency of presentation of science phenomena. A very important task is the good professional preparation of science teachers in the use of these hands-on experiments. The first experiences with use of human body hands-on experiments in teaching-learning science bring good results. Safety of the human body is also suitable content for formation of collaboration projects and positive cooperation.

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References
[1] Haury DL and Rillero P, Perspectives of Hands-On Science Teaching. Columbus, ERIC-CSMEE, 1994.
[2] Janik T, Najvar P, Slavik J and Trna J, Dynamicka povaha ucitelových didaktickych znalosti obsahu: pripadova (video) studie z vyuky fyziky na 2. stupni zakladni skoly, in Janik T, a kol. Pedagogical content knowledge nebo didakticka znalost obsahu?, Paido: Brno, pp.: 99-113, 2007.
[3] Shulman LS, Knowledge and teaching. Foundations of the new Reform. Harvard Educational Review, 57: 1-22, 1987.
[4] Trna J, Motivation and Hands-on Experiments, Porceedings of HSci2005, 2nd International Conference. Hands-on Science. Science in a Changing Education, Rethymno, Greece, Media, University of Crete, pp.: 169-174, 2005.
[5] Trna J, Science Experiment in Science Teacher Training, Proceedings of the International Conference Science and Technology Education in New Millennium, 3rd IOSTE Symposium for Central and East European Countries, PERES Publishers: Prague, pp. 201-206, 2000.
[6] Trna J and Trnova E, Cognitive Motivation in Science Teacher Training, in Science and Technology Education for a Diverse Word, M. Curie-Sklodovska University Press: Lublin, pp.: 491-498, 2006.
[7] Trna J and Trnova E, Everyday Living and Safe Living in Simple Science Experiments, in Science and Technology Education in the Service of Humankind, 12th IOSTE Symposium, Penang, Malaysia, School of Educational Studies, University Science Malaysia, Penang, pp.: 556-561, 2006.

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A Study of Educational Robotics in Elementary Schools

Ribeiro C, Coutinho C, Costa MFM and Rocha M

Introduction

Background and Motivation

Every teacher aims to find new pedagogical tools that motivate the students and that are ultimately effective in the teaching/learning process of a broad set of contents. Frequently, novel educational tools are developed that bring new sheds of hope to teachers, parents and students. Some of them are able to survive in the fierce competition, but most disappear in a short span of time.

The Information and Communication Technologies (ICT), as a whole, have offered lots of promises to education, and some even talk about a huge revolution. Nowadays, it is certain that its impact on the classrooms is still far from these promises, mainly in what regards elementary education. But, it is undeniable that nowadays there are already a number of tools that can be used by teachers and students. The question is shifting from “Will we use ICT in education?” to “How can we use ICT in education to obtain good results?”

In this context, Educational Robotics (ER), the research field that studies the application of Robotics as a pedagogical tool, has been growing in importance in the last few years as an emergent approach to Education. This development has been made possible by the technological advances in ICT and electronics, as well as by the progressive drop of costs.

The pedagogical potential of this new tool makes it suitable for a number of areas such as Mathematics, Physical Sciences and Technological Education. The results obtained with these tools have reported a lot of enthusiasm from the actors of the teaching/ learning process: students, teachers and parents. But if this enthusiasm is undeniable, lots of questions remain to be answered, in order to obtain a systematic and unbiased evaluation of this tool.

In fact, the use of Robotics in pedagogical tools has not been progressing in a homogeneous way, clearly lacking a systematic strategy to adopt this tool in the national curricula at the different levels. A large number of reasons can be identified to justify this fact, starting with the lack of adequate formation to teachers and ending with the lack of pedagogical material that can be used in the classrooms by teachers and students.

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Many of the unanswered questions about ER are no doubt due to the fact that the field is still in its infancy and will be solved with its natural evolution. In this process, it is important that the sciences of Education fulfil their role and conduct studies that can answer questions such as:

- The students learn with Robotics?
- In what way(s) do the students learn and how does this learning differs from other pedagogical tools?
- Who has more to gain from this tool?
- Which skills can be learned and what contents can be taught using ER?
- What individual characteristics of the students (e.g. gender, technological fluency) are important to constrain their performance in ER activities?

It is, undoubtedly, a huge task to answer all these questions and an even greater task to really integrate ER in the educational systems. But the future of this tool will depend of the successful compliance of this task and the results that are obtained. Those will tell if this is one more hope that vanished in the air …

Aims of the Work

The main question approached by this work is the following:
"Is Robotics an appropriate tool to allow elementary school students to acquire skills important in their instruction level?"
This question can be segmented into sub-questions, namely:

- Do Robotics activities motivate elementary school students to learn?
- Is the usage of Robotics kits that allow the construction and programming of robots adequate to elementary school education?
- What contents of elementary school can be approached using robotics bases activities?
- Are Robotics activities able to promote the acquisition of skills in elementary school education, and if that is true, which?

Educational Robotics

In the last decades, in several places in the world, a number of experiments with the use of Robotics in educational activities have been conducted. These have focused mainly on university education, although a number of these experiments have also been conducted in secondary and elementary levels. The introduction of Robotics in the school curricula can be achieved by simply inserting it has one more subject to teach/ learn, in a traditional view of this process [19]. This is the practice of some university degrees, where Robotics is explained at a technical level, focusing on electronics, automation or programming.
However, in this work, another view will be followed, where Educational Robotics (ER) will be approached as a broad educational tool, used in several levels of

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education, as a way to approach a number of subjects, under a constructivist view of the learning/teaching process.

Lego Mindstorms Platform

In 1998, a cooperation effort from MIT Media Lab and Lego Company gave rise to the creation of first Lego Mindstorms robotics kit that was based on the RCX controller. The main components will be briefly described next, once this was the platform used in this study:

- the RCX - It is the control unit (the brain) of the robot, possessing a microcontroller and internal RAM memory. It can execute programs that are loaded in its internal memory, being also able to interact with the environment through a set of sensors and actuators (Figure 1). The I/O interfaces allow the RCX to be connected to three input sensors and to three actuators (typically motors). It also has a LCD screen that transmits information to the user (e.g. the battery status or the selected program) and a speaker to emit sounds.

Figure 1. Lego Mindstorms RCX and its interfaces

- sensors – the sensors allow the collection of information from the environment and its transmission to the RCX. The basic kits have touch sensors that can detect obstacles in the neighbourhood of the robot (essentially a switch that is on when it is pressed) and light sensors that can measure the intensity of light.

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- motors – these are the actuators that are included in the basic kits. These are rotating motors that can be activated with several levels of tension, therefore varying the velocity of their movement.
- construction pieces – all kits have hundred of Lego building pieces that allow the construction of wide range o distinct robots. These include lots of technical pieces including several types of wheels, wheel rims, axes, pulleys, levers, etc.
- programming tools – there are several interfaces to program these kits. In this work, the option was to use Robolab, developed by National Instruments and Tufts University. This application is based on iconic programming and has different complexity levels, allowing the natural evolution of its users. With the development of this application the aim was to create an environment accessible to children and adults, but that would not impair the full potential of the equipments [14].

State of the Art of Educational Robotics

In this section, the purpose is to make a non exhaustive overview of the some projects and initiatives that were developed in the field of ER. In this field, the competitions have gained a special role, being the most participated activities in ER once they exert a special fascination over students, teachers and parents. In this context, the following can be referred:

- First Lego League (FLL): It is a competition created in 1992 by a partnership between FIRST and Lego that involves students with ages in the range from 9 to 16 years. In the 2006 edition, more than 60000 children were involved from 32 countries. In each edition, the competition has a different theme (in 2006 it was Nanotechnology and in 2007 it will be Energy Resources) and a number of challenges are proposed involving construction and programming of Lego robots. The teams have a period to train and then meet in regional, national and world-wide competitions.
- RoboCup Junior: This competition is incorporated in the RoboCup project, where the purpose is to organize several competitions of robotic soccer, with several types of robots. Since 1999, a partnership was made with Lego, enabling competitions of robots programmed by children, in a project named RoboCup Jr [8]. In this competition, teams of two robots compete playing soccer among each other. Other competitions have been created within RoboCup Jr, namely the rescue and dance events, therefore making the universe of events more diverse and also being more attractive to the participation of girls.

But, competitions are not the only activities in ER. In fact, numerous schools and other institutions all over the world numerous activities have been developed. These have been mainly developed as extra-curricular activities and the inclusion of ER in national curricula is still not quite developed. Some interesting works can be summarized in the following:

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- Bers and Urrea [2] describe a workshop promoted in Argentina in 1998 where 4^{th} and 5^{th} grade students, accompanied by their parents, spent two weeks involved in robotics projects. Each team selected a project, collected the necessary materials, built and programmed the robots and prepared a presentation for the other teams. Both parents and children worked in the project in full time (8 hours a day and 5 days per week) for the two weeks.
- In Tufts University, a number of ER projects have been conducted. Bers et al [1] describe a work made by pre-service teachers, working with K-2 children. The work implied the implementation of some constructionist environments and its evaluation. The projects developed with the students included the exploration of the concept of metamorphosis (with 3 year students), the concept of balance by building cranes (with 4 year students), the notion of life cycle (with 5 year students) and the construction of a robot able to protect some planted seeds (with 1^{st} grade students).
- In the same institution, Hacker [5] implemented an extra-curricular workshop with children from the 3^{rd} to the 6^{th} grades. In a first stage, the students learnt the basics of robotics, and in a later stage they developed their own projects, building and programming the robots. These projects were presented to the parents and other members of the community.

Pedagogical Foundations of Educational Robotics

The pedagogical foundations of ER are based on the work of Seymour Papert [13] and the ideas proposed by the constructionism. This is based on the constructivist theories and can be considered an approach to the learning/ teaching process based on constructivism.

The constructionism is based on the idea that human beings learn better when they are involved in planning and building artefacts that are significant to them and they share this with the community. The process of building the object is accompanied by the internal construction of the knowledge about the process.

The innovation, regarding constructivism is cantered on the added value given to the physical objects as a support to mental representations. The computational environments and Robotics make powerful tools to implement these ideas [16].

The origins of the constructionism can be found in the group leaded by Papert in the MIT during the 60s that became well known with the work on the LOGO language. This group built a shared vision of education that was based on the following main ideas [1]:

- Learning by designing – students learn by designing meaningful projects. Resnick [15] suggested that the interactions of children with technology should be more like finger painting than watching TV. In fact, computers and technology in general, can complement existing practise and extend these experiences to “learn by designing” [6]. This approach involves the students in learning through the application of concepts, skills and strategies to solving relevant real world problems that

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have a meaning and relevance to student. In this process, students are involved in problem solving, in decision making and in a process of collaboration [18]. The activities of ER fit perfectly in the previous description, since in this type of activities students learn by designing and building robots, solving problems created by a project and its underlying aims, where a number of obstacles created by the real world have to be overcome.

- Using concrete objects – In the elementary education there is a tradition of using manipulated materials (e.g. Cuisenaire bars). ER makes an interesting opportunity to follow this trend, allowing the students to design and create interactive objects. These work with concepts from Engineering, such as wheels, motors, sensors, pulleys or levers. They are also encouraged to integrate artistic materials to make their projects more aesthetically more pleasant.
- Powerful ideas – this term is used to denote a set of intellectual tools that when used with competence are really “powerful” in the sense that they allow novel ways of thinking not only about a problem, but also about the overall reasoning process. There is a consensus about the support to give children in the process developing new ideas by active experimentation and interaction with the surrounding environment. Is this process, powerful ideas come up and should be encouraged by the teachers [1].
- Self reflection – Self reflection has a prominent role in constructionism, allowing the author of the learning process to reflect about it in a critical way. In this context, documentation has a major importance as a basis to the analysis of this process and its adjustment. In ER, the documentation of the projects is a common practice and it is also a tradition to show the results of the projects to the community. Indeed, competitions are the more extreme example of this.

Potentialities of ER in the Reaching/Learning Process

A number of potentialities are normally attributed to ER in the teaching/ learning process. A number of them are briefly discussed here.

- Motivation and enthusiasm by the students: this is a common feature mentioned by most researchers that have conducted studies in the field. Indeed, the enthusiasm of all the participants (teachers, parents, students) is a constant in the studies in ER. Portsmore et al [14] even report students that were always ready to work during breaks and other spare time. It is also reported by some researchers [18] that students that are normally inattentive in daily activities show a special motivation in robotics. Given these reports it is not surprising to find that ER is usually a good solution to motivate students in “difficult” subjects such as Mathematics and Sciences, where good results have been reported [11].

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- Multi-disciplinarity – Robotics is clearly a multidisciplinary field involving a set of disciplines like Physics, Mathematics, Computing or Electronics. The activities in ER integrate a number of subjects and skills, from areas such as Mathematics and Sciences, but also Arts and Languages.
- Problem solving – When involved in ER activities the students (and of course also the teachers) are faced with numerous problems, that originate from the obstacles that have to be overcome to reach the goals implied by the aim of the project under development. The fact that these problems arise from the real world makes them very different from the "artificial" problems solved in the classrooms. Indeed, these real world problems can be difficult or impossible to solve, require the application of other techniques to be solved (e.g. trial and error procedures) and sometimes the solutions are a best effort and not a "perfect" solution.
- Imagination and creativity – the idea of "novelty" is normally connected with imagination, and those are related to the processes of problem solving. The processes of building and programming robots require a process of creativity, inviting the students to innovate in the process of problem solving.
- Logical and abstract reasoning – The process of building a robot implies the capacity of planning and designing it in order to be able to work well under a given environment and accomplish a number of tasks. This implies a process of modelling the robot and the environment in an abstract way, in order to predict its behaviour. Furthermore, the observation of errors implies the ability to reason about alternative scenarios and address concepts such as robustness. On the other hand, the programming of robots is conducted using a symbolic visual language, where the student needs to be able to map a set of symbols into the robot's physical behaviour and predict the behaviour of a given program or sequence of instructions.

Methodology of the Study

In this section, a description of the study that was conducted is performed, by characterizing the nature of the study, the subjects that were involved, the surrounding community, the stages of the study and the instruments for data collection.

Nature of the Study

The study conducted in this work was of a qualitative nature, under an interpretative and subjective perspective of educational research. According to Bogdan and Bilken [3] the qualitative research has as its main features the natural background, where the researcher becomes the main agent involved in data collection. Therefore, the data collected are descriptive, typically words and pictures.

Qualitative research focuses on the processes and less on the results or final products. Data analysis is performed in an inductive way. This type of research is not limited to analyzing behaviours but is mostly worried with the meaning that the subjects give to their actions and experiences, as well as with others.

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Merriam [9] emphasizes that in qualitative research the subjects are not treated as numbers, but are analyzed in their natural environments. Using descriptive data allows us to better capture some behaviour, attitudes and opinions, enhancing richer and more significant conclusions. On the other side, they have a natural limitation in the lack of generalization.
Ludke and André [7] identified several distinct forms of qualitative research. One the main approaches is the case study, the option followed in this work. This approach is characterized by the following main features:

- The aim is to discover novel elements and issues that are important to research that were not considered initially;
- Emphasis is given to the context where the study takes place, and to its importance on the final outcome;
- They characterize reality in a more complete and deep way;
- They use a more diverse set of information sources;
- They seek to represent the distinct perspectives in any situation;
- The language used is more accessible when compared with other methods of educational research.

The option to use this type of study in this work was, on one hand, the natural result of the objectives of the study and of the constructivist view that underpins this investigation. On the other hand, the resources available also limited the options available. Therefore, the main objective was to understand the phenomena related to ER, focusing on the processes that allow the students to acquire new skills.

Description of the Study

The study described in this text involved the development of a complete Robotics project, using Lego Mindstorms kits and involving a set of elementary school students (3rd and 4th grades). The project was implemented within a club of extra-curricular activities, organized by the parents association, during 5 weeks in the months of June and July 2006.
The robotics kits were partly gathered from a project leaded by the University of Minho that involved the Agrupamento André Soares, a group of schools that includes the elementary school where the study was conducted. Some of the kits were kindly lent by some members of the ER community from Minho, which is a quite dynamic group of teachers, parents and students. The study had a total duration of 30 hours, divided by 15 sessions of around 2 hours.
The main idea of this project was to dramatize a Portuguese popular tale: “Carochinha”. In this story, the famous lead character “Carochinha” is cleaning her house and finds a coin. She decides it is time to get married and announces her decision to the world, seeking a suitable candidate. A number of potential grooms appear, namely the cat, the dog and the ox but none of them is chosen by the demanding bride. Finally, the mouse comes and conquers the lady’s heart. But, he is quite gluttonous and ends up drowning on the pot where the wedding lunch was being cooked.

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The project involved the dramatization of a simplified version of this story, where each student was responsible for a character that was represented by a robot. The tasks of the project involved learning the basic of the Lego Mindstorms kits, how to build and program the robots for the project tasks, and also to design and build the scenario where the play took place.
The objective was to create a project that would be attractive to the students enhancing their motivation in a season where the competition was huge coming from outdoor activities such as the swimming pool. One important aim was to create a “show” that could be presented to the overall community.
The activities were organized in the following stages:

- Preparation: devoted to learning the basic concepts of Robotics and Lego Mindstorms. This was organized into three steps: first contact of the students with Robotics (1 hour); learning to build Lego robots (4 hours) and learning how to program Lego robots with Robolab (5 hours). These sessions included solving a number of exercises organized by increasing complexity in a script [17].
- Dramatization of the play “Carochinha”, organized into four main steps: first experiments in programming the characters (4 hours); rebuilding the robots for enhanced robustness (2 hours); programming the definitive versions of the characters (4 hours); integration of the wardrobe and final rehearsal (3 hours). The first programming experiences were conducted on the robots built in the first stage and in a preliminary set. Then, robots were rebuilt to avoid some problems (such as wheels that came out) and a new scenario was built, taking into account the results from these first experiences. Finally, the programming was fine tuned to this new set and all components were thoroughly tested in a final rehearsal.
- Presentation of the project to the community: firstly, presenting to the ATL where the project was developed and then a participation in the Science Fair and Robotics festival of the Hands-on Science 2006 Conference. These events were of extreme importance to the students that were extremely motivated and were quite satisfied with the positive reception of their work. The publication of two news in local newspapers gave them an extra motivation and reward to the participants.

Characterization of the Individuals and Community

The study was conducted in a Robotics club that was integrated in a summer program organized by the parents association of an elementary school, situated in the centre of Braga, the capital of Minho in the north of Portugal.
The overall program had about 40 students and 3 elementary school teachers. Only 5 of the students were directly involved in the project, but most of the others were involved by helping in the construction of the set, the wardrobe and the characterization of the characters (the cat, the mouse, the ox, etc). There was also an interesting cooperation from the parents of all the students. The community of this school can be socio-economically characterized as middle/ upper class with an

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urban prevalence.
The students in the Robotics club were from the 3rd (3 students) and 4th grades (2 students). Those were average students in Mathematics, Portuguese Language and Science subjects. They had a good background in Informatics, since they were involved in the Informatics club from the school. There were 4 boys and only 1 girl involved in the project.

Instruments for Data Collection

In the research, a number of instruments were used to collect data that are typical of qualitative research. These were all designed by the authors.
The main instrument was the direct observation. In the study the first author was also the participant researcher who did the observations. Bogdan and Biklen [3] suggest that this form of observation allows an increased approximation of the researcher to the participants and consequently a better evaluation of the meaning that the students give to their experiments and also of the context of the investigation.
Some of the advantages of this type of study are the fact that the researcher can select, register and analyze only the most relevant occurrences and develops an informal and intimate relationship with the participants (Bailey, cited by [4]).
In this study, the researcher was also the teacher and coordinator of all the activities. It is a complex role, but it also allowed an atmosphere of more complicity.
Furthermore, the sessions were all filmed on video for posterior observation. This allowed the researcher to carefully study all the sessions, capturing some details that its involvement in the activities impaired during the sessions and therefore improving the reliability of the study [4].
Both the direct observations and video visioning were written down in reports of each session that captured all the relevant actions, behaviours, reactions, attitudes and dialogues of the subjects.
Other important instruments were the questionnaires and interviews conducted both in the beginning and end of the project. The first questionnaire, answered by all the students previously to the study, had as an objective to determine the previous ideas and attitudes of the students towards the field of Robotics. So the students were asked to define robot and Robotics, to tell how a robot could be built and programmed and which tasks it could perform.
The final questionnaire had the aim to evaluate how these ideas evolved during the project. In this case, the questionnaire was performed orally. So the students were able to give longer replies and to explain clearly their opinions about the study. The set of questions was predefined but the researcher could follow up on some of the replies and get deeper insights on some issues.
Finally, documents that were produced by the students were also used in the study, mainly the programs developed in Robolab. These were all kept, maintaining all versions of the programs for every student. In this way, the problem solving strategy of each student could be better understood and the evolution of the students could be studied in detail.

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Analysis and Discussion of the Results

Categories of Analysis

A number of analysis categories were taken into account in the evaluation of the study, with a close relationship to the data collection instruments.
The direct and video observation allowed the researchers to analyze features such as:

- students' attitudes and behaviour: persistence, discipline, enthusiasm, commitment;
- quality of the students' work: organization, fulfilment of the tasks;
- skills: programming and building the robots, Mathematical skills;
- understanding the way students think and solve problems.

On the other hand, the interviews and questionnaires were most useful in:

- analyzing the students perceptions and attitudes towards the project, the tasks and Robotics in general;
- understanding the way students think and solve problems;
- evaluating the students level of enthusiasm and motivation.

Finally, the documents produced by the students allowed:

- understanding the way each students reasoned about the problems and found a solution;
- study the evolution of each student regarding programming skills.

Evolution of the Students' Behaviour

Since this was a qualitative study, a main concern was to describe in detail the attitudes and behaviours of the subjects involved [3]. The complete details of this project can be found in Ribeiro [17] and a brief description is given next.
In the beginning of the project, there was a lot of curiosity and enthusiasm. Everyone wanted to look and touch the robots and the students were anxious to start learning how to build and program them.
The sessions devoted to building the robot were quite enthusiastic and the need to build robust robots was becoming more and more clear.
The transition to programming was quite smooth. The first exercises in the script went very rapidly. As the problems became more complex, some students started to feel difficulties. Trial and error strategies became more common, since the logical reasoning was getting more difficult.
The start of the development of the dramatization increased the levels of motivation. The first signs of difficulty were easily overcome. But the most difficult tasks were still ahead.
The first experiments made clear that the first constructions were not perfect and the programming in the first scenario was difficult. The reconstruction of the robots

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to make them more robust was a success. A new stage was built with routes for each robot that were more adapted to the characteristics of the robots.
The final rehearsal helped to correct some last minute problems. The integration of the wardrobes made the robots more difficult to maintain the balance. Some adjustments both to the wardrobe and to the programming were made.
And everything was ready. The first to see the show were the colleagues in the summer program. And most of them were amazed with something quite different from what they were used. Then, the team conquered the community of robotics and the attendants of Hands-on Science 2006 Conference.

Analysis of Students' Interviews

The conceptions of the students about Robotics in the beginning of the project were rapidly changed by the work developed. They realized the difficulty of the building and programming tasks, even to accomplish simple aims. Some of the student referred the use of Mathematical concepts in these tasks. In the end, all students were quite happy with the results and eager to continue their work on ER in the future.

Skills

During the project a number of skills, identified by the Portuguese national curriculum for the 3rd and 4th grades were approached.
In Mathematics, arithmetical operations are heavily worked in several programming tasks, by calculating times, velocities, distances, etc. The ability to estimate results of operations is quite important, since in Robotics there are always errors and every calculation is approximate.
Geometry was another important area specially in building the robots, were geometrical constructions must be planned and executed, in order that a given aim is achieved. Skills related to visual perception are quite important. The ability to work with spatial routes and program the robots to follow them was essential.
Problem solving was another important area. ER projects create lots of real world problems, where solutions need to be developed and refined frequently using trial and error procedures.
In the subject of Natural Sciences, this project allowed a better understanding of the scientific methods in action. Furthermore, lots of important Physics concepts were pinpointed, namely velocity, acceleration, strength, transmission of motion, and also the concept of luminosity.
The contributions in Technology Education are quite obvious. An improvement of skills related to ICT was certainly achieved, but most importantly the experiment dealt with basic concepts of Engineering education, such as building spatial artefacts, programming, modelling and simulation, as well as dealing with noise, errors and unpredictable and stochastic situations.
The particular nature of this project gave a special attention to artistic expressions. In fact, dramatic expression is quite present in the aim of the project, music is also used taking advantage on the possibility of playing and composing music in Lego

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Mindstorms and plastic arts were heavily used in the sets, puppets and wardrobes. Finally, the Portuguese language skills were also used in the text of the play.

Conclusions and Further Work

Main Contributions of the Work

The work described in this text is one the first (at least to the author's knowledge) that investigates with some detail the applicability of Robotics activities in the context of elementary education. This makes one of its main contributions to the ER field, thus attempting a reply to the main question approached by the study (cf. section 1.2).

In this regard, this work gives an affirmative reply to the question: "Are ER activities suitable to elementary education?"

In fact, the students were quite able of building and programming Lego Mindstorms robots and, furthermore, they were even able to plan and implement a project where the final aim was to create a show where a popular story was dramatized.

All these tasks were achieved with merit and acclamation from all that had the opportunity to see the final result.

One important issue to accentuate is the broad set of skills, in all areas identified by the national curricula. In fact, skills related to Mathematics, Sciences, Technology, Language, Arts, Drama and Music were identified.

Conclusions

When, in a September evening, the team that had just presented the "RobôCarochinha" project in the Hands-on Science Robotics Festival was leaving the premises there was an enormous emotion and joy in all of us, students, teachers and also parents that joined us for the presentation.

The reception of our work from a community with know-how in ER was excellent. The students showed a continuous enthusiasm and a striking group spirit. And they kept saying they wanted to participate in more robotics activities.

It is obvious that none of these emotions are facts that can be used in a rigorous study of ER. Yet, these feelings are a confirmation of some results presented in literature by other ER studies that describe similar attitudes, perceptions and behaviours.

And not all conclusions are so subjective. It is a fact that it was possible to convince 5 elementary school students to voluntarily spend 5 weeks of their summer holidays working on a Robotics project. The persistence they have shown and the results obtained are a clear answer to the first of the sub-questions referred on section 1.2.

In fact, in activities that approach ICT in Education the students show a high degree of motivation in the beginning of the activities. However, as the study develops the levels of motivation typically subside. That was not the case with this work, where although the duration of the study was more than 1 month, the persistence was the dominant note.

The final results of the project, even in technical terms, surprised many of the "experts" in ER, especially given the fact that the authors were quite young (even

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younger than the 10 years recommended by the boxes of the Lego Mindstorms kits).
The success of this experience has opened the way to new experiences of this kind. This makes a different way to work with Robotics that attracts both genders equally and does not have some of the disadvantages of the ER competitions. It is also richer and more attractive than dance competitions, since it demands a more diverse set of skills from the students.
One of the main claims of this work is that it was really multidisciplinary, helping to develop skills in all major areas of the elementary school curricula.
Finally, in terms of pedagogical analysis, this work confirmed in our view, some of the epithets normally attributed to the constructionist practices. In fact, students learnt to build and construct robots, reaching a pre-defined goal and clearly improving their skills along the project.
All this was achieved through a learning process based on solving real problems in a meaningful context. It was clear that these activities meant a lot to the students and they wanted to show their work to the community and were willing to discuss every detail of the project and the best form of solving their problems.

Further Work

Given the innovative nature of the kind of ER activities presented in this work, a lot remains to be done to further validate this approach. So, in the near future the authors hope to be able to implement other projects that enable to further validate this approach in other scenarios.
A lot of work also remains to be done regarding the implementation of ER in elementary schools, namely in what regards the development of materials that teachers in this level can use in their classrooms.
The authors believe that if well designed materials are developed and suitable formation is provided a large number of teachers would welcome the implementation of ER activities in their classrooms.
These materials can focus on well defined skills and contents of the curricula, or they can be developed with a more multidisciplinary nature complementing other curricular activities. A long way is still ahead in this regard and the authors expect to be actively involved in these tasks.

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References

[1] Bers M, Ponte I, Juelich C, Viera A and Schenker J, Teachers as Designers: Integrating Robotics in Early Childhood Education. Information Technology in Childhood Education Annual, 123-145, 2002.
[2] Bers M and Urrea C, Technological prayers: Parents and children working with robotics and values, in Druin A and Hendler J (Eds.), Robots for kids: Exploring new technologies for learning experiences, Morgan Kaufman: New York, pp.: 194-217, 2000.
[3] Bogdan R and Biklen S, Investigação Qualitativa em Educação. Colecção Ciências da Educação, Porto Editora: Porto, 1994.
[4] Cohen L and Manion L, Métodos de Investigatión Educativa, Ed. La Muralla, SA: Madrid, 1990.
[5] Hacker L, Robotics in Education: ROBOLAB and robotic technology as tools for learning science and engineering, Thesis, Dep. Child Development, Tufts University, 2003.
[6] Kolodner J, Crismond C, Gray J, Holbrook J and Puntambekar S, Learning by design from theory to practice, Proceedings of the International Learning Conference of the Learning Sciences, Association for the Advancement of Computing in Education, pp.:16-22, 1998.
[7] Ludke M and André M, Pesquisa em Educação: Abordagens Qualitativas, Editora Pedagógica e Universitária Ltda: São Paulo, 1986.
[8] Lund HH and Pagliarini L, Robot Soccer with Lego Mindstorms, in Asada M and Kitano H, Eds., RoboCup-98: Robot Soccer World Cup II, LNAI 1604, Springer Verlag: Heidelberg, 1999.
[9] Merriam S, Case study research in education: A qualitative approach, Jossey-Bass: San Francisco, 1998.
[10] Ministério da Educação, Departamento da Educação Básica
[11] Nagchaudhuri A, Singh G, Kaur M and George S, Lego Robotics products Boost Student Creativity in Pre-college Programs at UMES, Proceedings of the 32nd ASEE/IEEE Frontiers in Education Conference – session S4D, 2002.
[12] Pacheco JA, O Pensamento e a Acção do Professor em Formação. Dissertação de Doutoramento, Instituto de Educação e Psicologia da Universidade do Minho: Braga, 1993.
[13] Papert S, Mindstorms: Children, Computers and Powerful Ideas, Basic Books: New York, 1980.
[14] Portsmore M, Cyr M and Rogers C, Integrating the Internet, LabView, and Lego Bricks into Modular Data Acquisition and Analysis Software for K-College, Computers in Education Journal, 11, 2001.
[15] Resnick M, Berg R and Eisenberg M, Beyond black boxes: Bringing transparency and aesthetics back to scientific investigation, Journal of the Learning Sciences, 9: 7-30, 2000.
[16] Resnick M, Bruckman A and Martin F, Pianos not stereos: Creating Computacional construction kits, Interactions, 3: 41-50, 1996.
[17] Ribeiro C, RobôCarochinha: Um Estudo Qualitativo sobre a Robótica Educativa no 1º ciclo do Ensino Básico, Dissertação de Mestrado, Instituto de Educação e Psicologia da Universidade do Minho, Braga, 1996.

ISBN 978-989-95336-2-2 ©Hands on Science Network 2008

[18] Rogers C and Portsmore M, Bringing Engineering to Elementary School Journal of STEM Education, 5, 2004.
[19] Teixeira J, Aplicações da Robótica no Ensino Secundário: o Sistema Lego Mindstorms e a Física, Dissertação de Mestrado, Faculdade de Ciências e Tecnologia da Universidade de Coimbra, Coimbra, 2006.

Paper presented at the 4th International Conference on “Hands-on Science. Development Diversity and Inclusion in Science Education",
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Art and History: New Motivations for Students in Materials Engineering Learning Classes?

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Introduction

A priori, Science and Art have been regarded as opposite sides in our educational world, whatever was the level of the student, and the country [1]. Also, the same statement could be announced about Science and History. While these fields were considered valuable and complementary for the ancient Greeks, at the moment, the dichotomy due to the successive selections during the scholar evolution leads to a complete ignorance of one or the other basic knowledge. Because these fundamentals of our culture are considered incompatible in the mind of common Portuguese people, let's try an experiment including Science, Art and History. Selecting only a narrow class of people, in the present case Materials Engineering students, let's see their evolution in the frame of one compulsory lecture, a practical work in laboratories. These students without warning then become pure study objects, real rats of laboratory for some weeks.

A new Course, new Lectures for Materials Engineering Students

Effectively, because of the Bologna agreement, several courses at University of Minho (Portugal) started their remodelling in order to follow the general line defined in this agreement. The new articulation of the lectures, and its content should obey some rules dictated by E. Manuca et al. [2] recently: "learning to know, learning to do, learning to live with the others and learning to exist". The transition was studied and proposed for several Engineering courses. Among these courses, Materials Engineering one becomes a new Master Integrated Engineering Course, i.e. the student could easily go into a 3rd University Cycle leading to Doctoral Studies [3].
The teaching progress of the students is evaluated semester by semester, so, for example, in the 6th semester (3rd Year of Materials Engineering), the new milestone included several teaching fields not only in the different materials areas (Ceramics, Metals and Polymers), but also in general formation (Electronics). The new lectures are the following:

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- Materials and Ecological aspects
- Electronics and Instruments
- Ceramic Processing
- Composition and Modification of polymers
- Thermal Treatments
- Integrated Laboratories V

For each lecture, the scheduled timetable gives 140 hours of study per semester, where 45 hours (3h/week) will be contact hours, i.e. in the presence of a teacher.
The concept of Integrated Laboratories is relatively new in our University, since, till now, every fundamental science (Physics, Chemistry, Computer Science...) and many applied sciences have their own practical work. With the new Bologna rules, the students have a reduced contact with their teachers, so they should study mainly by themselves.
In the frame of the practical lecture “Integrated Laboratory V”, the head teacher should integrate the various lectures of the same semester in an integrating subject, integrating also all the teachers of the same semester: The responsible for this lecture should manage lots of “integrations”!
Conscientiously, the difficulties for our young students, that didn’t use to fix so wide subjects was foreseen, but the difficulties for the different teachers in the supervision were also predicted.
Among the proposed subjects, one dealt with original baroque ceramic tiles (XVIIIth century); From original archaeological pieces lent by the Tibães Monastery, the students should produce copies like the originals using, by one hand, mineral components, by other hand polymeric reagents. The contribution of the metals, not fixed a priori, should be proposed by the students, but we expected a basic degradation/oxidation of a metal in order to get a pigment for the glazed phase.

Articulation of the Lab’s Work

The practical work will be evaluated during a public evaluation every month approximately. So these three evaluation with be the milestones of their work.
The first step of their work, is to define the “learning to know”, so they should plan their work during all the semester. Their plan is completely classical: Bibliography, Preparation of Ceramic Tiles by conventional way, and so application of polymers to substitute the glassy phase. Effectively these should be the correct steps...
Unexpectedly, the first difficulty occurs: there are very few publications dealing with the subject “Azulejos”, (Figure 1) even in Portugal where they are used in so many monuments. In fact, since this is a very old technology, it remained several centuries in the field of semi art-craft, or in little workshops. There were identified in fact mainly three production sites of ceramic tiles in Portugal (Gaia, Coimbra and Lisbon), but these were concurrent, hiding then their processes and technologies [5]. The nowadays production is completely different from the ancient way, and their raw materials. The only published works deal with recent innovations in terms of colours, firing or abrasion resistance.

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Then, they came back to more basic work, established a definition for the Portuguese Azulejo:
Structurally, the azulejo decorative tile is roughly composed by a clay tile covered with a white opaque enamel containing a high amount of tin oxide, where the decoration is then painted, using colours, whose pigments based on metal oxides will melt with the stainniferous enamel during the firing step. The common used colours included the typical blue derived from cobalt, green from copper, purple from manganese, yellow from antimony and lead, and reds and browns from iron.
The clay is an earthen material plastic when wet but non-plastic when dry. During firing, because of its thermal decomposition several reactions occur, giving a permanently hard compound. Clay types vary throughout the world, and even within a region, in terms of composition, crystallographic structure and impurities.
Since ceramic tiles with a first firing step were given to start the work, the students should focus their lab's work mainly in the glazed layer.
The earliest and most common method of clay tile decoration made use of tin-glazes which were essentially based on transparent lead glazes. The glazes were generally made with white lead, flint, or china clays ground up and mixed with finely ground metallic oxides that provided the colour. The Clay glaze, used more recently because of the lead toxicity, consists predominantly of clay, with a low melting point, that vitrifies during firing. The glaze is the generic term describing the vitreous surface used to cover pottery. The glaze gives the product brilliance and ensures that it is watertight. Tiles were either dipped into the glaze or the glaze was brushed on the tile surface.

Figure 1 *Azulejo* used as starting and reference material

Figure 2. *Azulejo* produced by cold processing using polymer cross-linking

Because few quantitative data were available, they decided to perform directly the characterization of the ceramic tiles lend by the Tibães Monastery (Figure 1). They used for this the habitual processes (Electron Microscopy, Chemical analysis, X-Ray diffraction) that they heard about in theoretical aspects in lectures during other semesters: It's the beginning of integration! Also, they contact by themselves other teachers in the Physics department and they manage the spectroscopic analysis of

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the glasses and the colour analysis of the pigments used in the XVII and XVIII centuries. This is "learning to do and learning to live with the others". The dynamic of the students were so high that they contact pigment companies, local porcelain factories. Also they meet and discuss with investigators from the Textile Engineering department of the University of Minho; from these, they bring later some pigments used to induce colours in clothes...!

The Results

Finally, using a mineral process, they prepared a glass composition in order to deposit over the terra-cotta piece and obtain the glazed layer. On the other hand, with the help of the teacher from Polymer Department, they prepared a complex mixture, based on polyester compositions. They included also some mineral pigments in order to give a colour to the transparent polymer and they applied this over the raw brown ceramic tile, in an original cold process of application of glaze over azulejos. (Figure 2)

Also, in the frame of their metallurgical formation, the students studied the metallic Cobalt, they selected the adequate conditions (time/temperature) in order to manage and control the oxidation step, and finally they evaluated the proportion of the different amounts of Co^{2+} and Co^{3+} in their mixture since the complete oxidation of Cobalt is difficult.

Moreover, they perform some tests of corrosion of the polymeric layer in order to evaluate its stability in outdoor conditions, like are man y of our azulejos in monumental panels suffering weather cycling along centuries.

Conclusion

The last criterion "Learning to exist", concerning their autonomy in the study, is completely fulfilled since, like a team they establish objectives and manage them. Their successful work makes them confident and enthusiastic about this course and their capabilities in leading a project, i.e. leading their life.

The integration of various lectures, what seems so difficult at the beginning, was managed efficiently by the students' side and by the teachers' one. Our conviction is that this kind of practical lectures will only work with flexible and available teachers that want/can to accompany the students in this uncertain route.

Finally, to answer to the first question: "Art and History: New Motivations for Students in Materials Engineering Learning Classes?" One could say that Materials Engineering could be a motivation to study Art and History. At the beginning, the students were doubtful about their capabilities and their reduced knowledge, but in their last oral presentation their dynamics carried them to proposed new ideas, new processes and new strategies for the study of the archaeological pieces from the Tibães Monastery.

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References

[1] Costa MFM and Clark A, Science and Arts. The Sc-Art Project, Proceedings of the 3rd International Conference on Hands-on Science, HSCI2006 - Science Education and Sustainable Development, Costa MF and Dorrío BV (Eds.), Braga, Portugal, pp.: 555, 2006.

[2] Manuca E, Gheorghiu P, Alexandru S and Gansac AM, Opportunities and Limitations of the Interdisciplinarity in Possible (Non) (In) Formal, Proceedings of the 3rd International Conference on Hands-on Science, HSCI2006 - Science Education and Sustainable Development, Costa MF and Dorrío BV (Eds.), Portugal, pp.: 559, 2006.

[3] Gomes J, Proposta de Reestruturação da Licenciatura em Engenharia de Materiais da Universidade do Minho, University of Minho: Guimarães, 2006.

[4] Ferreira do Amaral A, Reis da Mata AM, Dias Costa I, dos Santos JC and Dias Costa MJ, Mosteiro São Martinho de Tibães – Historias de recuperação, in Conservação e Restauro de Património Móvel e Integrado, IPPAR, pp.:33, 2003.

[5] Sampaio e Castro A and Sebastian L, A faiança de Revestimento : séculos XVII e XVIII (intervenção arqueológica 1998-2001), in Património Estudos, Conservação e Restauro de Património Móvel e Integrado, IPPAR, pp.:168, 2003.

[6] de Balanda E and Uribe Echeverria A (Eds.), Les métamorphoses de l'azur: L'art de l'azulejo dans le monde latin, Ars Latina: Paris, pp.: 29-39/409-428, 2002.

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Interactive Courseware for Computer Science Teaching and Learning

Divjak S

Introduction

Slovenian Ministry of Education and Sport granted several projects focused in development of-learning courseware which could be independent and compliant with the most popular Learning management Systems which are planned to be used in Slovenian Schools. The use of SCORM standard [2] was an obvious choice and also one of the prerequisites of these projects. This means that the learning content should be packaged in so called SCORM contents packages, a special form of zip files. Other preconditions were that the e-learning pages should be enriched with multimedia and interactive elements. The use of SCORM should also lead to the reusability of the developed materials.
The basic principle of SCORM is to implement SCORM compliant material on a server running LMS (Learning management System). The user (usually a learner) accesses this server as a client. However it should also be taken into account that only some schools are already using servers with learning management systems. In order to avoid restriction to such advanced learning environment it was decided that the developed learning material should be also runnable as usual hypertext.
One of the granted projects is focused in teaching and learning of Computer and information technology according to the official curricula in the secondary schools. The first phase of the project was dedicated to the analysis of these curricula and to the definition of particular topics that should be covered. In particular the subject of Informatics for general gymnasiums and the subjects of Computer technology and Computer networks for technical gymnasiums were treated.

SCORM fundamentals

SCORM, the Sharable Content Object Reference Model, is a technical specification that governs how online training (or "e-learning") is created and delivered to learners. It is a collection of standards and specifications for web-based e-learning. It defines communications between client side content and a host system called the run-time environment. The former is usually a function of a learning management system). SCORM also defines how learning content may be packaged into a

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transferable ZIP file.
Sharable Content Objects (known affectionately as SCOs) are small, reusable, building blocks of instruction. They are the interchangeable parts that people creating instruction can put together in different ways to create a lesson, a course, or even a curriculum. A SCO can be as small as an image, text, or audio used to support e-learning, a block of information such as a procedure or a concept, or a meaningful assembly of smaller objects like a lesson, a unit, or a course.
SCORM Navigation defines how learning and system initiated navigation events are triggered and processed, resulting in the identification of learning activity for delivery. Navigation is the process by which a learner and an LMS cooperate to identify navigation requests to realize a learning experience.
For a learner to access a course or any of its activities, it must issue a navigation request. The result of each navigation request is one of two things: an activity is delivered to the learner or the current activity is taken away. Only one activity can be experienced by the learner at a time.
How the LMS knows which activity to deliver in response to a navigation request is defined by the content package's activity tree and sequencing information. By default, a learner experiencing a content package will choose an activity from the tree to launch. Some typical navigation events are the following:

- **Start**: request to identify the first activity of a tree, generated automatically by the LMS when the learning begins his learning.
- **Resume:** request to resume a previously suspended attempt on an activity tree
- **Continue**: request to go to the "next" learning activity available in the tree
- **Previous**: request to return to the "previous" learning activity (in relation to the current activity) in the tree
- **Choose**: request to "jump" directly to a specific learning activity in the tree
- **Abandon**: request to immediately terminate the current activity

SCORM 2004 defines the sequencing information that describes how SCORM-conformant content may be sequenced to the learner through a set of learner or system-initiated navigation events. It provides the ability to prescribe the intended learning sequencing strategy.
SCORM is a standard still in development and currently many tools support its previous version, SCORM 1.2 and only some are compliant with the current SORM 2004 (also known as SCORM 1.3).

Structure of the Courseware

One of the main questions was the granularity of the developed material and corresponding content packages. One possibility was to embed the entire subject in one single content package. This could simplify the importing of the SCORM package into a given learning management system. But it also means decrease of the flexibility and reusability of such courseware. Therefore a second alternative was chosen. According to this each particular topic was considered as a package.

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The disadvantage of this approach is that the administrator has to import many packages in order to publish on the server the whole subject.
This disadvantage was bypassed with the introduction of composite content packages. This means integration of several content packages, all belonging to a particular subject, into a single- more complex package. From the internal point of view we should know that each content package is represented by a single zip file which contains a so called manifest file (imsmanifest.xml). This file describes how the content package is to be used by a LMS. Such files become sub-manifests of a larger package.

Interactivity of Examples

The basic didactic units are represented as hypertext pages which contain pictures, animations and also interactive examples, mostly represented by flash animations and some enriched with applets. Following the experience with well known physlets [3] the interactivity of applets was achieved by public functions which permit the integration of interactive commands in hypertext. Some attention was paid to reusability of such applets in different didactic scenarios.
One example of such generalized applets is shown in the Figure 1. It demonstrates the model of a simple computer. The algorithm can be written as a pseudo code or in a simplified assembly language.

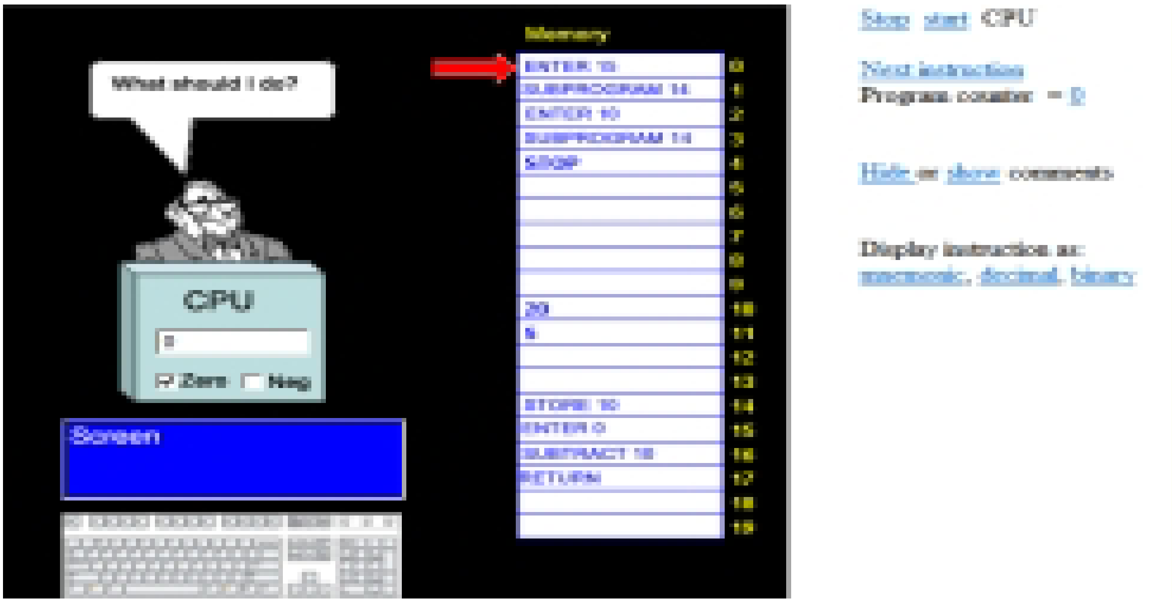

Figure 1: Interactive example of a simplified computer, controllable by JavaScript functions. Other scriptable applets are used for illustration of history timeline, comparison of analogue and digital data, demonstration of basic digital circuits, etc

One basic problem of such interactive demonstrations is that it is sometimes difficult to find the idea what can be animated with such approach. This is in contrast to the

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experience in natural sciences, in particular in physics where the interactive simulations of natural phenomena are an obvious didactic alternative.

More Problems

One basic problem encountered during development and adaptation of the already available materials was the incompatibility of tools with selected standards. Some authoring tools are still supporting SCORM1.2 or their declared conformance with recent version 2004 is only declarative. Sometimes the deficiencies can be discovered only on some internet discussion forums. Even using conformance test tools provided by the official associations the behaviour of the developed courseware is sometimes strange, unexpected. Therefore it was decided to use only the possibilities that represent a common denominator of used authoring tools and most popular learning management systems. Despite interesting possibilities of courseware sequencing defined in SCORM2004 it was decided not to use it and use only navigation possibilities.

Conclusions

During the project more than 800 hypertext pages were created or adapted. These pages were enriched with more than 1500 pictures and more than 200 flash or java animations or interactive elements. In development several problems were encountered. One was the lack of needed learning materials and most of them have to be rewritten. The second was that the official curricula have many discrepancies. The third problem vas the lack of experience with SCORM standard and encountered nonconformities of used tools with it.

References

[1] WEB page of the project http://colos1.fri.uni-lj.si/ERI
[2] Advanced distributed learning: http://www.adlnet.gov/
[3] Physlets home page: http://webphysics.davidson.edu/Applets/Applets.html

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Developing the Spirit of Innovation through Hands on Science: An Indian Perspective

Patairiya M

Introduction

Generally it is believed that necessity is the mother of invention. At the same time it may also be understood that there are many other factors which are responsible for a successful innovation, i.e.:

- how quickly one is able to identify the necessity or a problem
- how he or she develops an urge to find ways and means to solve that particular problem
- how one is equipped, in terms of skill and technology
- how he moves on to solve the problem and
- how he involves people through group discussion for further refinement of the solution of the problem reaching to a socially acceptable innovation!

Incidentally, India's traditional innovation system demonstrates a great deal of people's collective wisdom and potential. The age-old potter's wheel is being traditionally used for making mud pots. The shape, design and usages were remained almost same for the centuries. This traditional technology is still continuing to offer livelihood to millions of potters in India. Rotation of the wheel on its routine axis causes lot of friction taking more time for making a pot. Moreover, its uneven rotation affects the shape of the pot and the potter has to be extra careful. Recently, a grass root innovator, with his keen observation and ability problem solving, has introduced a simple modification in a potter's wheel, a ball bearing. This simple attachment has turned up as a remarkable breakthrough in the traditional pottery industry. It has not only enhanced the efficiency and quality but also liberated the potters form irksome process of uneven rotation of wheel. Now, at some places, the hands operated potter's wheels have been upgraded to power operated. Therefore, understanding the problem, keen and minute observation, questioning and finding answers to them are some of the basic attributes essential for innovativeness.

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Scope for Innovative Ideas: NCSTC's Perspective

Since its inception, the NCSTC has encouraged, adapted and enriched new experiments, innovations, new ideas and schemes in the field of S&T communication and popularization. Nowadays, several ways and means are being used for S&T communication and popularization, affecting the life style of common man directly or indirectly. The main aim of such programs and activities is to disseminate scientific and technical knowledge, and to inculcate and foster development of scientific temper and understanding among them using all possible media.

It is not so that all the ways, techniques, means and media have been tried out. As a matter of fact, we have touched only a few facets of this diversified area of communication techniques for science communication and there is an ocean to be discovered, adopted and tested. The scope for new ideas and innovations in the field of S&T communication is as much as that in fundamental research in S&T. All that is needed is to explore, discover, adapt such innovative ideas and put them in to practice.

In 1987, Bharat Jan Vigyan Jatha came up with a new and novel concept and it is realized that where our print, electronic and other media have limitations to reach, Vigyan Jatha using folk media could reach. Its impact was enormous and format was proved to have infinite potential. So all of us, who are closely associated with science communication, should take the responsibility of exploring newer vistas and make new frontiers for science communication.

Who knows, when a bright innovative idea flashes in whose mind! So let us tune and condition our minds for the purpose. Generally, new ideas come either on requirement, as we say “necessity is the mother of invention” or something may click all of a sudden. Both of these types of ideas have their own importance.

The NCSTC/ DST had started encouraging young minds towards innovations in much more vigorous manner in the form an international program ‘Steer the Big Idea’ in 2005 in association with Confederation of Indian Industry (CII). Some 10 young innovators were selected from across the country based on their innovative ideas and were supported for developing the idea into prototype. They were also taken to an International Innovation Fair held in Japan organized by Japan Institute of Invention and Innovation. It was an exciting program for the children. Now the program has been given new shape under the name ‘Initiative for Research & Innovation in Science (IRIS)’ incorporating two programs with common mission of promoting the spirit of innovation and science. The merger of Intel Science Talent Discovery Fair and Steer the Big Idea has given birth to IRIS that offers a variety of innovative activities for Indian children as well as their exposure to international innovation scenario.

S&T Temper and Method of Science

Merely acquiring scientific knowledge does not imply to have scientific temper. A scientifically qualified person may lack scientific temper, while as a contrast, even one who has not been a science student can manifest scientific temper. Scientific temper reflects one’s logical, rational and analytical thinking, systematic and orderly

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way of his performance in all spheres of life, his reasonable behaviour and conduct in the society and of course a rational and informed and logical decision making power. The scientific temper and method of science portray one's overall personality, which is clearly visible through actions. Spirit of innovation in one way or the other can be seen as a conglomerate of all these attributes at one place.

The state of mind geared up to use of hands in a systematic manner in any technological operation is known as technological temper. In other worlds, the technological temper can be referred to the spirit of using head and hands for accomplishment of any task in a systematic and orderly manner to achieve excellence.

It may be possible to make it more vivid by citing an interesting example. One may come across an electronic engineer not capable of undertaking even a small repair work of his own transistor set. On the other hand, one can find persons, who have not undergone the regular training, but have acquired the knowledge and skill only with the application of technological temper, who can do the needful.

We observe that a particular mechanic or carpenter or any other such professional is excellent in his work and we even recommend his name to others. This is recognition of his technological temper. In fact, by way of inculcation of a technological temper, a qualitative and systematic performance is expected from a person, in every walk of human activity that would lead him to perfection and excellence.

You may find a hand pump, which is not working or municipality's tap with leakage of water. Similarly, one can find a telephone, with no dial tone. This situation needs to be corrected. Here the role of State may be important, but above all, it is our attitude, the technological temperament, which the author is talking about. If we are able to develop a technological temper among masses, it can automatically lead to enhancing the level of innovativeness in the society.

Technology Day

Eleventh May 1998 was a very special day for Indian technology. We had three important technological events on that day. The first event of the day (12:50 p.m.) was of the successful test flight for final certification of Hansa–3, the first all composite indigenous aircraft, built by CSIR. The second was (followed a few minutes later) the successful test firing of the Trishul missile. The third and the most momentous was, the three successful nuclear tests, known as Pokharan-II. In view of the series of our technological successes, the then Prime Minister had declared 11th May as the National Technology Day, just as 28th February is celebrated as National Science Day in recognition of discovery of Raman Effect. Consequently, to give more impetus on technological innovation, technology communication and inculcation of a technological temper, we have so far celebrated technology day each year. Every year a focal theme is selected and children are exposed to a number of hands on activities that allows them trigger an interest in science and technology in general and in innovation in particular.

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Towards an Innovative Society

Infusion of innovativeness and creativeness may be one of the major tasks before any technology communication effort. Technology communication does not only mean to communicate technological information from laboratories or technological institutions to the people. It can be two ways. In case, some kinds of technologies or technological ideas emerge from among the people that can also be carried to the scientists and technologists, so that it can be evaluated in terms of its viability, efficacy, workability and novelty. It can also be reshaped, modified and upgraded, if necessary. Similarly, specific area can be identified, where a certain kind of invention is needed to solve a specific problem, such issue or problem can be brought to the technologists/ engineers/ scientists, etc., enabling them to develop suitable invention/ innovation.

It has been a general observation that in the age group of 15-25, the creativity of children and youth is very high and they come up with a number of novel ideas. As an average, at any given time, 2-3 such brilliant students do exist in each medium size city/ town in India, who are interested in creative endeavours and putting things together in novel ways. A mechanism can be worked out to harness the potential of such individual innovators. It has also been seen that such persons are not necessarily interested in textbooks or curriculum, but they posses a proven ability of doing technical things.

Obviously, sometime they cannot secure good marks in their examination, but at the same time, their technological endeavours can prove an asset for the society. Such efforts need to be promoted and supported. The mechanism can be developed so as such technologically motivated persons driven with zeal and gleam in their eyes to doing something new and relevant, reach to the scientific/ technological R&D institutions, laboratories, technology centres, etc., and are able to try their head and hands.

Another vivid example is noteworthy here: A farmer Mr. Sunda Ram Verma of Rajasthan state has developed an eco-friendly technique for keeping termite away from his farmland. A fine morning he noticed that the Eucalyptus wood has a peculiar characteristic. The Eucalyptus wood attracts the termite from all around. He placed a number of Eucalyptus twigs around a termite manifested field and surprisingly found next day that all the termites were vanished from the field, as they found their way to reach the Eucalyptus twigs. Then Mr. Verma removed the twigs and burnet them along with termites. Thus a simple observation and experimentation was resulted into an economic and eco-friendly innovation. Incidentally, chemical treatment of termites costs not only money but also risks human health.

India's Innovation System

The Department of Science and Technology, Govt. of India has established the National Innovation Foundation (NIF) of India in February 2000, with the main goal of providing institutional support in scouting, spawning, sustaining and scaling up grassroots green innovations and helping their transition to self supporting activities. To help India become an inventive and creative society and a global leader in

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sustainable technologies without social and economic handicaps affecting evolution and diffusion of green grassroots innovations is the mission of NIF. Its objectives, amongst others, included : evolving strategies and conducting, coordinating and supporting research, design and development efforts in the country on grassroots innovations so as to attain and maintain technological competence and enhance self reliance, building linkages between excellence in formal scientific systems and informal knowledge systems and creating a Knowledge Network to link various stakeholders through applications of information technologies and also otherwise, and promoting wider social awareness, and possible commercial and non commercial applications of know-how generated as a result of above and encouraging their incorporation in educational curriculum, policies and programs.
The Ministry of Science & Technology, Govt. of India has launched a novel program known as "Technopreneur Promotion Programme (TePP)" jointly operated by Department of Scientific & Industrial Research (DSIR), Technology Information Forecasting and Assessment Council (TIFAC) and Department of Science & Technology (DST) to tap the vast innovative potential of the citizens of India. TePP offers a crucible to promote individual innovators to become technology-based entrepreneurs (Technopreneurs). Indian citizen having original idea/ invention/ know-how can apply. Proposals from individual innovators to convert original idea/ invention/ know-how into working prototype/ processes are invited and considered for support. That apart, Indian Institute of Technology has its own outfit in the name of Foundation for Innovation & Technology Transfer. National Research Development Corporation, Council of Scientific & Industrial Research also support, promote and recognize innovation.

Conclusion

Technological innovations are visible in various farms, rural and domestic technologies across the country. But almost no patent has been taken for such technologies, due to lack of awareness and technicalities involved in patenting process. Common people and even educated people are unable to file a patent in their names for their invention. As a contrast, some people seek patent rights, though their innovations may not be patentable. Therefore, awareness about patentable and non-patentable inventions, preparation of application for a patent, writing/ drawing a patent specification, process of getting a patent and maintaining a patent is required to be spread deeper into the society. In the light of new IPR regime spearheaded by WTO, this may form a major component of technology innovation programme.
Since the process of technology innovation and inculcation of a technological temper stimulate the new product development, the people must be made aware about intellectual property rights to protect their innovations and developments. Innovations are increasingly seen as a means of economic growth and are instrumental in facing competition poised by globalisation. A strong trend of internationalisation of innovations can be observed the world over and its growing role in global economy. This trend is reflected in the increasing number of offshore research and development centres especially those located within emerging

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economies like China and India. Any society cannot flourish in today's rapidly changing world without a strong and sustained innovation system and the creative hands on science experiments have a crucial role to play in this direction.

References

[1] Manoj P, Technology Communication, NCSTC Communications, May 2001.
[2] Manoj P, Scope for Innovative Ideas, NCSTC Communications, June 1993.
[3] Manoj P, Children Discover New Horizons, NCSTC Communications, January, 1994.
[4] Manoj P (Ed.), Communicating Science: Highlights 2006-2007, National Council for Science & Technology Communication, New Delhi, 2007.
[5] Proceedings of 5th Asia-Pacific Symposium on Scientific Culture & Innovative Development, Beijing, November 4-6, 2006.
[6] Rajnish T, Global Innovation: Opportunities of Internationalization of R&D, Institute of Technology & Innovation Management, Hamburg University of Technology, Hamburg, 2006.
[7] Rajnish T, India's innovation System: Exploring the Strengths, Institute of Technology and Innovation Management, Hamburg University of Technology, Hamburg, 2007.
[8] Science, Technology and Innovation Policy, UNESCO, Paris, 1999.
[9] National Innovation Foundation, Ahmedabad, http://www.nifindia.org
[10] Technopreneur Promotion Programme (TePP), Ministry of Science and Technology, Govt. of India, New Delhi Http://dsir.nic.in/tpdup/tepp/tepp.htm
[11] Science and Technology Policy 2003, Ministry of Science and Technology, Govt. of India, New Delhi, 2003.
[12] Report of the First Technology Day, May 11, 1999, CSIR, New Delhi, 1999.
[13] Parth B et al, Intellectual Property Rights Information through Digital Medium : A Case Study, Indian Journal of Science Communication, January-June, 2003.
[14] Pandey DK et al, Initiative for Research & Innovation in Science (IRIS), Intel, CII, NCSTC, New Delhi, 2006.
[15] Traditional Knowledge Digital Library (TKDL), National Institute of Science Communication and Information Resources, CSIR, New Delhi.

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The Trio: Research Institute, University and School to Promote the Interest for Science

Timus C

Introduction

It is not unusual that the task of the EC is to try to build a knowledge based society, nowadays when despite of a long history of civilization it seems, that rather revenge and hate are more prominent than wisdom, peace and progress. It could be necessary people to understand that extending the knowledge, could be a way to avoid wars and all kind of divergences in the world, to stop the terrorism and save human lives, to promote collaboration, understanding and peace.

All around the world in the last decades the interest for sciences in the schools decreased thus a strategy had to be adopted in US and Europe in order to stimulate the interest of the scholars for sciences. This strategy means the collaboration between all the actors involved: schools, families, ministry of education but the universities, research institutes and the industrial companies, as well.

It is not by chance that the national responsible for this project in Romania is a research institute the National Institute for Lasers, Plasma and Radiation Physics in Bucharest: the reason consists in the fact that in this branch of activity it is easy to notice the decrease of the quality of the students graduated from the faculties of sciences. The formation of young scientists is an activity to be continued in the research institute.

Why not to try to contribute to the development of the future scientists from the very beginning and have an easier task later?

Why not to try to discover the gifted scholars for sciences earlier and guide them correctly and support them in a professional way?

Why not to validate the experience of a scientist working with the new generations in due time?

The paper will point out some of the good results developed in Romania in this context and stress the contribution of each of the above mentioned actors. In this respect it is necessary to recall that before the fall of the iron curtain Romania had a policy favourable to the development of education in science – the curricula for mathematics, physics, chemistry, and informatics were much consistent and the graduated students became soon good experts. As considering the “brain drain” phenomenon, quite important in the last 17 years, Romania offered for the European work market specialists in computer science, while Hungary in

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comparison experts in economy and sociology [1]. The structure of the economy could absorbs engineers, chemists and physicists but the tremendous change after 1989 had consequences on the interest for a job in different other fields. The work market is ever changing since 1989 and the process is not yet stabilized.
Nevertheless it is worth to mention that the experience in informatics of the young experts from Romania was much appreciated at the world level – the famous Nokia bought Intellisync, to which belonged the local company SoftVision and Brains Group (UK) by merge with Alfa Global Solutions (AGS) founded the company Endava for East Europe in Cluj – city from Transylvania Romania, while Microsoft has subsidiary in Bucharest. Siemens opened an office branch in software in Cluj. Soft companies from Cluj offers IT consultancy for Europe and USA regarding financial services and telecommunication and recently on media, as well.
The Romanian graduates in informatics had been absorbed by Canada, US, Australia due to their policy to select the experts.
After 1990 the shortage produced in the non efficient industry in Romania and the change in the economy scene produced the increase of the interest for economy and law study and the number of graduates was in excess. The interest for humanistic studies increased as well as for other new profession very limited before 1989: media, modelling, financial space, management etc.
This short presentation of the situation is to allow understanding the necessity to establish equilibrium and try to compensate the decrease of the interest for science study.

The national Symposia "Hands on Science"

The aim of the network is to promote the development of education in science and scientific literacy, the innovative hands-on experimental approaches to science and technology in school teaching, as well as rising the attractiveness of science in education.
In the last scholar year we assisted to a tremendous interest from behalf of the different teachers to organize national symposia, the first having in mind the model of the international conference attended last September in Braga. The Romanian delegation to this conference, consisting both of senior and young scientists, high school teachers and scholars, one of the largest in this conference had an active contribution: oral presentation, participation in two round tables, two tutorials experiments in Science Fair etc. It was the first time the high school teachers attended an international conference and the scholars, as well and this interesting experience had a stimulus effect.
The very large diversity of topics and kind of activities: oral presentations, experiments, demonstrations, contacts between the attendees of all the ages were of high stimulus for each attendee.
The delegation was happy to notice a great success, as one of the participants, the X^{-th} class scholar Vasile Valvoiu from "Zinca Golescu" High School Pitesti (Figure1) who presented the paper "Biohazard's Solar System 2.0" a proposal of edutainment software to explore the universe in 3D virtual, interactive environment running on a medium performance PC received the trophies of Science Fair.

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The passion for software of the scholar is not new as he was the winner of more than 35 prizes at different national and international contests among the last ones a special prize at the “National Conference of Virtual Learning” in 2005 (out of 172 authors and 84 papers) and the 3rd Prize and bronze medal at the International concurs “INFORMATRIX” an educational soft in 2006 (out of 84 finalist teams from 24 countries).
For a student in the high school the prize represents the recognition of a hard work he developed to improve the software and this is stimulating him in the activity to come. He was master on his work, the presentation was on line, showing the facilities of the edutainment software and managed very well to convince the audience about this contribution. He was able to have the presentation in English, establish contacts and friendship relations that show the capability of the young people to be easy integrated in Europe.

Figure 1. The winner of the trophies Science Fair in Minho Universidade Campus - Braga

Figure 2. Tests of the food quality (High School Costin C. Kiritesccu – Bucharest)

To attend the international conference in Braga was much stimulating for the teachers, who being back begun to organize the national symposia. The project was starting quite hesitating at the very beginning, as teachers were not convinced about their own possibilities, but only the start was difficult.
These national symposia represent a life school for all the attendees, since every edition means a new experience, an improved quality of the presentations, the opportunity to listen different other points of view, different new forms of expression and add new features to the own expertise.
The problems approached by the scholars are various, most of them being close to the life aspects: control of the quality of some foods, of the water, environment aspects, pollution, meteorological phenomena as tornados, the heating of the planet.
The extra curricula activities developed by the scholars with the teachers in the frame of “Science clubs” represent a challenge both for scholars as for teachers, because of the variety of aspects this common cooperation offers: for scholars the relevance of some special gifts, the refinement of the expression possibilities, more authority and mastery of the topics approached, for teachers on the other side to be

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closer to the scholars, to open new and various ways of communication and impose the professional authority.
The symposia are attended by participants from different other cities, who bring the report of their original activities. The teachers are stimulated and encouraged to be original and every national symposium seems to be different and to enlarge the expertise of the attendees. The comments are transmitted to the network, so each new organizer could benefit from the positive aspects or avoid the negative ones.
Now it is possible to say that a real competition is in progress, as each symposium organizer has the ambition to bring the proof of its personality, to add new ideas, to find new forms of expression, to extend the interest for science over the common curricula. In this ever developing progress there are not only the scholars and the teachers involved but the parents and even the grandparents and the results are amazing because of such large implications.
The possibility to change the information to discuss, to attend the presentation, experiments, exhibitions, posters, artistic shows on scientific topics all represents suggestions to improve the symposia, to innovate, but most of all to stimulate the pupils to attend extra curricula activities.
The "Media Technical College" in Bucharest organized the 6^{th} symposium in this scholar year, dedicated to "Light" registering a participation of 175 people from Bucharest and different other cities, some very far located. The symposium offered the opportunity to have various forms of presentations related to this generous topics "light" from physics, astronomy, ethics, arts and also literature. The various forms of approaches: oral presentation, drama, dance, songs, paintings, photos, experiments is the proof of the extra curricula activities, the ability to use the internet information and to focus on the selected subject.

Figure 3. National Symposium "Young people for Europe of tomorrow" Spiru Haret Dobroudja College

Figure 4. Symposium hosted by the Technical University from Pitesti, Faculty of Mechanics and Technology

The recent symposium organized in a college situated on Danube river Tulcea dedicated to the celebration of 124 years of education in this city was the opportunity for the attendees to have a nice trip in the Danube Delta to better know the flora and fauna of this unique place of Europe, to be in contact with natural reservation, to know the policy adopted at international level for such protected

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areas. The symposium entitled “Young People for the Europe of Tomorrow” show the interest of the organizers for civic education, as well and for the integration in the large family of European countries. Moreover Bulgarian scholars have been invited to attend the symposium, thus the regional cooperation and friendship relations are promoted in a very concrete way.

I have to mention that the participation is not only large as number, but also as regards the affiliation: scholars, teachers, parents, university professors (interested to contact gifted students in the science) scientists from the research institutes able to change information, to be helpful to each other, to establish new contacts, to organize new activities. Photo 4 shows an instant from the university hall in which was hosted the symposium in Pitesti, an opportunity for scholars to be closer to the next education level of education, the university and for the professors to be able to notice new future students. The symposia in Bucharest are attended as well by university professors from “Politehnica” University interested to discover gifted scholars in science.

The web site http://.education.inflpr.ro was organized to illustrate the main activities to be developed in the frame of the project “Hands on Science” in Romania. All the events are announced and the comments are distributed to the teachers from different other cities to be interested to become the actors of new events.

The “Center for Education in Science and Training” coordinated by Dr. Dan Sporea – the national representative of Hands on Science in Romania was organized in this research institute, having the mission to support the education and training in science for everyone (primary/secondary/high school/vocational) using real and virtual experiments. The training of specialists, education and public information in the fields associated to the NILPRP activity by means of lifelong learning, as well as the coordination of the educational network “Hands-on Science”- Romania represent other objectives of the centre.

The research institute has more connections with the universities from abroad and many contacts all over the world. The participation in different international conferences and meetings represent other opportunities to keep informed and to disseminate the good practices in the education and training in science [2].

The contacts of the research institute with the companies producing scientific instruments and apparatus are important to develop reciprocal contacts, there are different companies: Microsoft, Vernier International, (http://www.vernier-intl.com/).

National Instruments, Volvo, etc disposal to sponsor the education to offer support and contribute to the formation of new experts to be absorbed by the working market.

The different experimental kits developed in the universities and companies are distributed in the schools to be used for real experiments and develop the skills for this training among the scholars.

It is important that these three main actors: school, university and research institute to keep and develop contacts, since the education is gradual and there is only the cooperation to assure the best results.

This continuous collaboration is a stimulus for each of the actors to improve himself and the community as well, because they are in competition and have the opportunity to demonstrate their skills, innovative thinking, and active spirit to

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approach new unconventional methods of teaching. To develop experiments all together, to find solutions, to project new set-ups, to comment and discuss the results this means not only get expertise but it is an opportunity to take responsibility, to manage in unpredictable situations to improve the working style, to be more motivated to face new situations, to be able to report upon the contribution in a large working team..

Conclusion

The results of the development of the project “Hands on Science” in the last scholar year, both the enthusiasm of scholars and teachers and of the scientists as well, represent the proof of a positive initiative, to be extended.

References

[1] Csedõ K, The labour market incorporation of highly skilled migrants: The case of Hungarians and Romanians in London, paper presented at the International Conference “New Patterns of East-West Migration in Europe”, Hamburg Institute of International Economics, 18-19 November, 2005.

[2] Timus CA and Sporea D, L’éducation scientifique permanente – La Roumanie en train d’accès à la Communauté Européenne, International Conference « Evaluation des Competences des Adultes dans l’éducation Permanente », Iasi, October 20-22, 2006.

Paper presented at the 4th International Conference on “Hands-on Science.
Development Diversity and Inclusion in Science Education",
Açores, Portugal, July 23 27, 2007.

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Science Fairs as an Annual Students Project

Esteves Z and Costa MFM

Introduction

In School Education the teacher, the classes, the study' organization, the school, the social environment… everything is important and will condition the effectiveness of student's learning process. However if we want our students to learn and care about science, we have to stimulate and offer them the opportunity to put in practice what they are learning or have learned, because for the vast majority of students the better way to "learn is by doing" [1].

Young students had to be stimulated to science and one of the fine ways to do it is by developing scientific projects, like in science fairs, because they offer a better comprehension of science and nature developing skills, fundamental in science but also in the everyday life, and promote a more critical opinion in face of problems [2]. Despite the importance of this kind of activities, in Portugal events like these are still rare, and there is almost no specific literature that could help us in this organization process. There for it was decided to study and organize a science fair in Externato Maria Auxiliadora. The final objective was to promote, in the last week of school' classes, a science fair were students present their work at the school and community.

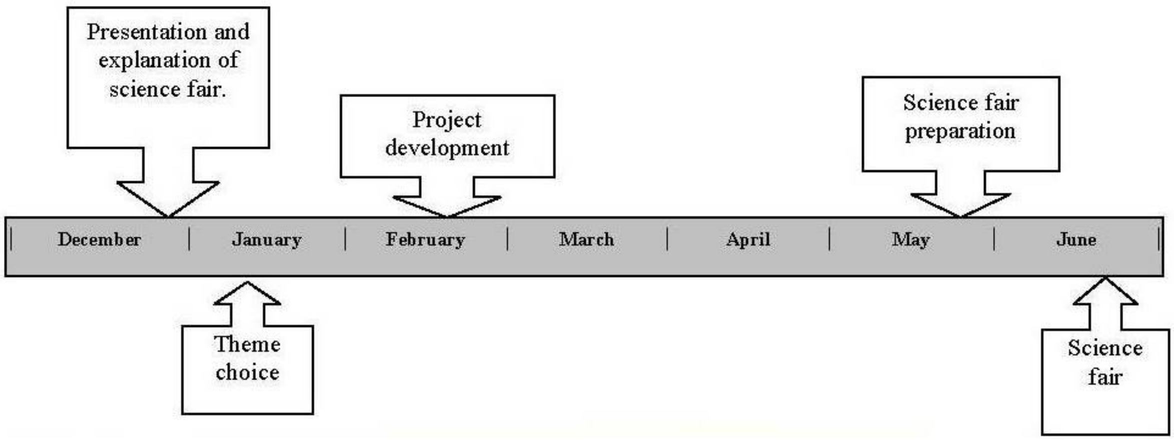

Figure 1. Chronogram of science fair project stages during the school year

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Annual Project Phases

The science fair organization was divided in five different stages. The deadlines in Figure 1 aren't strict, and not every student developed their project in the same period of time.
The first step, at the end of December 2006, was to present the idea of doing a science fair project to the students, so they can be able to think about a project during Christmas vacations. When we explained to the students what a science fair is all about and proposed them to participate, curiously most of them already knew the meaning of science fairs in spite they never participate or attended one. Most of them show interest in participate, despite the fact that they will have to work in their spare time.

Figure 2. Students working (laboratory)

At the beginning, the science fair projects were only expected to be performed by students with ages between twelve and fifteen years old, due to the fact that they had already a certain background level of knowledge of science at the extent we expected to be needed or advisable for the type of activity we envisaged. However, some younger students show interest in the science fair project, having some good ideas, and it was decided to let them participate.
At the restart of classes, early January, it was defined in the school to schedule three hours per week, during lunch time, for the participating students to work on the project at school. The students had access to the school computers and laboratory, to do their research and test their projects, like we can see in Figure 2. However, most of the students prefer to develop their project at home, only working at school when they needed some guidance.
The first weeks were dedicating to research, allowing the students to gather some information about previous ideas, to finding new ones, to "know" more about their subjects.
Since middle of February the project development phase begun. The time available in the schedule were only dedicated to the development of the project. In this stage, students assumed the role of a scientist: they search, observe, experiment and explore and try to prove different hypotheses [1]. The student enthusiasm on

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working in this kind of projects has leaded some of them to develop more than one science fair project.
The last stage before the science fair is the preparation of the presentation they should deliver at the science fair. Most of the students started to prepare their presentation at the end of May. They create posters to post on the science fair day, like we can see in Figure 3. The structure of the poster was optional, but all of them should contain the identification and a general idea of the experiment. Obviously it should be attractive and the ideas should be presented clearly and correct scientifically [5].

Figure 3. Students preparing the science fair presentation

The Teacher's Role

The first guidance that the teacher needs to develop this type of activities to lead the students to a science field interesting to them [3] ,in which they can select an everyday life phenomenon that they don't understand but would like to know more about, or select a previously known experimentation, yet without repeating a previously done work [1].
Despite the enthusiasm shown by the students, it's important to refute them, frequent, previous idea that developing a science fair project is to replicate an experiment previously seen on television or on the internet.
The first obstacle is when or if the students realize that is not simple to reproduce an experiment. Also when it is necessary to improve the work most of the students don't know what to do. So, it's necessary to follow and encourage the students, especially when there project don't work, or when it doesn't happen what they expected.
The role of the teacher is thus to help students to work and reason and don't let them give up. Whenever possible the professor should guide the students to perform better and improve their projects even more [4]
Another important aspect is not forgetting to remind the students that they have to finish their project before the deadline, because most of them think that they have… always… enough time.

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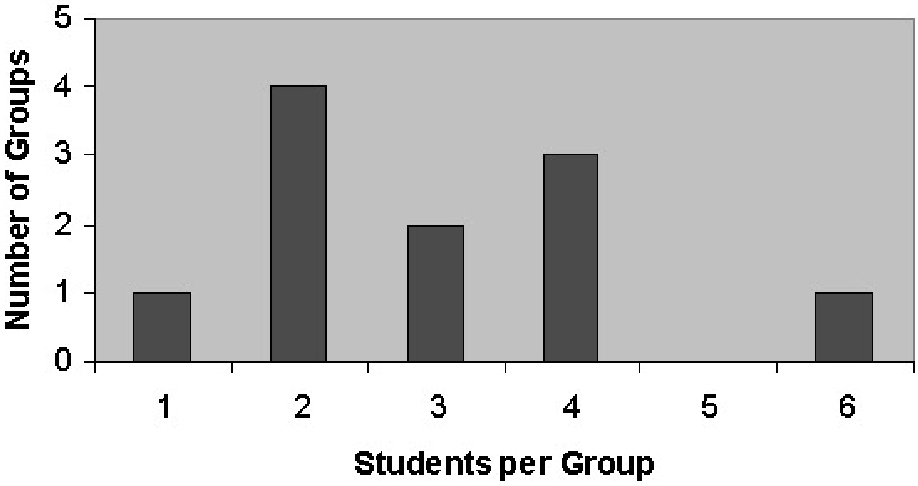

Figure 4. Distribution of students per group

The teacher needs to be "always" asking the students how the work is doing, so they don't forget that they have to finish it and feel supported… but not "pushed". This attitude is to prevent that, when it appears some aspects that the students don't expect or if they can't finish the project on time, they don't lose their motivation interest and goals. The teacher encourages the students, so they can see that we care about their projects and their efforts [3].

It's very important to help the students preparing the science fair presentations too, because they can learn more when they have to teach the others, and if the explanation is attractive and clear everyone can learn with it… and the students will feel it!

The Science Fair

At the science fair, there were fifteen experiments presented by eleven groups of students organized as we can see in Figure 4.

The difference between the number of groups and the number of projects were due to the fact that some groups developed more than one project, as is possible to see in Table 1. This fact diverted the students from the initial objective of the science fair, which is the understanding the science behind the experiment, leading them to a somehow under-development of each individual project.

Not all groups that participated in the process through the year lead the work until end, and were not present at the fair, mainly because they had no enough time, for instance, due to the fact that they started later than other groups. Some of them were actually obtaining some results but didn't want to participate because the project wasn't entirely concluded. This fact in one hand could show their levels of exigency on themselves but also, eventually for some students, that their main worry is to reproduce the experiment, disregarding the fact that the most important thing was their learning process.

The projects presented at the fair were distributed between chemistry and physics subjects, as it can be seen in the graph of Figure 5.

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One important aspect of this science fair was the participation of one student with special needs. He decided to develop the project individually (yet with some help from other students, on their own initiative), and presented it at the science fair, quite successfully, in spite the low expectations of everyone. This student needed to be helped in a lot of matters during the year but it was possible to verify his increasing interest and a large evolution along the way.

Group	Nº of elements per group	Project
1	1	Volcano
2	2	“Fluver”
3	6	Imploding can Volcano Resonance frequency
4	4	Coca-cola effects
5	2	Lamp
6	3	Curie effect Solar watch
7	4	“Glass of champagne”
8	2	Perfumes Changing colour solution
9	3	Compass
10	4	Bearing car
11	2	An egg in a bottle

Table 1. Name and number of projects per group

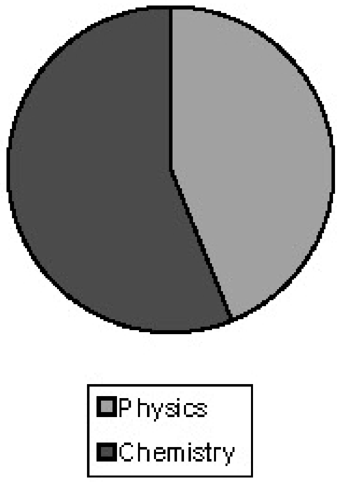

Figure 5. Distribution of the projects between the science fields

The science fair projects needed, finally, to be evaluated. A jury was formed the included school’ teachers in different subjects, and they were unanimous on choosing the winning group. Despite of having a lot of well done projects the two winning groups demonstrate a larger interest in their project: the perfumes and the Bearing car, Figure 6. They didn’t worry only on to replicate experiments but researched their topics, investigated, innovated and were even able to talk about fails and discoveries (unlike some others that mainly worry about the final result). One of the most important aspects was that they were able to explain their project in an exceptionally clear way and with scientific accuracy.

Conclusion

It was clearly proven with our experiment that a science fair project develop different positive attitudes in the students involved. Even students that didn’t participated had shown interest and curiosity about science and science fairs. One difficulty detected is the fact that students mainly value the “experiment itself” and valued not enough the research they had to perform and the doubts and ideas they

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came up with and explored, often not realizing the fact that they acted like scientists. The students acquire with this type of activities a greater interest and knowledge on Science. They developed also a positive curiosity about the science fair projects made by other students, about daily life phenomenon and other themes discussed at classes.

Figure 6. The winning groups (perfumes at left and the bearing car at the right)

Student's participation in the regular classes improved clearly, in general, after they started to develop their science fair project. This happened not only because the relationship between student and teacher changed by working in an informal way, but also because students started to develop more interest about class' issues.
Science fairs' activities promote creativity, autonomy, research capabilities, and scientific knowledge.
Students understand better what science is and that it is present in everything that surrounds them.

References

[1] www.feiradeciencias.com.br
[2] http://portal.mec.gov.br
[3] Young T, Science Fair Projects bring it all together, Book Report, 2000.
[4] www.content.bvsd.org/tag/elemscifair.html
[5] http://www.scifair.org/articles/steps.shtm

Paper presented at the 4th International Conference on "Hands-on Science. Development Diversity and Inclusion in Science Education",
Açores, Portugal, July 23 27, 2007.

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Thermonuclear Power Plant Model

Sena-Esteves J and Sepúlveda J

Introduction

Scale models may be very useful aids to science teaching or divulgation. This paper describes an eye-catching 85cm x 40cm N scale (1:160) model of a thermonuclear power plant with electrical substation (Figures 1 and 2) built for educational purposes. It has been successfully used in classes and in science-fair events.
Section 2 lists the main materials used to build the model.

Figure 1. Thermonuclear power plant model

Figure 2. Top view of the model

Section 3 presents the model components and gives a brief technical explanation on the main components of real-world nuclear power plants and electrical substations. Section 4 gives some details on an operational railroad integrated in the model. Section 5 contains the conclusions of the paper and a list of references is given in Section 6.

Materials Used to Build the Model

The main materials used to build the model were the following:

1 *Heljan* nuclear power plant kit, ref. 1718; 1 *Revell* transmission substation kit, ref. 2018; 1 *Revell* power transformer kit, ref. 2015; 1 *Brawa* metallic high voltage towers set, ref. 2659; 1 *Peco* train shed unit kit, ref. NB-80; 1 *Vollmer* container crane kit, ref. 7905; 1 *Kibri* diesel oil filling station kit, ref. 7430; 1 *Fleischmann* N scale electric locomotive, ref. 7968; 1 *Seuthe* smoke generator, ref. 100; 6

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Fleishmann N scale model cars; 1 *Fleishmann* N scale van; 1 *Busch* transfer traffic symbols, ref. N 7197; 1 *Preiser* set of 6 N scale workmen, ref. 09105/79105; 1 *Preiser* set of 6 N scale cows, ref. 09155/79155; 16 nuclear waste containers; 1 loudspeaker magnet; 1 *Bachman* N scale bogie; 1m of *Peco* N scale flexible track; 1 N scale railroad sandbox; 2 reed relays; 6 switches; 15cm of brass tube with diameter 0,95cm; 5 sets of 3 *Viessmann* N scale brass street lamps, ref. 6690; 5 sets of 3 *Viessmann* light bulbs (16V, 30mA, ϕ1,8mm), ref. 6228; 8 miniature 12V light bulbs; 6 LEDs; 7 N scale trees.

Other materials include a wooden base, balsa wood, plastic glue, white glue, enamel and acrylic paints, cardboard, light cardboard, double-sided adhesive tape, green and multi-coloured sawdust, electric wire, a power transformer and the electronic components used in the circuits that monitor and control the train movements.

Model Components and Real-World Nuclear Power Plant Components

The model has a main building with nuclear reactor, an electric generator house, a cooling tower (Figure 3) and an electrical substation (Figure 4). It also includes facilities such as an operational railroad, a train shed, a container crane (Figures 5 and 6) and two diesel oil filling stations (Figure 7).
The main building has its own interior illumination and a smoking chimney that actually works. The original plastic chimney was replaced with a brass one equipped with a smoke generator. The train shed and the cooling tower bottom also have interior illumination. Street lamps illuminate the other facilities and a red signalling lamp lies at the top of the crane.
The substation is very detailed, with a three-phase power transformer, section breakers and other components. A *Brawa* metallic high voltage tower (Figure 8) was used to hold the outgoing main power line of the substation.
Some workmen, cars, a van, nuclear waste containers, trees and even a few cows complete the environment.

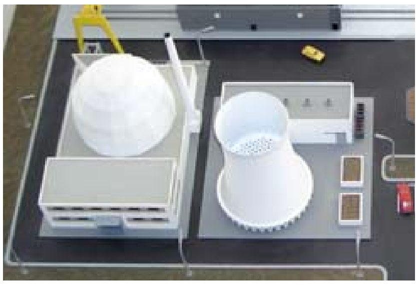

Figure 3. Main building with nuclear reactor (left), generator house and cooling tower (right)

Figure 4. Electrical substation

Figure 5. Train shed and container crane in the foreground

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The rest of this section contains a brief technical explanation on the main components of real-world nuclear power plants and electrical substations.

Nuclear Power Plants

Nuclear power plants are thermal power plants that convert heat produced by nuclear fission into electricity. They contain a nuclear reactor, where nuclear fission takes place; a heat transfer system, which heats water until it is converted into steam; a steam turbine mechanically connected to a synchronous generator, used to convert steam pressure into rotational movement, thus producing electricity; and a steam cooling system, to convert steam into water again. Overall efficiency of these power plants is between 30% and 40%, due to inherent low efficiency of thermal machines [1].

Nuclear reactors are devices were controlled nuclear chain reactions occur, generating heat that will be converted into electricity. There are several types of nuclear reactors.

The **Pressure-Water Reactor** (**PWR**) is the most common type of reactor in power plants around the world [2]. Water is used as a coolant and neutron moderator under such a high pressure that it does not form steam. Some reactors use light water (ordinary water, H_2O). The others use heavy water (water with deuterium isotope, D_2O). Two cooling circuits are used: in the primary circuit, the coolant is kept at very high pressure, transporting heat from the nuclear core to a heat exchanger and a pump keeps the coolant flowing; in the secondary circuit, another pump inserts water in the heat exchanger, were it turns into steam, which will be conducted to the steam turbine. Then, the steam coming from the turbine is condensed into water again.

PWR reactors have some advantages: they are very stable, because they have the tendency to produce less power as temperature rises; they may use natural uranium dioxide as fuel, although heavy water must be used in this case; the turbine is unlikely to be contaminated by radioactive materials, because it is in a secondary cooling circuit; and control rods are inserted from the top, making them easy to insert in the reactor if power fails. On the other hand, there are also some disadvantages: the primary coolant circuit must be kept at very high pressure, raising the risk of accident due to a fracture in the circuit; most of these reactors can’t be refuelled while in operation; a sudden coolant temperature descent would raise power production, causing emergency shutdown of the reactor.

Steam turbines are used to convert steam pressure differential into mechanical rotation movement. They consist of a high-pressure (HP) turbine, a medium-pressure (MP) turbine and a low-pressure (LP) turbine, usually mounted on the same shaft, connected to an electric generator. Each turbine has many radial blades that deflect the steam, producing torque. The size of the blades (and, therefore, the diameter of the turbine) depends on the steam pressure: the blades of LP turbines are the longest and the blades of HP turbines are the shortest.

The **condenser** is responsible for diminishing low-pressure steam temperature until it condenses into water again. Enormous quantities of fresh water are needed to

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carry the heat away from the condenser. The cooling water may be driven from a river, or from a cooling tower, and its temperature typically increases 5ºC to 10ºC.

Figure 6. Side view of the container crane and part of the train shed

Figure 7. Diesel oil filling station

Figure 8. Metallic high voltage tower

Cooling towers are needed when the power plant is located in a dry region, or when the heating of water streams is undesirable. The cooling towers freshen up the condenser by means of evaporation. The circulating water is exposed to the surrounding air by means of creating an artificial rain inside the tower: the hot water coming from the condenser is fed to the top of the tower where there are lots of small pipes with holes; then, the water is dropped on an open reservoir placed on the tower's bottom, where water may be pumped to the condenser again. A small part of the water is lost in the process, but can easily be replaced from a stream.

Electrical Substations

An electrical substation is the part of an electrical energy system where line voltage and current levels are modified using power transformers, in order to diminish system installation and operation costs. There are three types of substations, along and electrical energy system: the generating substation, the transmission substation and the distribution substation.

Electrical power plants generate electricity by means of synchronous machines working as generators, called alternators. For technical reasons, these machines output voltages are limited to a few kV (18kV, for example). So, it is necessary to raise the generated medium-voltage to the high-voltage levels necessary to transmit the energy economically. This transformation is accomplished by **power**

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transformers existing in generating substations. The model described in this paper has a substation of this type; however, all types of substations are similar.
Besides power transformers, substations usually contain the following equipments: circuit breakers, air-break switches, disconnecting switches, grounding switches, surge arresters, current-limiting reactors, grounding transformers, and measurement transformers [1]. The model contains some of these elements (Figures 9, 10 and 11).

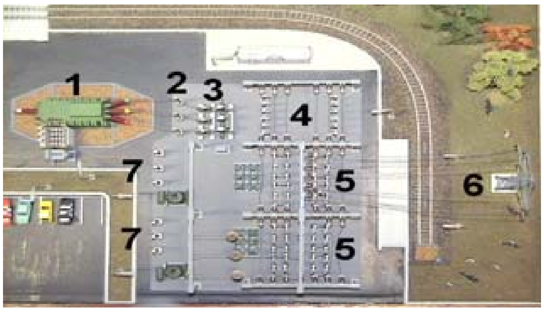

Figure 9. Electrical substation layout: 1 – main transformer with underground feeder; 2 – measurement transformers; 3 – main circuit breakers; 4 – main bus; 5 – main bus air break and disconnecting switches; 6 – outgoing main power line; 7 – outgoing secondary lines (not mounted)

Figure 10. Close-up on main transformer (left) and circuit breakers (right)

Figure 11. Close-up on main bus air break and disconnecting switches

Circuit breakers are designed to interrupt normal or short-circuit currents. They may be remotely operated by a human supervisor, and they automatically open when electric parameters (current, voltage, etc.) become off their limits. There are five types of medium/high-voltage circuit breakers: oil, minimum oil, air-blast,

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sulphur hexafluoride and vacuum circuit breakers. Each type has some advantages and some disadvantages.
Oil circuit breakers have a steel container and their moving contacts are immersed is insulating oil. When a fault occurs, a spring is released, and the contacts are opened. An electric arc is produced, which volatilizes the oil around the contacts, producing a turbulence that renews the oil around the contacts, thus extinguishing the arc. These circuit breakers are relatively simple, but have the danger of explosion and use oil that is very aggressive to the environment.
Minimum oil volume circuit breakers use the same working principle, but they have an explosion chamber around the contacts and moving pistons, which inject high pressure fresh oil in the chamber where the arc is formed. They are more efficient than the first type and require lesser quantity of oil, reducing environment hazards and explosion risk.
Air-blast circuit breakers have the moving contacts inside a chamber where very high-pressure air is blown into when the contacts open, causing the arc to be extinguished. The high-pressure air is stored in containers, near the circuit breakers. This type of circuit breakers has enormous cutting power and is used in the highest voltages. However, the noise of operation is so loud that exhaust systems are required and they cannot be used near residential areas.
Sulphur hexafluoride (SF6) circuit breakers are totally enclosed, having their moving contacts sealed inside arc chambers filled with insulating gas SF6. They usually have moving parts, which renew the SF6 in the arc extinction chamber when the contacts open. This type of circuit breaker is usually used when space is critical, because they are the smallest type. Operation noise is also relatively reduced.
Vacuum circuit breakers use a working principle that is different from the one used by other types of circuit breakers: their arc chambers and moving contacts are sealed in vacuum, instead of some insulating material. They need very little maintenance, as the contacts never become polluted, and they are also very silent. However, their maximum rated voltage is about 30kV. They are used in places of difficult access, for example in underground distribution systems.
Air-break switches have a moving blade that engages a fixed contact, both mounted in insulating supports, operating in free-air. These switches are able to cut transformer excitation currents and line no load currents. They have arcing horns, where electric arc is formed when they are opened; the arc moves upward, becoming longer, and eventually extinguishing itself.
Disconnecting switches are similar to air-break switches, but they can’t interrupt any current at all: they must be operated only when no current flows through them. Disconnecting switches are intended to provide visible isolation of other components (transformers, circuit breakers, lines, etc.). These switches are constructed in the most simple and reliable way, without springs or other complicated mechanisms. When they are opened, gravity tends to maintain them that way.
Grounding switches are devices used to assure that lines are definitely connected to the ground (for maintenance security, for example). They have a moving blade similar to a disconnecting switch, for each phase. Obviously, they are operated only when line voltage is zero.

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Surge arresters are intended to protect several devices – namely, transformers – from over-voltages that may occur due to thunderstorms or switching surges. They are connected to the ground and provide a low impedance path for discharging surges directly to the ground, avoiding any damages in other more sensitive equipments. At normal voltage operation, they should remain with high impedance.

Current-limiting reactors are connected in series with the power lines, in order to increase short-circuit impedance and control short-circuit current gradient. The voltage levels involved are very high and overall impedance is low. So, without current-limiting reactors, the short-circuit currents would be enormous and circuit-breakers wouldn't be capable of cutting them. That would result in severe damages in many expensive and slow to repair components of the power grid.

Grounding transformers are used when it is necessary to create a neutral wire on a three-phase, three-wire system, transforming it in a three-phase, four-wire system. Usually, these transformers are three-phase autotransformers connected in zigzag, with the middle point connected to the ground. This helps keeping system balanced in the case of connecting single-phase loads between one line and the neutral.

Measurement transformers are used to reduce voltage and current to safer levels, in order to measure or monitor voltages and currents on the transmission lines and to provide electrical isolation between measurement and power lines. There are two types of measurement transformers: voltage transformers, whose primary winding is connected in parallel with the lines, and current transformers, connected in series with the lines.

Figure 12. Locomotive with container carrier

Some Details on the Model Railroad Construction and Operation

The model railroad is used by a locomotive that pulls a container carrier (Figure 12). This latter was built by fastening a loudspeaker magnet to a model coach bogie (Figure 13). Two reed relays (Figure 14) placed on each extremity of the track (Figure 15) are connected to a logic and timing electronic circuit (Figure 16). This circuit controls a locomotive motor drive [3] connected to the rails. The motor of the locomotive is powered via its wheels. When the container carrier passes over a

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reed, its contacts close; the logic and timing circuit makes the train stop for a few seconds; then, the train sense of motion is reversed and the train is set to move again.

Figure 13. Bottom view of the container carrier

Figure 14. A reed relay

Figure 15. Reed relay placed between the rails

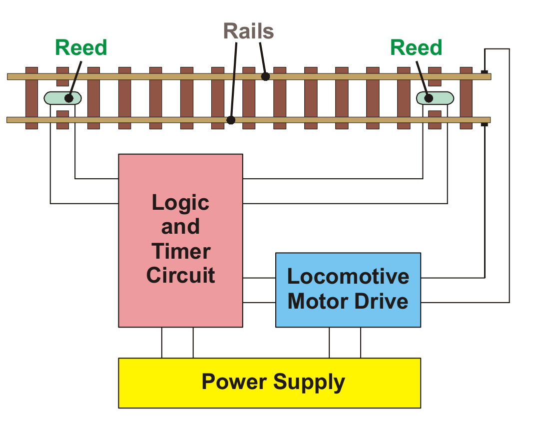

Figure 16. Train control system

Conclusions

A model of a thermonuclear power plant with electrical substation, built for educational purposes, has been described. Some construction details were explained. A brief technical explanation on the main components of real-world nuclear power plants and electrical substations was also given.
The model is very eye-catching and most suitable for classes or science-fair events. It has been successfully used in both kinds of activities.

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References

[1] Wildi T, Electrical Machines, Drives, and Power Systems, Prentice Hall International, 1997.
[2] http://en.wikipedia.org/wiki/Pressurized_Water_Reactor
[3] Mennis R, Comando bidireccional de motor, Elektor Electrónica, 79/80: 79-28, 1991.

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Children's Perceptions on Endangered Species and Threatened Environments: Results from Unique and Universal Project

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Introduction

Taking children to field trips can expand their understanding of concepts by letting them observe social and ecological systems, and concepts of world around them [1], because field trips help them obtain first-hand experiences in using scientific strategies (e.g. observing, collection and analyzing information, and drawing conclusion). Out-of-class experiences and activities, e.g. field trips, give pupils the opportunities to involve in direct contact with the various aspects of the environment [2] and engaging in these outdoor opportunities promote the pupils to develop affective (responsibility, sensitivity, self-confidence…etc) and action skills (responsible behaviours) as well as cognitive skills (knowledge) [2, 3]. Field work studies / field trips also allow pupils to observe, record, analyze, preset and interpret their own analysis and investigation [4]. Children can easily grasp the language of the nature and the cause-effect relationship within the nature when they are given chance to go to the natural environments (regions). This also helps students internalize the theory and abstract concepts taught during the classes.

As it is apparent in the findings of the existing research studies done with primary school students in Turkey [5, 6], lower grade students had some misconceptions about the ecological and environmental sciences concepts because of the previous experiences, peer talk and wrong orientations. Taking them to field trips and giving them chance to meet natural environment and to observe, collect data …etc can overcome their misconceptions.

U&U project aims at filling the gap between theory and the practice. Taking the children to the field trips and allowing them to have not only hands-on but also minds-on experiences, promotes the students to develop environmental literacy which is one of the ultimate aims of the environmental education. When students start to learn how eco-system functions and about environmental action strategies, they can start to develop responsible environmental behaviour (REB) [7]

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International U&U Project

U&U project that aims to be global and tries to reach children from different countries was started in September 2005 with the coordination of METU Foundation School, Turkey. Today, the Project is in its second year with the growing participation of different countries. The primary school students from Turkey, Romania and USA participated in the project in 2005 and then 2006. A group of Bulgarian students indicated their desire to participate in to the Project in 2006.

With this project, it is aimed to reach the children from all around the World and help them become aware of global values which are endangered species and threatened (regions) environments in this project. Within the project, students are taken to the field trips, wetlands and lakes (nearby to their schools) under the guidance of their coordinator teacher, and they are encouraged and guided to observe cause-effect relationship in the natural environment. Students witness the possible problems in those areas and try to find ways for solving and preventing these problems.

Purpose of the Study

The main purpose of the study was to reveal Turkish elementary school students' perceptions on endangered species and threatened environment. This paper presents in-depth analysis of findings of the case study focused upon Turkish children's perceptions on these topics.

Methodology

Turkish students' perceptions in the first year (2005) of the Project were reflected here by considering their responses to pre- and post- administration of the data collection instruments. The results revealed students' conceptions about endangered species, particularly Yanardöner plant *(Centaurea tchihatcheffii)*, also called as love flower, which is endemic and endangered, their attitudes toward the endangered species and threatened environments, and their motivation to act for helping protect those environmental values.

Sample and Sampling

Even though U&U was an international project including three elementary schools each from Turkey, Romania and USA (in 2005), this paper only focused upon a group of students from Turkey.

Twenty-one fifth grade Turkish students constituted the sample of the present study. These students were selected based upon their volunteer participation from coordinator school [coordinator of the U&U Project], METU Foundation School, Ankara, Turkey. All the fifth grade classes were contacted and asked for their participation in the project. A total number of 21 students (10 female, 11 male) showed an interest to participate in the project.

Along with a consent form, an invitation letter was sent to their parents. Parents kindly proved the consent form for their children's participation in the project, and accepted the invitation letter to attend in field trips and some of the student

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presentations.

Data Collection Instruments

Six different data collection instruments developed by the researchers were used. Each of the instruments pertained to any components of environmental literacy structured by Volk and McBeth [8].

The Knowledge Test including eight open-ended questions was designed to investigate primary school children's knowledge about endangered species and threatened regions, and to determine their source of knowledge on these topics.

The Attitude Questionnaire was designed to investigate primary school children's attitudes toward endangered species and threatened regions. The instrument consisted of 13 closed-ended items on a 4 point Likert-type scale (1-strongly disagree, 2-disagree, 3-agree and 4-strongly agree). For each item, the students were required to explain the reasons behind their tendencies and responses.

The picture form was designed to determine to what extent the students know the characteristics of the endangered species they were studying. The students were asked to draw a picture of Yanardoner Plant. The students were also required to indicate the characteristics of this species.

During the field trips, two different *Field Tests* developed by the coordinator teacher were used. The first one was designed to determine students' knowledge about the scientific experiments (identifying problem(s), determining variable(s), collecting data, interpreting data and presenting the results/findings) carried out during the field trips. The second one was designed to determine the students' knowledge of the endangered species upon which they focused.

The Interview Schedule including thirteen open-ended items was designed to investigate the students' perceptions on endangered species, threatened regions and the contributions of the project to themselves.

Data collection process

In order to assess students' outcomes and attainments, and to determine the extent to which the objectives of the project were attained, the instruments were administered to the students at the different time intervals during the project.

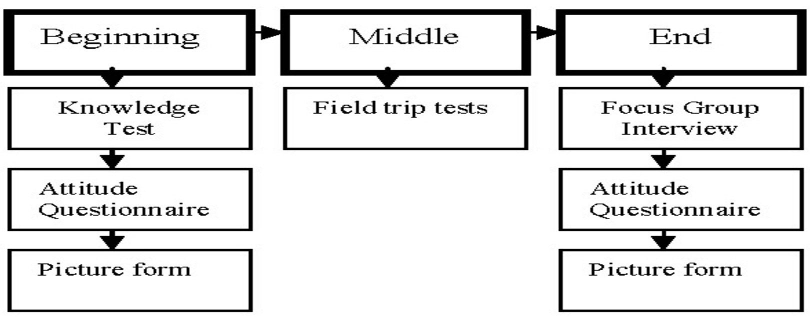

Figure.1 Data collection instruments used during the project

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The data collection process was realized in three main steps, at the beginning, in the middle, and at the end. How and when these instruments were administered was explained below.

(a) *Data Collection at the Beginning*: At the very beginning of the project, that is, before instructions and field trips were started, knowledge test, attitude questionnaire and picture form were given to the students and asked to fill out them in the classroom environment in order to determine students' initial knowledge about and attitudes toward endangered species and threatened environments. This process was realized to determine whether students had initial experiences, knowledge, conceptions and feelings about threatened regions and endangered species.
Having administered these instruments, regular meeting hours were scheduled by the teacher and the students and the meetings were organized with students as two class hours in each week. Then these meetings were held regularly with the participation of the students during the project. During the meetings, the Mogan Lake and surroundings were introduced to the students in an interactive environment. From time to time, the students were required to make searches in the internet and library and bring what they found to classroom to discuss on it / them with their peers.

(b) Data Collection in the Middle: During the process, field trips were organized to the selected threatened region, which was Mogan Lake nearby the school. In addition to the threatened region, students were asked to select one of threatened and/or endangered species living around the selected region. The Turkish students selected the Yanardöner Plant *(Centaurrea tchihatcheffii)* which is located only around Mogan Lake and is one of the endangered and endemic plants to Turkey.
Before and after the field trip, field trip tests aiming to determine students' initial (pre-) and further (post-) knowledge about endangered species and threatened regions were given to the students.
First test was given to the students at the beginning and at the end of the experiments that the students carried out by themselves with the water samples taken from Mogan Lake. This test was basically about determining their problem solving skills (including the steps of identifying problem(s), determining variable(s), collecting data, interpreting data and presenting the results/findings). The students were also required to reflect what they found in their experiments and interpret those findings.
Second test was given to the students during examining the Yanardoner Plant located around the Mogan Lake. The students were required to fill out the test based upon their observations, presentations done in the meetings and the search they did before the field trips.

(c) *Data Collection at the End*: After meetings and the field trips were completed, the picture form and attitude questionnaire, which were administered initially, were again given to the students in the classroom

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environment. Alternative to knowledge test, focus group interview was carried out with the students who were put into groups of five, two groups of five students, two groups of four students and one group of three students. The timetable for focus group interview was scheduled with the students and conducted in three weeks. Focus group interviews were carried out with these groups separately in the science laboratory in which the students felt themselves acquainted and comfortable.

Data Analysis

Since the project was under pilot testing, the instruments prepared were also piloted and tried to be validated. The data collected at the very beginning was analyzed initially and the necessary changes like wording were made for the last administration. Furthermore, most of the items in the interview schedule were developed based upon students' responses to knowledge test.

Since the instruments included not only open ended but also closed ended items, both qualitative and quantitative data analyses methods were employed. Once all the data was gathered from the participants, the data analysis procedure could begin.

Since the attitude questionnaire includes closed ended items with explanations, the responses given to those items were analyzed by use of descriptive statistics, particularly mean, standard deviation, percentage, and frequency. The explanations of each item were content analyzed. Before analyzing the attitude items, the reverse items were first manipulated. The total score of attitude questionnaire ranges from eleven to forty-four. The higher the students' score, the more positive their attitude toward endangered species and threatened regions.

Students' responses to open-ended questions in the knowledge test were written in the separate sheet and their responses were content analyzed.

Their initial and last drawings with the explanations on Yanardoner Plant were matched and the differences were noted in the separate sheet.

Interview with the students were recorded in the cassettes and later transcribed verbatim. Five focus group interviews were coded, and the themes and/or categories were emerged from these codes.

In order to ensure confidentiality of the students, the names were not given here. Instead, the initials of the students' names and surnames and their gender are stated in the quotations and pictures.

Results

The findings of the study are discussed here in four main titles, (a) students' knowledge, (b) attitudes, (c) skills and (d) responsible behaviours.

Students' Knowledge on Endangered Species and Threatened Environment

The students believed that there were some factors threatening to endangered and

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rare animals and plants. They claimed that unconscious behaviours toward the environment, destruction in living areas, air and water pollution, uncontrolled pesticide usage in agriculture, excessive hunting, urbanization, and deforestation threatened to the natural balance of the environment and endangered and rare animals and plants. Similar to species, the students also believed that some of the natural regions were threatened because of lack of regular control and protection, pollution, disposal of uncontrolled industrial and chemical waste, urbanization, uncontrolled construction, fires, using poisonous pesticides in the agriculture nearby these natural areas, natural processes themselves, hunting, and disposal of sewer.

Although there have been some protection measures taken to preserve these regions in the World and in Turkey, the students believed that these precautions and protections were not sufficient to deal with the problems. Students were more concerned about the insufficient warnings and the information about these regions and lack of awareness that people held. Students claimed that the people did not have adequate awareness and consciousness about these important regions, and the people were not sufficiently informed about these regions.

As their responses indicated, students' knowledge about other endangered species and threatened regions were limited. Even though some of the students knew about limited number of species and regions, they did not know why these were threatened.

Students reported that they got informed about the threatened regions and endangered species through the use of following sources, the internet, their teachers and schools, science books, encyclopaedias, documentaries, their parents, newspapers, the U & U project itself and the environmental club associated with the project.

As a source of their knowledge about the topics, the students asserted that the classroom instruction, classroom activities and textbooks were partially enough and/or not sufficient, because of the time limitation and structured content in the curriculum.

The students' pictures of an explanation on Yanardoner Plant indicated that their knowledge about this plants with regard to shape, characteristics, living and germination condition were limited at the very beginning of the study. However, at the end of the study, students were observed to have much more knowledge about this plant. Their drawings and explanations were more detailed. Four pictures of Yanardonar plant were selected among all drawn at the end of the study (Figure 2). The following four pictures reveal that students drew their pictures by considering detailed characteristics of the plants (shape of the petals, leafs, stem, roots and pistils).

The focus groups interview aiming to obtain students knowledge and opinions in-depth at the end of the study pointed out that the project meetings and field trips dramatically impacted students' knowledge on the selected topics. As reported by the students in the focus group interviews, they learned so many information regarding as Mogan Lake and the Yanardoner plants. They indicated that participating in field trips to Mogan Lake, preparing posters and presentations on these topics, making discussions with peers and parents, and searching in the internet contributed them to increase their knowledge and understanding on these

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topics. Their limited knowledge observed in the knowledge test was turned to be sufficient about endangered species, in particularly Yanardoner plant, and Mogan Lake and water quality assessment for these age group students.
At the very beginning of the project, the students were only talking about environmental problems which physically appeared in the natural areas (in particularly, Mogan Lake). It was emerged from the students' responses in interviews that they started to talk not only about environmental problems, but also about environmental issues which were more social and political in nature. These issues could be identified as disagreement associated with an environmental problem and its proposed solutions [9, 10].

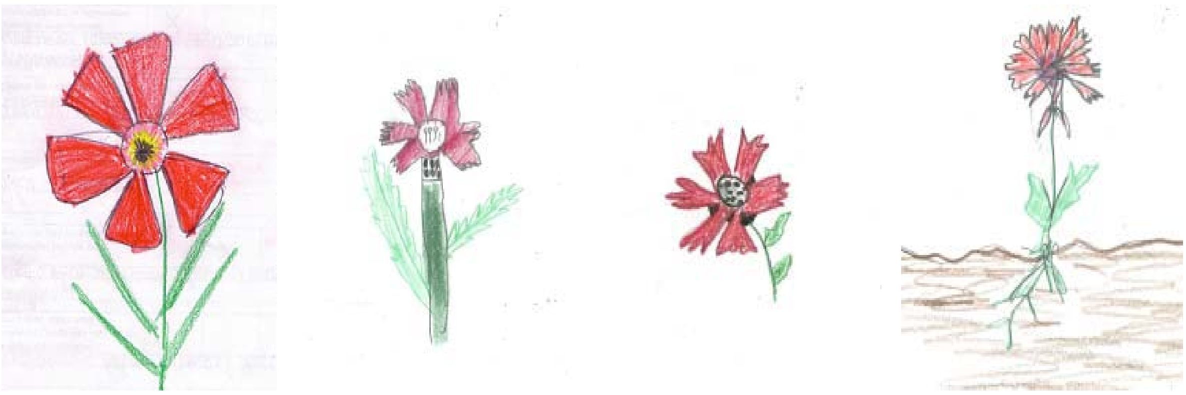

Figure 2. The pictures drawn by four different students at the end of the study

Students' Attitudes toward Endangered Species and Threatened Environment

Students' initial and latter attitudes toward endangered species and threatened regions were given in Table 2 comparatively. Their attitudes were generally positive. Students' pre-attitudes were appeared to be similar to their post-attitudes. The total mean score of the students from the attitude questionnaire is

$$\overline{X} \text{ (pre)} = 43.87 \text{ (Sd = 3.75) and } \overline{X} \text{ (post)} = 45.05 \text{ (Sd = 3.11)}$$

indicating their positive attitudes. The paired t-test between pre- and post-total scores indicated non-significant result, t (15) = -1.542, p>.05. Table 1 summarizes the paired t-test results.

	$\overline{X}$	Sd	t-test	SI
Pre	43.87	3.75	-1.542	.144
Post	45.05	3.11		

Table 1. Paired t-test result (valid case 16)

The correlation between students' pre-total score and post-total score was

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significant at .05 significance level, r (16) = .614, $p<.05$.
There were observable changes only for the items numbered 5, 11 and 12. These changes suggested that the project meetings and searches in the internet and in written documents helped them become aware of protection studies done for these regions and species, and changed their attitudes slightly.

#	Item	Response ***	At the beginning	At the end
1	The endangered plants and animals are needed to be protected.	Agree	20	18
		Disagree	-	-
2	The pesticides are needed to be used under control of agriculture engineer.	Agree	17	18
		Disagree	1	-
3**	The wild animals are needed to be killed.	Agree	2	2
		Disagree	17	16
4	I am very excited when I am doing search and examination about endangered species.	Agree	17	18
		Disagree	3	-
5**	Unplanned industry, population growth, and urbanization have no negative impacts on endangered species.	Agree	4	-
		Disagree	16	18
6	Humans' doing nothing on protecting endangered species and threatened natural areas makes me unhappy.	Agree	19	17
		Disagree	1	-
7	The natural resources are needed to be used carefully and cautiously	Agree	19	18
		Disagree	-	-
8	Attending a project aiming at protecting endangered species and producing a solution make me happy.	Agree	19	18
		Disagree	-	-
9**	I am approving that human makes change on the natural areas so as to build a new building, park areas and business office based upon their needs.	Agree	3	1
		Disagree	15	16
10	Each individual in a society need to do something for protecting the endangered species.	Agree	16	18
		Disagree	2	-
11	The projects aiming at protecting the endangered species and threatened natural areas in the world are adequate.	Agree	1	7
		Disagree	16	10
12	The projects aiming at protecting the endangered species and threatened natural areas in the Turkey are adequate.	Agree	1	4
		Disagree	16	13
13	Thinking on solutions for preserving endangered species and threatened natural areas make me happy.	Agree	17	18
		Disagree	1	1

*** Some of the students did not respond to some of the items in the attitude questionnaire.**
**** These items (# 3, # 5 and # 9) were reverse items.**
***** "*Agree*" indicates a total number of "Agree" and "Strongly Agree" responses, and "*Disagree*" indicates a total number of "Disagree" and "Strongly Disagree" responses**

Table 2. Students' responses to attitudes items (n=21)*

Students' affirmative attitudes were supported with their responses to "why questions" subsequent to each closed-ended items. Students were more concerned about the rights of the living organisms. They believed that the rare and endangered species and wild animals were needed to be protected because they also had right to survive like human beings, and they were a part of ecological cycle. If those species were destroyed and killed, the natural balance and ecological cycle would be accordingly ruined. As student stated, these species were also important because they created a natural beauty in the natural environment. Some other students were concerned about economical and tourist values of these species. To

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the students, because of these all reasons, they have to be protected and the agriculture done within the growing and locating area of these species should be carefully planned, and the pesticides should be used under the control of agricultural engineers. Similar to protecting species, they believed that ensuring the sustainability of the natural and ecological balance of the natural regions was also necessary for all living organisms.
Even though a few students said boring, most of them reported that being in the project and doing research on and thinking on the solutions for protecting endangered species made them excited and happy, because by doing this, they believed that they could get informed about endangered species and try to find ways for saving their life. One of the students reported that "*When I am in the project, I feel myself like super-man. That is, I can save the life of living things*". Furthermore, they indicated that involving in these studies and projects would support endangered species' life, and some other students reported that we needed to protect them because we needed them for natural cycle.
They believed the importance of every citizen's being responsible of helping protect endangered species and threatened regions, and resolve the problems and issues. Otherwise, these species would be extinct and the natural balance would be ruined. They believed that this was necessary not only for the natural environment but also for human being them. When the natural balance was destroyed and the natural sources were depleted, this situation would directly influence the life of human being and make the life worse. As it was indicated in students' responses, they inferred dual relationship between natural environment and life of human being.
Some of the students proved that a construction(s) in natural regions could be done because we needed it, but they thought that these constructions should be done carefully so as not to interfere with natural balance and ecological cycle. The other students were totally against constructions in the natural areas, because they thought that these constructions would totally ruin the natural balance and destroy the animals' nests.
Thinking on the solutions and behaving accordingly for protecting endangered species and threatened environments made the students happy because they believed that they saved animals' and plants' life, and acted as an actor for ensuring the sustainability of the natural balance and ecological cycle.
It is apparent that some students' negative feelings (such as toward pesticide usage, feeling unexcited, the effects of uncontrolled construction, individual responsibility, and the protection studies in Turkey and in the World) observed at the very beginning were turned to be positive at the end of the project.

Students' Problem Solving Skills

At the very beginning of the study, in the knowledge test, the students were asked about what the water quality parameters were like that they were going to test / measure by using water samples taken from Mogan Lake. A few of them indicated that they knew the meaning of one or two of those scientific terms, but nearly all of them reported that they did not know how to measure them.
During the project, the students were taken to the field trips in which they were

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required to observe and test three types of parameters in order to get qualitative and quantitative data. These were: (1) physical parameters of water quality such as temperature, depth, and turbidity, (2) chemical parameters of water quality such as DO, pH, nitrates, phosphates, iron and copper and (3) biological parameters of water quality, such as phytoplankton, zooplankton, insects and amphibians.
The field tests initially administrated supported to the findings of knowledge test. Under the guidance of their teacher and field assistance, each group of the students (two students in each group) were required to make observations around the Mogan Lake and determine the pollutants, take water sample from the Lake, analyze these sample by making use of easy-to-use experimental equipments, and share and discuss the results of their experiments with their peers.
The field trips and discussions among the students pointed out that the students started to critically and deeply analyze the problems in Mogan Lake through their observations, discussions, collaborations and the use of hand-on science experiments, and think about solutions of the problems in this Lake more critically.
Once the observations around the Lake and experiments with water sample were completed, the students were taken to the other area nearby the Lake. This area is the only place in the Turkey in which Yanardoner Plants are growing and germinating, and planted and protected by the biologists and scientific organizations. The students were instructed here by one of the scientist who is working on these plants. The students were required to make observation inside and outside of the protected areas and write down their observations to the second field tests given to them. Students' responses showed that students scrutinized the plants (petals, stem, roots…etc) and observed the living conditions of the plants. It was apparent in the responses that their investigation and problem solving skills were improved.

Students' Responsible Environmental Behaviour

At the end of the project, the students were observed to be highly motivated toward taking responsible action so as to protect endangered species and threatened regions. They indicated that even though there were some protection studies for preventing the problems in Mogan Lake and around, they were few and not sufficient to overcome all the problems. They claimed that the precautions taken for protecting particularly for Yanardoner Plants were not sufficient, either. They believed in the importance of taking responsible environmental behaviours for protecting those species and regions. The findings pointed out that Turkish children were willing to participate in the protection studies jointly coordinated by local ministry and Non-governmental organizations for the purpose of ensuring the sustainability of those species and natural regions which were located nearby their school.
Some of the students mentioned that after participating in the project, they started to go to Mogan Lake with their parents so as to pick up spilled garbage around the lake and talk to the people who came to that place for a picnic and spilled their garbage in the Lake. Furthermore, some other students talked about these topics with their families, schoolmates and relatives in order to let them know the

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importance of these regions and plants as environmental values.
Some students indicated that they were planning to prepare presentations and invite the people to the speeches, and to contact with other people, local NGOs and local governmental officials to encourage them to start a project and increase the awareness among the society.

Conclusions

An in-depth analysis of twenty-one Turkish students' responses to six different data collection instruments supported that environmental behaviour, one of the ultimate aims of EE, was associated with environmental value [2, 11], environmental knowledge [7, 11], environmental awareness [3], environmental sensitivity and self-confidence [2]. Furthermore, this study also pointed out that the more the children had awareness of the environmental problems and issues, the more they were motivated to take responsible action and act accordingly.
The children voluntarily participated in the project because they indicated that they would like to save the plants and animals, and natural regions. At the end of the project, they were observed to be fully motivated and have self-confidence to take some responsible action for protecting Mogan Lake and sustaining the life of Yanardoner Plants.
The findings in this study were parallel to the findings of the study done by Palmerg and Kuru [2] in that the students were appeared to have three groups of conceptions, egocentric, guardianship and eco-centric conceptions.
Turkish children were willing to participate in the protection studies jointly coordinated by local ministry and Non-governmental organizations for the purpose of ensuring the sustainability of those species and natural regions which were located nearby their school. The children believed in that destruction in living areas, air and water pollution, pesticide usage in agriculture, excessive hunting, urbanization, and deforestation were negatively influencing the natural balance of the environment. They believe in the importance of taking responsible environmental behaviours for protecting those species and regions. Three different types of behaviours were observed in students' actions and plans in order to help prevent and resolve the problems in Mogan Lake and around, physical action (eco-management), public and individual persuasion, and political action.
As far as their responses to attitude questionnaire were concerned, their attitudes toward the endangered species and the natural environment appeared to be high.
This study showed the importance of field trips for developing environmental awareness and knowledge, positive attitudes and responsible environmental behaviours. For this reason field trips should be included in extra-curricular activities in schools.

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References

[1] Taylor SI, Morris VG and Cordeau-Young C, Field Trip in Early Childhood Settings: Expanding the Walls of the Classroom, Early Childhood Education Journal, 25, 141-146, 1997.
[2] Palmberg IE and Kuru J, Outdoor Activities as a Basis for Environmental Responsibility, Journal of Environmental Education, 31, 32-37, 2000.
[3] Yerkes R and Haras K, Outdoor Education and Environmental Responsibility, (ED 414 112, ERIC Document reproduction service), 1998.
[4] Neal P, Handbook of Environmental Education. Routledge, London, UK, 2004 http://site.ebrary.com/lib/metu/Doc?id=1005 8342&page=105
[5] Bozkurt O and Aydoğdu M, İlköğretim 6, 7, ve 8, Sınıf Oğrencilerinin “Ozon Tabakası ve Görevleri” Hakkındaki Kavram Yanılgıları ve Oluşturma Sekilleri, Kastamonu Eğitim Dergisi, 12: 369-376, 2004.
[6] Çobanoglu EO, Er DZ, Demirtas E, Ozan B and Bayrak C, İlköğretim Ögrencilerinin Çevre Sorunlarını Algılamaları, Özet kitabi (s. 1032-1035). 15. Ulusal Egitim Bilimleri Kongresi, 13-15 Eylul, Muğla Üniversitesi, Mugla. 2006.
[7] Dresner MG, Environmental education at summer camp, Journal of Environmental Education, 25: 35-42, 1994.
[8] Volk T and McBeth W, Environmental literacy in the United States: What should be…What is…Getting from here to there, A report funded by the U.S. Environmental Protection Agency and submitted to the Environmental Education and Training Partnership, NAAEE. Washington, DC: U.S. EPA, 1997.
[9] Hungerford HR, Litherland RA, Peyton RB, Ramsey JM and Volk TL, Investigating and evaluating environmental issues and actions: Skills development program (Teacher Edition), Stipes Publishing L.L.C: Champaign, 1996.
[10] Marcinkowski T, Anderson G, Drag J, English P, Lunsford J and Sward L, The Everglades case study: An extended case study for the investigation of a threatened watershed and ecosystem (A Student Work text). Florida Institute of Technology: Melbourne, 2000.
[11] Karch P, Environmental awareness in Germany and The USA: A Comparative study of two selected students bodies, Unpublished doctoral dissertation, University of Southern California, California, 2002.

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An Intergenerational Research Motivation-Relation between Mathematics and Artistic Decoration of Animal Skin

Reis R

Introduction

Relationships between the art and beauty of pictures, geometric or not, paintings, virus ways, cellular images, sculpture, music and mathematics had nowadays come up to the public bringing fine and true master pieces of Art.

Figure 1. Leopard

Figure 2. Zebra stripes

A great part of these relationships had been known for many centuries. What is now new is that technology development brought great interactivity between Art and Science. On this interactive context the main purpose of my talk is to look at the artistic pictures of Keith Devlin's renowned book Life by numbers and point out how mathematics became a type of language which is very creative and nice, and how the curiosity of a child in an intergenerational relation could motivate such a deep question.

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The search

The motivation

I will start my talk by presenting a poetic phrase by James Murray, a well-known mathematician from the University of Oxford (England), reproduced by Keith Devlin on the above-mentioned book:

When I ´m walking in the woods, I find it quite difficult not to look at a fern or the bark of a tree and wonder how it was formed -why is it like that?

Figure 3. Giraffes stripes

Murray is the father of a very beautiful daughter and frequently reads bedtime stories to her. One of them concerned a fantasy on how a leopard gets its spots through the five fingers of an Ethiopian tribesman who touches it with them. Although the young girl loved the story she was already clever enough to ask him how does the leopard really get its spots?

The two generations (father and daughter) began thus teaching each other. Trying to find a good explanation for her daughter, Murray asked his biologist colleagues about it but couldn't get a concrete answer then. He also asked them how tigers and zebra get their stripes.

Murray noticed that his biology colleagues knew that the cause of an animal's coat coloration is the same chemical product that makes fair skinned people develops a tan whenever exposed to the sun: a chemical substance called melanin, produced by cells just beneath the surface of the skin. However, they couldn't explain why the shape of leopard spots is so different from tiger and zebra stripes. He was also comparing the above leopard skin with a cougar's

Keith Devlin then tells us how Murray became more and more curious and deeply interested in explaining the fact to his daughter. He began researching with such enthusiasm that he wouldn't stop for twenty years until he could finally offer a mathematical explanation.

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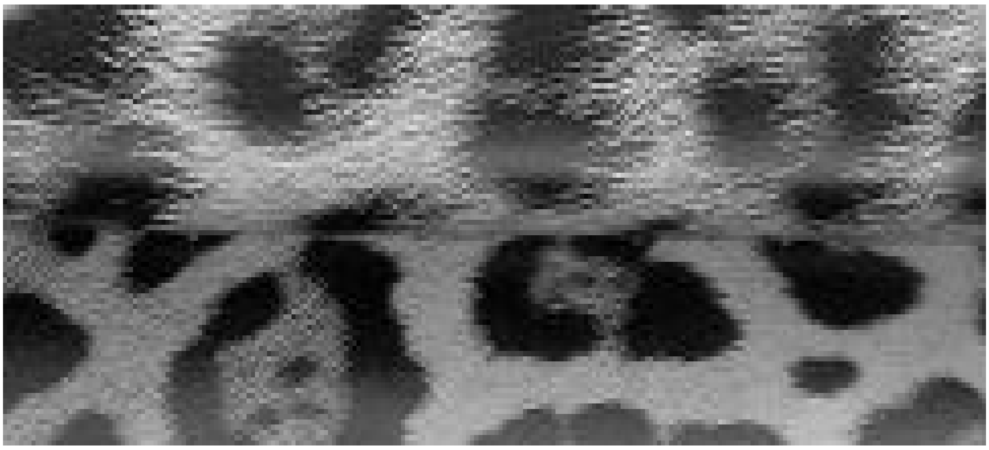

Figure 3. Comparing a leopard and a cougar

A mathematical model

Indeed he had developed a mathematical model related to the chemistry laws that rule diffusion and reactions. As an experimented mathematical researcher he assumed the following Axiom 1:

Some chemicals stimulate the cells to produce melanin.

From it he inferred that visible coat patterns are the reflection of invisible chemical patterns in the skin. If the chemical concentration is high, melanin coloration will appear, if it’s low the skin will be mostly colourless. For Murray the question now was:

What causes the melanin-inducing chemicals to cluster into a regular pattern formation so that when those chemicals “switch on” the melanin to turn colour, the result is a visible skin pattern?

To obtain a question he applied a reaction diffusion system which is a system in which there are two or more chemicals in the same solution (or the same skin) reacting and diffusing throughout the solution as in a fight for territorial control. Then Murray assumed the Axiom 2:

In the skin two chemical are produced: one stimulates the production of melanin, the other inhibits this production, and production of the stimulating chemical triggers production of the inhibitor.

From this he considered that some “islands” of stimulating chemical could appear surrounded by “fences” of inhibitors that originate the formation of melanin “spots”. If the inhibiting chemical diffuses faster than the stimulator and a concentration of the stimulating chemical is formed, thus triggering the production of the inhibitor, the faster-moving inhibitor could encircle the slow diffusion stimulator. Further expansion is in this way prevented, and a “spot” of stimulator can form, encircled by

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a ring of the inhibitor.

An analogue case

Trying to clarify the system, Murray presents an analogy: Suppose, he says, that you are in a very dry forest and the authorities are fear forest fires. They have helicopters and fire-fighting equipment stationed throughout the forest. If a fire breaks out (the stimulator), the fire fighters (the inhibitors) spring into action. Of course helicopters can move much more quickly than the fire (the inhibitor chemical diffuses faster than the stimulator)
However, the intensity of the fire (high concentration of the stimulator) is such that the fire fighters cannot contain the fire at its core.
So, using their greater speed they outrun the front of the fire and spray fire-resistant chemicals onto the trees, and when the fire reaches the sprayed trees, its progress is stopped.
Seen from the air, the result will be a blackened spot where the fire burned, surrounded by the green ring of the sprayed trees and beyond it the green of the remainder of the forest.
If a number of fires break out all over the forest, the landscape seen from the air will show a pattern of patches of blackened, burned trees interspersed with the green of the unburned trees.
If the fires break out sufficiently far apart from one another, the resulting aerial pattern could be one of black spots in a sea of green. On other hand if nearby fires are able to merge before being contained, different patterns could result.
So, the pattern will depend on various factors, in particular the number and relative positions of the initial fires and the relative speeds of the fire and the fire fighters (reaction diffusion rates)
With this model in mind Murray concentrated on the question: Are there any rates that, starting from a random pattern of fire sources, would lead to recognizable patterns, such as usual spots or stripes?
Then he took the well-known partial differential equations of the type

$$\frac{\partial^{2f}}{\partial t^2} = v^2\left(\frac{\partial^2 f}{\partial x^2} + \frac{\partial^{2f}}{\partial y^2}\right)$$

which describe the way chemicals react and diffuse and assumed that he had only two chemicals reacting and diffusing at different rates. Putting these assumptions and equations into a computer Murray was able to turn them into pictures on the screen, showing the way the reacting chemicals dispersed. Then, by changing some constants (numbers) on the equations in the computer, he realized that he could transform a spotted tail into a stripe.

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Figure 5. Transforming spots into stripes (3(

So, as Devlin describes, Murray was surprised that with only two chemicals his mathematical model could produce dispersal patterns looking exactly like the patterns on the skin of animals. He could then answer to his daughter that her question might be found by looking at reaction-diffusion systems.

Simulating

Murray then went on changing numbers on the equations which correspond to the area and shape of the skin region: for very small regions there was no pattern at all, for larger regions he got stripes, small spots of leopard's, large spots, reminiscent tail stripes, zebra stripes, the small spots of the cheetah, the large spots of the giraffe for very large regions he got no patterns at all. The next question he asked himself was:

Besides the area and the shape of the skin region, should there be a reason for leopards to produce spots and tigers stripes, given that leopards and tigers have very similar sizes and shape?

Then Murray, as it is common in mathematical research, made a conjecture: This difference has to do with embryonic development.
He then made a computer simulation of a leopard embryo developing its spots conjecturing that the pattern we see on the adult animal will depend on the size and shape of the embryo when the process occurred.
He also looked at other animals:
On the case of mice, according to Murray's model, no pattern is possible (the chemical reactions occur when the embryo is very small)
On the case of the zebra there is a four-week period early in the year-long gestation

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during which the embryo is long and pencil-like and, according to Murray's model, if the reactions occur during this period, the resulting patterns will be stripes.

Final Considerations

Step by step, for twenty years, Murray established, regardless of some questions (that are still open problems) a quite clear relation between some mathematical equations and different artistic decoration of animal skin and it all occurred because of a little girl's question.

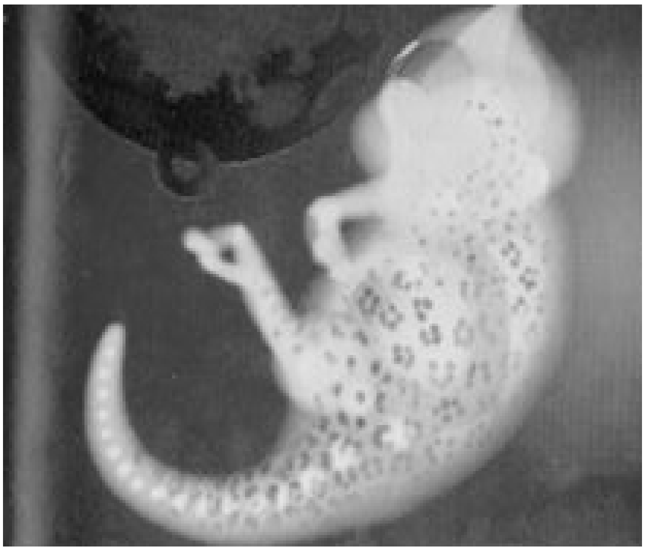

Figure 4 Computer simulations [3]

Acknowledgements

I should like to thanks the Association Hands on Science on the person of the President of this Conference Prof. Manuel Felipe Costa to invite me to help to prepare it and to trust my work on a nice solidarity and collaboration.

References

[1] Ivins Jr and William M, Art and Geometry-A study in space intuitions, Dover Publications: New York, 1964.
[2] Ghyka M, The Geometry of art and life, Dover Publications: New York, 1977.
[3] Devlin K, Life by numbers, John Wiley & Sons: New York, 1998.
[4] Reis R, Educação pela Arte, Universidade Aberta: Lisboa, 2003.

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Work Done in Kindergartens by Our Students Orientated by Distance Learning

Seixas S

Introduction

In Pedagogic and Scientific complement course for Kindergarten teachers, the last discipline is called Seminar. This discipline develop along one year and consists in practical work done in each college by our students and the evaluation of our students were made by the written report, according by the manual [1], and by oral presentation of work and oral discussion . Our students are kindergartens teachers without university graduation, this is why they must do this course in order to maintain their works.

The aim of this discipline is to learn the kindergartens teachers how to plain an activity and how to evaluate their impact in children and involve community. In last two years 29 students were orientated by methodology using in distance learning.

Tools used to orientation of seminars

Because our students came of all parts of the country, the seminars were orientated by distance using the tools at disposition to this type of learning: telephone, videoconference, e-mail and learning platforms. In this case the students, in general, did not like use learning platforms, which is Moodle platform. In fact were verifying that a lot of them did not trust, so the way that almost the students like is by e-mail or telephone.

In the first step of the work that the students must done, is to choose a theme and justify their importance and establish the objective. Second step is to prepare the temporization of activities, identifying for each one of the objectives.

After applying the project evaluated if objectives were reach and if not why. They also determine what were the impacts of this work done with children in community. In some cases the community is small and the activities of children have reflection in the changed of the behaviour of the families.

Theme Chosen by Students and Work Development

The themes chosen by students were different and each student has different

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requirements, this may be the reason why e-learning platforms were not the tool chosen by students.
The themes chosen by students were about subject:

- vegetable gardens, its importance and the role in human alimentation,
- protect endemic flora,
- care with pine forest,
- protect species of animals in particular endangered species,
- knowing the needs and importance of cattle,
- care of domestic animals.

The theme around vegetable gardens, the children helped to prepare the field, put seeds in it, different techniques of planting, different roots, stems, flowers and fruits. The children take care of the garden and development the concepts of what's the needs of plants, meanwhile some of the students put in classroom plants in water and add some colour to the water in a way to explain that in fact plants need water, also put some plants in dark to show the children that light is essential. When they made the crop, with the vegetables the children participate in the elaboration of a salad and a soup to eat at lunch. The repercussion of these works with children is that they start in their homes to eat soup and salads without reclaim. Some parents notice that they also want to participate in garden careering.
The theme of protect flora were developed by our students that lived near a protect area. The work with children starts to show the differences between types of plants (Figure 1). Visits to the protected area and teaching why and how they can preserve and respect the nature. A lot of works were done in field and in classroom. In public locals of exposition the works like drawings, gluing and clay pieces were exhibited. The result in community is that all members of the family learn what the importance of the flora nearby and behaviour changes.

Figure 1. Children visiting a botanic park

Figure 2. Children made classroom drawing about turtles

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In Portugal the fires of pine forests is a concern. So some students that live nearby pine forest development the work with the children in this area. First try to learn to children what is a pine, the importance of pine to their habitat. They went with children and observed the other communities of animals and plants living in pine forests. Also explain the importance of wood to men and also the importance of resin. Development in children the correct behaviour when visiting the forest and what to do if saw a fire. These works haven't immediate results in community but in future these children remember some of the concepts.

All the students that chose protect endangerment animals had good results. Normally the students, in these two years, chose endemic species came from the isles, such as marine turtle (Caretta caretta) of Azores, Cory's shearwater (Calonectris diomedea) of Azores, Mediterranean monk seal (Monachus monachus) that is one of the most endangered mammals in the world and lived in Madeira archipelago and Zino's petrel (Pterodroma madeira). All these students investigate first the specie and then programmed the activities.

One of the most interesting is that marine turtle die if swallow a plastic bag, children assimilate so good the concept that try to change attitudes of their parent to use more the same plastic bag and speak with all people around to never quit a plastic bag to sea because the turtles can die. In general the work done with children that includes visiting to nature, to local museums, dramatization, drawings (Figure 2), etc, lead that children and their families learn about specie and cares necessary for preservation of it.

The work developed with children about respect, needs and how cattle are important to Human Being is very important to the children understand the aliments that eat. In case of cow the children participated in doing cheese (Figure 3) and butter. Normally this theme had no repercussion in community except that all of children asked persons of family that have cattle if they call the vet to medicate, given vaccines and take care of them.

Figure 3. Children made cheese

Figure 4. Dog made by children with recycled material

The theme of respect the domestic animals is centre in cats and dogs. The aim is to take care of animals and avoid abandoned animals in the street. Our students done

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with children a lot activities and one done a “sculpture” of a dog with empty bottles of water and other material (Figure 4). As happen with last theme children asked to all persons knew if animals have a vet and how often are the visits. Some asked to parents to adopt an animal.

Problems Felt by Students

During First Stage

The first type problem of students is what theme to chose. After is given questioner to fill where the students must wrote the theme, objective, justification of the chose and methodology chosen. During the period giving to fill it the students prefer telephone to put their questions. In this period they contact a lot with us. During this period the average of contacts by students was 5 times.
Was establish a data for conclusion of these period and they send us by email or by post. Was evaluated and if considerer ok they continue is work.

Application of Work

During the application of work the email is preferred by students. Normally the first questions were theory about subject and they want bibliography references to understand the theme. The need of bibliography was more evidence in students that chose an animal endanger, local animal and endemic flora. In this theme is necessary teaching the student how to distinguish the different species.
They send us schemes to given an opinion, asked how to programmed the things to do in visits with children, what kinds of entities can they contact, what persons can they invited to the classroom, send us the questionnaires that they given to parents of the children to fill, asked how to deal with legal questions such as photograph the children and use these to put in written work and use in future, etc.
During these stage the contacts were constant and in some cases three or four days a week.
After every activity or in end of activities was necessary evaluating the repercussion of them and identifying problems and things to be changed in future actions. These also reveal complicated for the majority of the students (about 70%).

Write the Work

The roles to write the work was establish in manual of seminar (general for all themes, in this paper only referred theme of biology).
The students contact to ask the items referred in contents, and they always had problems in writing everything in the 20 pages. Annex can be apart but it only allow put their photos and a copy of questionnaires done.
During the writing, normally, contact to ask the role and with doubt about how to introduce bibliography references in the middle of the text and how to do final references. To the last group orientated was send to all a text with all these explain and with examples. But when the final work was evaluated verified that a few number did not understand everything and done mistakes in it.

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In this stage the contacts of students was by email and two times per week (average). A very few try to use Moodle platform at this stage.

Presentation of Work

To present the written work orally, they have 10 minutes, the doubt is what tool to use. The students of continent went to university in Lisbon to done this presentation and students of islands done it by videoconference. The tool chose after our explanation was computer program PowerPoint.

Conclusions

This distance teaching is ideal for this kind of work because allow a permanent contact between teacher and students. The doubt that the student had can be explain in a few time. For the teacher was only necessary to have a computer with access to internet. Is equal a very good tool when our students came for all parts of country. In relation to the evaluation done by our students of the impacts the work had in communities the results were very good. In a lot of communities the mentalities of persons who contact with children (family, friends, neighbours, etc.) in fact stay more alert to several problems.

Acknowledgements

To my students and their parents that allow the use of the photos.

References

[1] Pereira A and Miranda B, Problemas e Projectos Educacionais, Universidade Aberta, 2003.

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Aquarium as a Tool for Teaching Sciences at All Grades Levels

Seixas S and Martinho M

Introduction

Teaching sciences is not easy in classroom and students need to contact with real situations to understand the theoretical concepts. Is also not easy arranging an activity that involves and allows practical activities for disciplines such as biology, physics, chemistry and mathematics. One toll that can be used is aquarium in classroom. Normally the aquarium stimulates a lot of interested in the students, and is a moment of learning and relaxing.

What kind of environment and fishes in it

The first step is to choose what kind of environment. If the objective of set-up an aquarium is to study a determine environment, is easy. Otherwise if objective is using the aquarium as a tool to teach sciences in general, our advice is to choose a warm freshwater environment, because is easy to maintain and have a lot of potentialities as you can understand below.

Our advice is chosen environments with warm water. Is easy to put a thermostat and maintain the temperature than put a chiller to maintain low temperature and the last equipment is very expensive. The other reason to choose warm water is because fishes that lives in that conditions are colourful and have more attractive, in general.

The marine aquarium can be done in classroom, but the price of the equipment is higher, time necessary to the stabilization of the aquarium is longer and his maintenance is more complicated.

Choose a freshwater environment aquarium allow the classroom study in advance what kind of river or lake they like to set-up.

In first levels the teacher can explain that the current, temperature and water chemistry is different. This can be done showing photos of rivers and lakes and chemistry is easy if different kinds of bottled mineral and natural water are given to taste to the students.

In high levels can be explain the different conditions of environments and put students to study what the differences in water chemistry, current, etc, between the

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different environments. Can also study what species are in endangerment in each habitat. Our advice is to study a river environment with current, one of lakes of rift (Malawi or Tanganyika), Amazonian environment and Asian environment. The students can also study the needs of the fishes of each environment and compatibility between them. Composition of decoration must be study and the possibility of introduce it in each environment. Is also necessary study the behaviour of fishes if is better to maintain a couple or maintain a shoal. If were considering: a rift lake of Africa, which has high pH, calcareous stone and gravel, must be chosen, Amazonian river that have low pH, natural roots are the appropriate. The necessary current also be study and students calculated the power of the pump need for an aquarium and to a determine environment.
Temperature is very important and in warm water are a lot of fishes with different requires. For example Amazonian environment the temperature is 28ºC and in Rift Lake is 25ºC.
Fishes live in different water layers. There are fish species mostly swim near the surface, in the middle or near the bottom of the aquarium. In order to have fish in all water layers is necessary considerer this when selecting the fish.

Plants

The aquarium must have plants. A beautiful planted aquarium is a relaxing and decorative. Apart of decorating plants also help the maintenance of a healthy aquarium and offer the fish hideaways and reduce the stress. Plants are also, good places to young fish hide from the adults.
Plants are an excellent oxygen provider and remove nitrate that is an algae grow promoter.
The plants to introduce in aquarium must be of different types and with optimum of living appropriate to environment chosen. Is interesting choose a plant that gives flowers. In classroom can be discuss the different types of plants and their requirements. The quantity of light, radiation necessary and temperature are essential to a good grown and to maintain healthy plants.
Another aspect to take in account is avoiding plants that the fish chosen to eat.
When was considered the height of plants there are three types. Foreground Plants that must be smaller to not obstruct the view into the aquarium. Middle ground plants that can be solitary or planted in groups and backgrounds plants that decorating the back of aquarium and help to hide the material necessary for the correct functioned of it.
Depend of the environment chosen can also be introduce floating plants.
Plants must be “fed”, they must be had a good substrate (like home plants) and in some cases must be added to water a fertilizer.

Set-up the aquarium

To set-up the aquarium is need the glass aquarium. The aquarium of 80 cm length is enough, if there is space limitation it can also be an aquarium of 60 cm length.
The localization of aquarium in classroom must be appropriate. Choose a quiet

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place away from direct sunlight, because sunlight can promote algae growth. The power supply should be above the aquarium, if possible, to prevent water spills going into the outlets during maintenance. After put the tank in final localization, must prepare the other equipment necessary: filtration system, heater and lighting.
To have a good water quality is necessary have mechanical filtration and biological water cleaning. In the last one microorganism, such as bacteria, make that pollutants such as fish excrements and dead plants are broken down biologically. Both of these process can be done by modern extern filters, is only necessary put inside the filter sponge to made mechanical filtration and a substrate that provides ideal condition for bacteria (these must have large and rough surface).

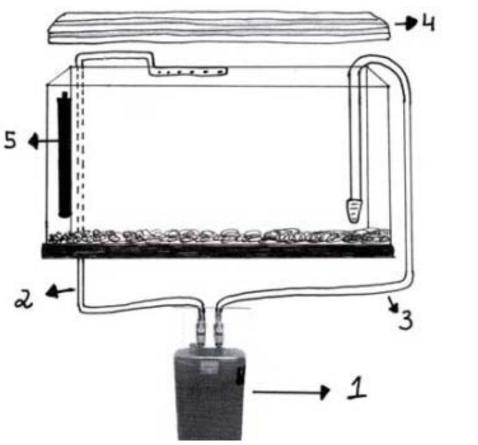

Figure 1. Scheme of an aquarium with equipment. 1 – External filter, 2 – Water from filter to aquarium, 3 – Water from aquarium to filter, 4 – Lighting, 5 – Heater

Figure 2. Aquarium with 60 cm length after set-up with Amazonian environment

The bottom must have a substrate that contains essential nutrients, valuable humid acids, as well as trace elements, that provide the plants with everything they need. After that a layer of gravel were added (Figure 1).
The gravel and decorative pieces must be natural, such as roots, bog wood, stones (granite, limestone, lava, etc.), these as referred above must respect the environment chosen.
Before start put decoration and plants inside the aquarium must be planning the decoration design, technical equipment in the aquarium (filter, heater, etc.) can be hidden in such a way that they become invisible when you look to the aquarium.
After decorating the aquarium and put the plants you can fill it with water and turn on the equipment. Tap water needs to be conditioned according to the requirements of the fishes. The tap water quite often has disinfecting chemicals such as chlorine to kill dangerous bacteria and pathogens. But the chemicals also provoke damages in fish and kill bacteria of the biological filter. The products to conditioner the tap water are easily found in commerce. When fill the aquarium put a plate in bottom to avoid the flux of water remove the gravel.
Fish are only added a few days later, with this allows the bacteria to grow in our

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filtration system and all small particles that stay in suspension after filled the aquarium will be in the bottom of the aquarium or in the filtration system.

Maintaining the aquarium

After the aquarium is functional, with all animals and plants in it (Figure 2), another step is begun - the maintenance period.
Students collect data, with a periodicity estimate before, from an aquarium by measuring and recording water temperature, pH, GH, KH, nitrate, nitrite and ammonia levels. The data can be plot in a graph, and the information studied. Observe the trends can be correlating the differences with events in aquarium. For example if water is changed and the new water is from home canalization can be seen pH variances. After setup and before the aquarium is stable the levels of nitrate, nitrite and ammonia are an excellent period to explain in high levels the nitrogen cycle. If pH must be correct, adding products, the quantity of product necessary can be done as an exercise of chemistry in classroom.
In biology classes the student can observe the growth rates of the different animals and plants and register these.

Figure 3. Cichlid Fishes with fry

Figure 4. Cichlid Fish protecting the nest

The type of food added to fish can be also a good example to study different types of alimentation. Introduce a leaf of spinach in aquarium lead to some herbivorous fishes going to eat it and some carnivorous will try it and then throw out the spinach. Is interesting observe some herbivorous graze on algae that grow in glasses and decorative things.
The observation of coloration of fishes (when they have sexual dimorphism) is a good away of understanding the differences and also observed that before spawning period the colours are intensifying. The courtship period, if the students were lucky to be observed the aquarium in this period, is also very interested to observe a particular behaviour.
The different types of reproduction can also be observed, if you choose a fish that easily reproduces and in aquarium you have fishes that the parents take care of the fry, like the fishes belongs to cichlid family (Figure 3) the students can observed a

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very interested behaviour (Figure 4).
If the aquarium have livebearers can be easily observe the behaviour of viviparous and students can compare the differences.
There are some cares that is necessary for a healthy aquarium. One is water changed, 20 % per week is good. Cleaning the external filter is also necessary. The sponge can be wash normally but biological part no, because is necessary prevent the dead of the bacteria. Algae can be removed from the tank glass with an algae magnet or scraper. Regularly remove any dead leaves from live plants as was done to home plants. If plants need some substrate it must added to water.
The alimentation required by fishes lived in an aquarium can be different and is necessary given different kinds of food in a way of given to everyone their appropriate food. Take care to do not overfeed the fishes as this will cause excess waste in the water which will settle at the bottom of the tank and need to be removed.

Final Consideration

With an aquarium in classroom students understand the relationship between producers, consumers, scavengers, and decomposers.
The aquarium allows students to understand the biological concepts as competition for a territory, between animals and between plants. Furthermore, by studying its chemistry, students realize how quite dependent the biotic community is on the abiotic components of the system.
In relation to chemical of water students can learn the nitrogen cycle, pH, hardness of water and how these parameters changed.
Students become sensitive to the effects of destroying part of an ecosystem or removing a particular organism. They also consider more complex issues, such as endangered species and the impacts of human intervention in a habitat.

Acknowledgements

To Delfim Machado to allowed the use the photo of Figure 3.

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Data Acquisition Experiments for Earth Science Lessons

Garabet M and Neacşu I

Models for Producing Alternative Current

Electromagnetic induction is the production of voltage across a conductor situated in a changing magnetic field or a conductor moving through a stationary magnetic field. Inductance is an effect which results from the magnetic field that forms around a current carrying conductor. Electrical current through the conductor creates a magnetic flux proportional to the current. A change in this current creates a change in magnetic flux that, in turn, generates an electromotive force (emf) that acts to oppose this change in current. Inductance is a measure of the generated emf for a unit change in current. For example, an inductor with an inductance of 1 H produces an emf of 1 V when the current through the inductor changes at the rate of 1 ampere per second. The number of turns, the area of each loop/turn, and what it is wrapped around affect the inductance. For example, the magnetic flux linking these turns can be increased by coiling the conductor around a material with a high permeability.

A model for producing alternative current in hydroelectric power plants and wind turbines are presented.

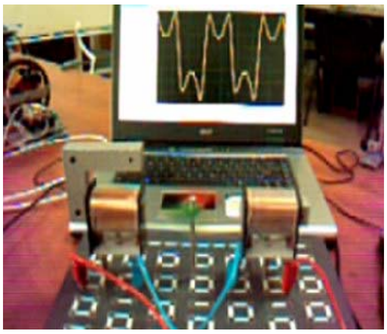

Figure 1. Experimental set up for demonstrating electromagnetic induction

Figure 2. Experimental model of hydroelectric power plant

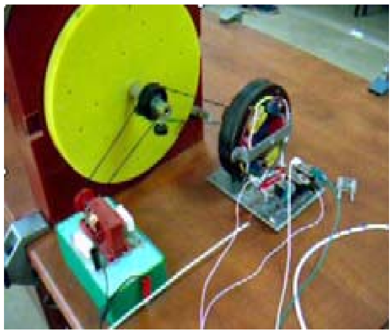

Figure 3. Experimental model of hydroelectric power plant

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In Figure 6 you can see a handmade model of the wind mill, while in Figure 7 we are presenting the signals registered from our model of the wind mill during a down wind.

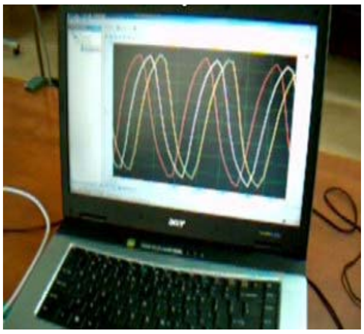

Figure 4. The registered signals from three channels of the data acquisition board

Figure 5. Wind mills

Figure 6. Experimental model of the wind mill

Rectifiers

A rectifier is an electrical device that converts alternating current to direct current, a process known as rectification (the opposite of inverting which converts DC to AC). Rectifiers are used as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid state diodes, vacuum tube diodes, mercury arc valves, and other technologies.

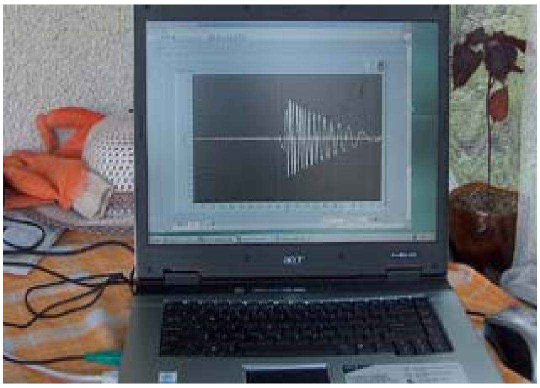

Figure 7. The registered signal from the data acquisition board, during a down wind

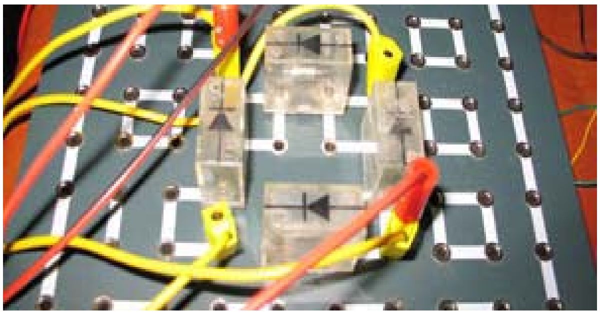

Figure 8. Experimental set-up

Full-wave rectification converts both polarities of the input waveform to DC, and is more efficient. However, in a circuit with a non-centre tapped transformer, four diodes are required instead of the one needed for half-wave rectification. This is due to each output polarity requiring two rectifiers each, for example, one for when AC terminal 'X' is positive and one for when AC terminal 'Y' is positive. The other DC output requires exactly the same, resulting in four individual junctions (See

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semiconductors/diode). Four rectifiers arranged this way are called a bridge rectifier:

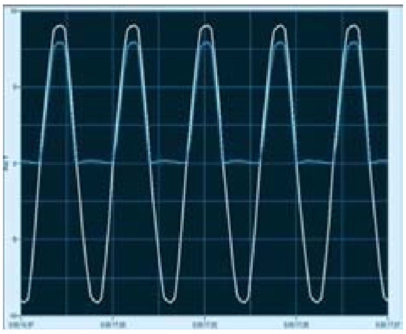

Figure 9. The registered signals from the channels of the data acquisition

Figure 10. The registered signals from the channels of the data acquisition board in full-wave rectifier

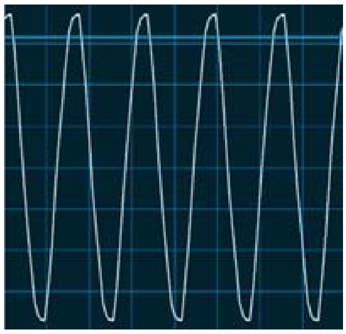

Figure 11. The registered signals from the channels of the data acquisition board in full-wave

A full wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output by reversing the negative (or positive) portions of the alternating current waveform. The positive (negative) portions thus combine with the reversed negative (positive) portions to produce an entirely positive (negative) voltage/current waveform.
For single phase AC, if the transformer is centre-tapped, then two diodes back-to-back (i.e. anodes-to-anode or cathode-to-cathode) form a full wave rectifier.

Environmental Science

How Much Oxygen Is Required To Sustain A Flame?

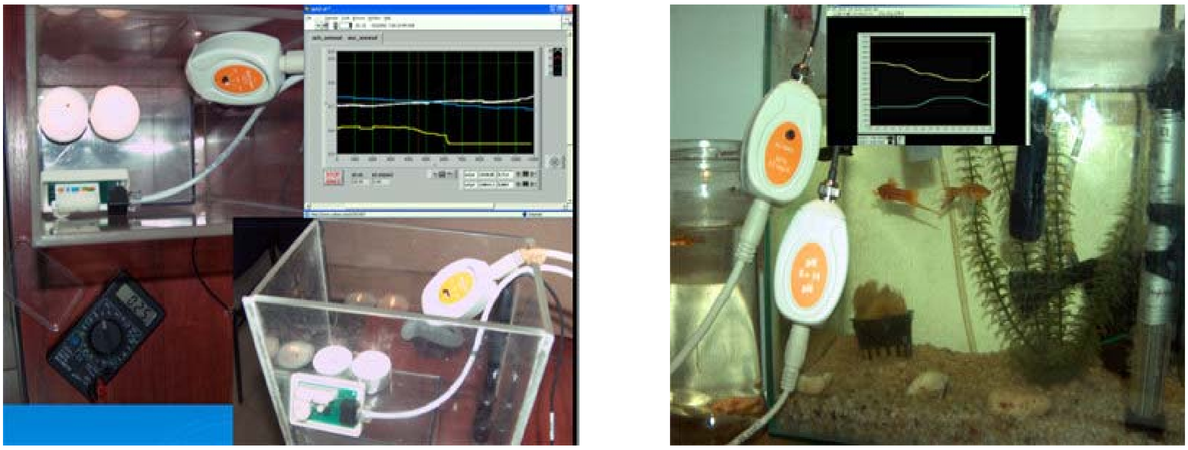

Figure 12. Monitoring burning candles

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Three elements must be present at the same time for a flame to burn: fuel, oxygen, heat. If any of these elements are reduced or removed, then a flame will be extinguished. This experiment uses the Oxygen in Air sensor to monitor the oxygen level required to keep a flame burning.
Combustion of a typical paraffin candle will give you carbon dioxide and water vapour. But the water vapour will condense to liquid water. The original air was 78% give or take a bit of Nitrogen and 1% argon plus the balance mostly oxygen. Exactly how much of the oxygen is used by the candles depends on a number of variables, such as temperature of the experiment, exact composition of the candle, type of wick etc. In other words we can't give an exact figure. But pretty close to all of it. There may be a couple % left, but it varies. The results of monitoring the fish tank looks like the Figure 12.

Acknowledgements

Our study is developed in the framework of the Comenius “Hands on Science” Project. We intended to find the right way to show how the Nature works to our students. Thanks to “Hands on Science” Network.
Thanks to “Hands on Science” Network România, and to the Centre for Scientific Education and Training, CSET, for the support they give us in the frame of the Project “*Educatie si instruire în domeniul stiintelor pentru o societate a cunoasterii*” (Contract nr. 58/2006). Our activities were developed in the Physics Lab from the Theoretical High School “Grigore Moisil” from Bucharest and in the Mobile Natural Lab from Valea Lunga, Dâmbovita.

References

[1] Savu T and Savu G, Informatica-Tehnologii asistate de calculator, Editura ALL, 2000.
[2] Munteanu M, Logofatu B and Lincke R, Aplicatii de instrumentatie virtuala – LabVIEW, CREDIS: Bucharest, 2000.
[3] Garabet M and Neacsu I, Lectii experi-mentale în laboratorul de fiyica, Editura Niculescu: Bucharest, 2004.
[4] www.ni.com

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Home-Made Science in Parallel with the Curriculum

Şaylan DU, Göğüş E and Alpar MA

Introduction

As educators we often ask ourselves the question: What do we like to achieve in science education? Our aim is to teach our students “a way” to look at the world around them. We would like them to perceive their environments with observation, not with hear-say and we would like them to build a systematic knowledge of the material world as a whole.

Fortunately humans are born this way, preschool children continuously observe their environments and draw conclusions from their experiences. They are curious and they are neither afraid nor reluctant to explore their environments, they constantly fiddle around and they are eager to learn about anything that comes to their way. They also have a tendency to check their newly gained knowledge with their prior experiences, trying to tie different bits of pieces of information to each other.

Until the preschool students start any systematic school education their knowledge of nature is mostly observational and self-gathered. At school however, learning experience is quite different, usually the knowledge is not acquired by the students, but it is given to them in prepared packages. Assessment of this knowledge is quite mechanical as well, exams usually seek for the information given in a certain package, failing to encourage them to make links between packages let alone to make any link with nature as a whole.

In such a classroom environment children may lose their curiosity and creativity, and they may even lose the motivation to explore. To prevent this, we should keep the students active at school. We should look for ways to constantly create opportunities for them to observe and experiment on their surroundings. The obvious way to do this is to supply them with hands-on activities in parallel with the curriculum. Such hands-on activities not only create an interactive and fun classroom environment, but also derive self learning [1].

Turkish Education System

In the Turkish education system the first eight years is mandatory. These eight

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primary school years include the five years of elementary school and three years of middle school education. Starting at 3^{rd} grade, students start to take required science and technology classes. Starting at 9^{th} grade, science classes are divided into physics, biology and chemistry. In the four years of high-school education, the topics covered from the 3^{rd} grade to 8^{th} grade are taught in more detail.
In the last few years there has been an effort to change the curriculum aiming to make all primary school graduates to be science and technology literate. However, especially in public schools the laboratory facilities are quite limited. Even in schools where there are science laboratories, the equipment is not sufficient to allow all students to have an extensive hands-on experience. This is why it is very important to integrate applications of science with simple materials to the curriculum.
Fortunately, there are unlimited resources of such applications in our everyday lives. One can get a lot of ideas from the internet and there are already several books written on possible applications of science with everyday materials, see for example [2, 3, 4]. Although a lot of these applications can be extremely simple, a systematic and scientific way to observe these applications not only may allow students to realize the link between science classes and nature itself, it may even change the way they look at the world around them.
For the last few years, we have been exploring the world of “home-made science” in parallel with the primary-high school curriculum in Turkey. We are trying to collect and design a series of course modules that are cheap, easily built, simple and effective in learning. These modules are in the form of small scale experiments, demonstrations and games.

Home-Made Science

Demonstrations and Experiments

Students can be involved in the designing / building process of most of these modules. Some of these modules allow to take data and to obtain some quantitative results and some of them are just useful in demonstrating scientific phenomena.
A few examples to this type could be as following:

Gravity:
There are two very easy demonstrations showing the effect of gravity on objects on the surface of the Earth. We only need a book and a piece of paper to perform the first demonstration. Let the students drop the book at a distance from the floor and let the students observe the fall. Separately let the paper fall from the same distance. At this point one can discuss the effect of gravitational force on objects. Finally putting the paper on the book and dropping both together observe that the book and the paper fall to the ground at the same time, regardless of their mass.
Second application requires a little bit more equipment. An appropriately sized table can be used instead of the platform seen in Figure 1. Height of the table is preferable higher than one meter. Materials needed are a strong magnet, a rod almost as the same length of the chosen platform, one steel or iron ball, one plastic ball, a small and preferably thin nonmagnetic plate. Glue the magnet on one side of the rod. Fix the small plate on one side of the platform. Magnet holds the steel ball

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as shown in Figure 1, while the plastic ball stands still on the other side of the platform. Pushing the plastic ball by applying a horizontal force on the platform will start the plastic ball move towards a horizontal projectile motion, while at the same time will let the steel ball fall vertically downwards. An optional plate can be placed on the floor to make a sound as the steel ball reaches the ground, so watching only the plastic ball's motion is sufficient. Both balls regardless of their mass fall to the ground at the same time since their motions vertical to the ground are identical [5].

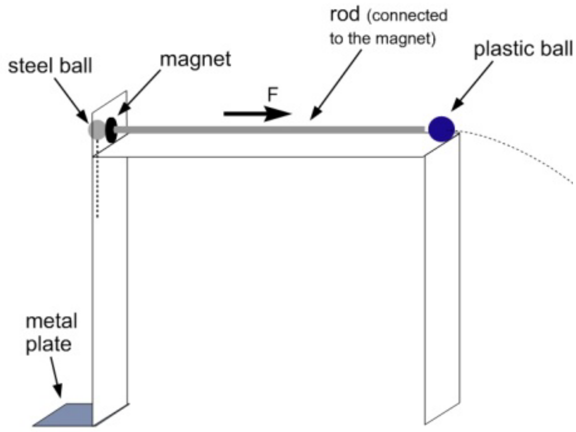

Figure 1. Set-up for the gravity experiment

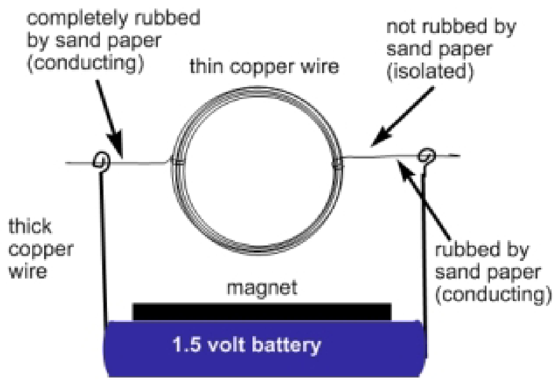

Figure 2. An example motor design

PH Indicator:
A lot of flowers and fruits are natural pH indicators. Red cabbage is one of them. The natural dye of the red cabbage can be extracted by soaking cut cabbage in boiling water. When strips of white filter paper are dipped into this water we have our home-made pH indicator. After the prepared pH indicators are dried they can be tested with household materials such as detergent, soap, lemon, vinegar etc. The indicator turns red with acidic materials and turns blue with base [6].

Simple Motor:
Simple motor is a quite an elegant device which demonstrates transformation of electrical energy to mechanical energy. Another great thing about motors is that students can make their own motor design. One only needs conducting wire (preferably coated copper), magnets, connecting wires, battery (1.5 V batteries are usually enough).
While discussing the topics of magnetic flux and magnetic force, it can be a good exercise for the students to build their own simple motor.
One possible design is shown in Figure 2. This motor design is adopted from [7]. The loop consists of about five turns and two sides of the copper wire that are extended as seen in Figure 2. A sand paper is used to left side completely conducting. Right side of the wire is rubbed partially by sand paper. At the position seen in Figure 2 a current flows through the circuit and the magnetic force turns the loop. When the loop is upside down, the right side of the wire is no longer

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conducting and the current stops. This way the loop can keep on turning and we have a simple motor.
Another quite interesting motor design is the homopolar motor, the details can be found at [8]

CD Spectroscope:
Light is quite an interesting topic of science and one can built a very simple device to observe the spectrum of light. A used CD and cardboard is what is needed to build this device. A cylinder with radius about 3 cm and length 50 cm is formed by the cardboard. Close to one end of the cylinder the cardboard is cut with an angle about 30 degrees as seen in Figure 3, a CD is placed in the cut and secured with isolation tape such that no light can escape. On the other side of the cylinder a slit is opened for the light to enter. Light should not enter from anywhere except the slit so isolation tape can be used to cover all openings.
A hole is opened on the cardboard at the top of the CD for observation. When the light enters the cardboard and reflects from the surface of the CD, different wavelengths reflect with slightly different angles and one can observe the spectrum of the particular light source. Different light sources such as incandescent light, fluorescent light, neon lights and sun light can be observed and the properties of their spectrum can be discussed [9].

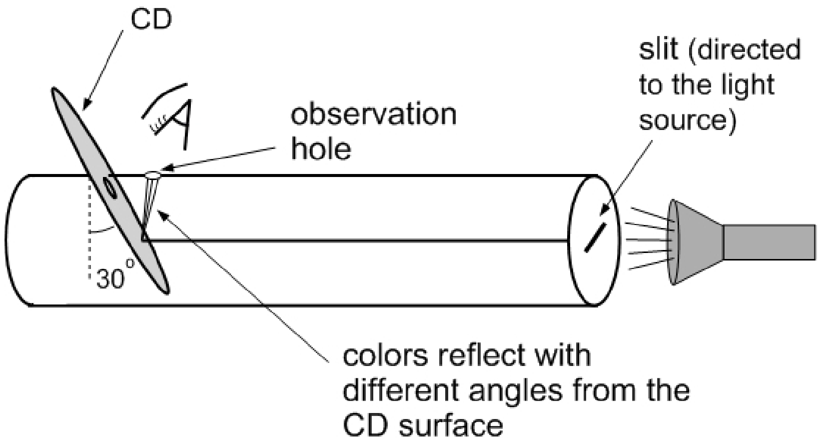

Figure 3. CD spectroscope

Ice and Buoyancy:
By using only ice and water one can demonstrate the concept of buoyancy and the structure of water in liquid and solid phase. Firstly we fill a balloon with water and freeze it. After water freezes, we put the ice in a preferably transparent bucket of water and label the level of water with ice in it. Then raise the question “Will the water level, increase, decrease or stay the same once the ice melts? Students may discuss this and explain their answers. After observing that the water level does not change, one can raise the second question: Why are we afraid of the rise of the sea

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level if the water level does not change upon melting of the ice? [10]

Games

This category is especially effective for preschool and elementary school students. Some examples to this type are as following:

Rollercoaster:

A model of a rollercoaster can easily be built by isolation pipes from a warehouse and marbles. The rollercoaster game [11] is organized as a competition between student teams. Same number of isolation pipes is given to teams and they are asked to build roller coasters which start at a start line at the same height on the wall.

Students try to build tracks on which the marbles can be rolled as far as possible, with as many loops and turns as possible. This game demonstrates the conversion of mechanical energy. The energy loss mechanisms can be discussed, at a higher level the motion of the marble can be analyzed in more detail.

Speed Game:

At the constant speed game [12] 5-6 students form a line standing at equal intervals (5-10 meters) all holding chronometers. A student starts to run at a distance and all the chronometers are started simultaneously. The runner tries to maintain a constant speed on a straight line. When the runner passes by a student with a chronometer, the timer is stopped. The readings of all the timers are recorded and a position-time graph can be plotted to clarify the concept of speed.

Cell Game:

Cell game is a board game which is designed to teach students the cell structure and its processes [13]. At this game a cell is associated with a city and different organelles of the cell are associated with city buildings, for instance the nucleus is the city hall, the smooth endoplasmic reticulum is the river passing through the city, the rough endoplasmic reticulum is the part of river where there are factories, ribosomes are the factories, mitochondria is the power plant etc. A large scale cell is drawn on a cardboard and buildings made of cardboard boxes are placed on the organelles. There is a path on the board that goes around the cell and has stops near every organelle. This path has numbered divisions on it. The students throw dice to move on the path. At every division there is either a question to answer or an act. When a player comes to a particular organelle he/she talks about its processes. Players start the game with equal number of beans, they gain a bean for every correct answer, and lose a bean for every wrong answer.

How to Integrate Home Made Science in the Curriculum?

Freshman Project Course

Project 102 is a one semester project course aimed for the first year university students at Sabanci University. Faculty members offer various topics in science and

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engineering and supervise teams of students throughout the semester. For the last few years we have been offering the project “Designing, building and testing of science course modules aimed for primary-high school curriculum” through Project 102.

Students who sign up for our project firstly analyze the curriculum and try to come up with ideas which could be used in parallel with certain parts of the curriculum. Ideas are discussed and shaped under our supervision. During the rest of the semester, students work on these ideas, gather materials and complete a prototype of the modules. Students are also asked to prepare manuals for each module. Each manual includes some background information on the relevant scientific concept, directions for gathering materials and construction.

Of course, in order to safely recommend these applications to teachers we would like to systematically test them at schools and check student response.

Civic Involvement Projects

Civic Involvement Projects (CIP) is a one year course which is mandatory for every Sabancı University student. Through CIP students take active roles in civil society in cooperation with national and international nongovernmental organizations and state institutions [14].

CIP has a wide range of projects, about child development, human rights, environment, consumer responsibility and handicapped people. Child development projects are a big part of CIP and they are organized in cooperation with the Ministry of National Education and local primary schools. In these projects Sabanci University students visit certain underprivileged schools for a year and perform activities with the children. These activities are sought to be fun and educational.

Freshman students who are taking Project 102 course usually are also taking CIP at the same time. This is quite an advantage for Project 102 students to test their modules. They systematically take these modules to CIP schools and get feedback from the children. We then have a chance to modify our modules according to the feedback obtained at CIP schools.

We try to share our past and present experience with CIP coordinators and supervisors regularly, this way we get them to use these ideas in their own CIP activities.

Conclusions

Even if at schools with no laboratory facilities, students can have a lot of hands-on experience with experiments designed with easily obtained materials. Such experiments are aimed to be integrated into the primary-high school curriculum. These applications may help students connect science classes to nature more effectively, encourage them to look further and investigate, and they may even boost students’ self-confidence since they are directly involved in the learning process.

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References
[1] Michaelides PG and Miltiadis T, Science Teaching with Self made apparatus, Proceedings of the 1st International Conference on Hands on Science Hsci2004 – Teaching and Learning Science in the XX1 Century, 5-9 July 2004, Ljubljana, Slovenia, pp.: 47-52, 2004. http://www.hsci.info/hsci2004/PROCEEDINGS/FinalPapers/040530.pdf
[2] Churchill ER, Loeschnig LV and Mandell M, 365 Simple Science Experiments with Everyday Materials, Black Dog & Leventhal Publishers: New York, 1997.
[3] Valadores EC, Physics Fun and Beyond, Prentice Hall: New Yersey, 2005.
[4] Compiled by Unesco, 700 Science Experiments for Everyone, Doubleday: New York, 1956.
[5] Kahvecioğlu M, Özden O, Gülan C and Atakan S, Project 102 - Fall 2006, supervised by Kalemci E and Üçer D.
[6] Başkaya A, Yılmaz C, Uyar Z and Hamzaoğlu M, Project 102 - Spring 2007, supervised by Üçer D, Göğüş E and Alpar MA.
[7] http://fly.hiwaay.net/~palmer/motor.html (influenced from the TV show "Beakman's World". http://www.sonypictures.com/tv/kids/beakmansworld/
[8] http://youtube.com/watch?v=3aPQqNt15-o
[9] Saygaç T, CD Spectroscope, prepared Nov 2006.
[10] Güvenel ZG, Döver ZS, Babacan O and Şahan Z, Project 102 – Spring 2007, supervised by Üçer D, Göğüş E and Alpar MA.
[11] Şahbaz S, Bağatur AB, Gülhan MM and Erdem O, Project 102 – Spring 2007, supervised by Üçer D, Göğüş E and Alpar MA.
[12] Güvenel ZG, Döver ZS, Babacan O and Şahan Z, Project 102 – Spring 2007, supervised by Üçer D, Göğüş E and Alpar MA.
[13] Sanaç D, Köseler M and Özman A, Project 102 – Fall 2006, supervised by Üçer D, Göğüş E and Alpar MA.
[14] Civic Involvement Projects: 2005. http://cip.sabanciuniv.edu/eng/

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Mechanical Oscillation Superposition and Lissajous’ Figures

Días Tavares A, Da Mota LACP and Vieira GJ

Introduction and Theoretical Aspects

In most cases, the composition of ondulatory phenomena is presented [2] to the students only in the context of the experimental work for some Electromagnetism discipline.

However, in these experiments oscilloscopes and signal generators which quite easily present phases and frequencies differences are used. This allows for the reproduction and study of many aspects of wave superposition. Indeed, these practices are very good to illustrate these phenomena. But, for at least three important reasons, they should be changed. The first of them is that it creates the false idea that superposition occurs mainly (if not only) with electromagnetic signals, disregarding the large range of applications and phenomena where it occurs. The second reason is related to the concepts most people have about rigour and precision in scientific experiments. They think it is mandatory to use relatively sophisticated equipments like oscilloscopes, signal generators and, last but not least, computers. The third and not least important reason is that Physics is a science that demands capacitation in order to perform observations and notice the occurrence of the most various phenomena in the surroundings. Therefore, it is fundamental that the students learn how to look and see what is occurring in each event. When we eliminate the observational difficulties in didactic experiments, these become incomplete. So, these experiments become insufficient in transmitting to the students what they must know in order to carry out their roles as observers and, at the same time, they incite to a constant change of commercial apparatus used.

We are going to limit ourselves to the phenomena that are directly related to the Lissajous figures, that is the composition of simultaneous oscillations in two mutually perpendicular directions.

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Particle Oscillating Simultaneously in two Perpendicular Directions, with the Same Frequency and Constant Phase Differences

Let us consider two harmonic motions on the rotor diagram [1]. In Figure 1, the x coordinate of the tip of the rotor in the lower diagram gives the x-coordinate of the oscillating particle and the y-coordinate of the tip of the rotor in the upper diagram gives its y-coordinate. Hence, by projecting up and across from the tips of these rotors, the position of the particle at any time can be determined. The diagram shows its position at some arbitrary time t.

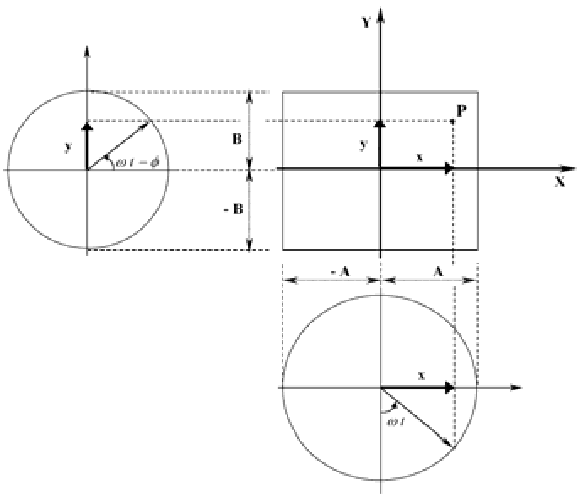

Figure 1: Graphic composition of two harmonic motions

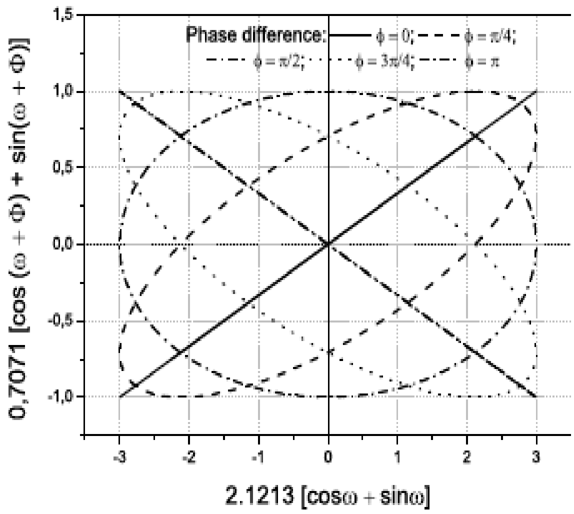

Figure 2: Composition of orthogonal motions of equal frequencies but different amplitudes. The initial phase angle ϕ is varying from 0 to π (0, π/4, π/2 , 3 π/4 and π)(Axis not in scale)

The general expressions for the x and y- coordinates of the oscillating particle $P(x,y)$ are:

$$x = \text{A} \sin(\omega t) \tag{1}$$
$$y = \text{B} \sin(\omega t - \phi) \tag{2}$$

These are the equations of the path of the point $P(x,y)$ in the parametric form. Eliminating the parameter t one obtains the Cartesian equation described by P.

$$x^2 /\text{A}^2 + y^2 /\text{B}^2 - 2xy \cos\phi \, \text{A B} = \sin^2 \phi \tag{3}$$

This represents an ellipse inscribed in a rectangle with sides 2A and 2B, that is, the double of the amplitudes. Figure 2 shows that situation.

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Study of Several Cases

(a) General case, any ϕ value.
When the value of ϕ is anyone, that is, it does not assume a particular value. For example, ϕ is a multiple of $\pi/2$ ($\pi/2$, π, 2π, $3\pi/2$, etc) P describes a generic ellipse with maxima and minima corresponding to the ellipse axis (Fig. 2) presents the several cases superposed.
(b) ϕ is an odd multiple of $\pi/2$ ($\pi/2$, $3\pi/2$, ...). In this case

$$\sin\phi = 1 \text{ and } \cos\phi = 0\text{, so equation (3)}$$

becomes

$$x^2/A^2 + y^2/B^2 = 1 \qquad (4)$$

That is an ellipse with semi axis A and B respectively with inclination B/A = 1/3 (Figure 2).
(c) $\phi = 0$. In this case we have: $\sin\phi = 0$ and $\cos\phi = 1$ and equation Eq. (3) becomes:

$$x^2/A^2 + y^2/B^2 - 2\,xy\cos\phi/AB = 0 \text{ or } (x/A - y/B)^2 = 0$$

Then $x/A = y/B$, that is, $y = (B/A)\,x$. The ellipse degenerates into a straight line with angular coefficient B/A (Figure 2). The expression is the same when $\phi = 2\pi$, 4π.....$(2m)\pi$, (m = 0, 1, 2, 3 .....).
(d) When $\phi = \pi$, $\sin\phi = 0$ and $\cos\phi = -1$, equation (3) becomes:

$$x^2/A^2 + y^2/B^2 + 2\,xy\cos\phi\,AB = 0 \text{ or } x/A + y/B = 0,$$

which results in $x/A = y/B$, that is, $y = -(B/A)\,x$.

The ellipse degenerates into a straight line passing by the origin and with angular coefficient − B/A (Figure 2).
(e) With B= A, the equation [3] becomes:

$$x^2/A^2 + y^2/A^2 - 2\,xy\cos\phi/A^2 = \sin^2\phi$$

$\phi = \pi/2$, implies in $\sin\phi = 1$, $\cos\phi = 0$ and then: $x^2 + y^2 = A^2$, that is the equation of a circumference with radius A. In this case, the rectangle turns into a square and the ellipse into a circumference (Figure 3).

Oscillating Particle Simultaneously in Two Perpendicular Directions, with Almost Same Frequencies and Constant Phase Difference ϕ

Let us consider the orthogonal oscillations:

$$x = A\sin\omega t \text{ and } y = B\sin\omega_1 t\phi$$

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with $\omega = 2\pi N$ and $\omega_1 = 2\pi N_1$. Assuming that $N-N_1 = \varepsilon$ and substituting this into the equation for y yields:

$$y = \text{B}\sin[2\pi(N-\varepsilon)\text{t} - \phi] = \text{B}\sin[2\pi Nt - \psi(t)]$$

with $\psi(t) = 2\pi\varepsilon t$. Therefore Equation (3) becomes:

$$x^2/\text{A}^2 + y^2/\text{B}^2 - 2xy\cos\psi(t)/\text{AB} = \sin^2\psi(t) \quad (5)$$

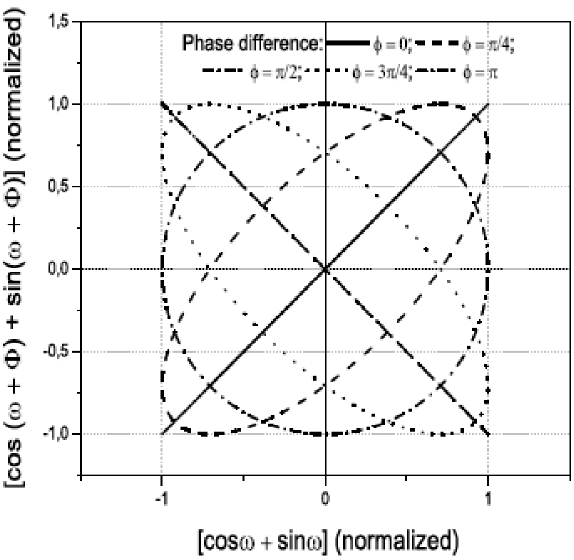

Figure 3. Composition of orthogonal motions of equal frequencies and amplitudes. The initial phase angle ϕ is varying from 0 to π (0, π/4, π/2 , 3π/4 and π)

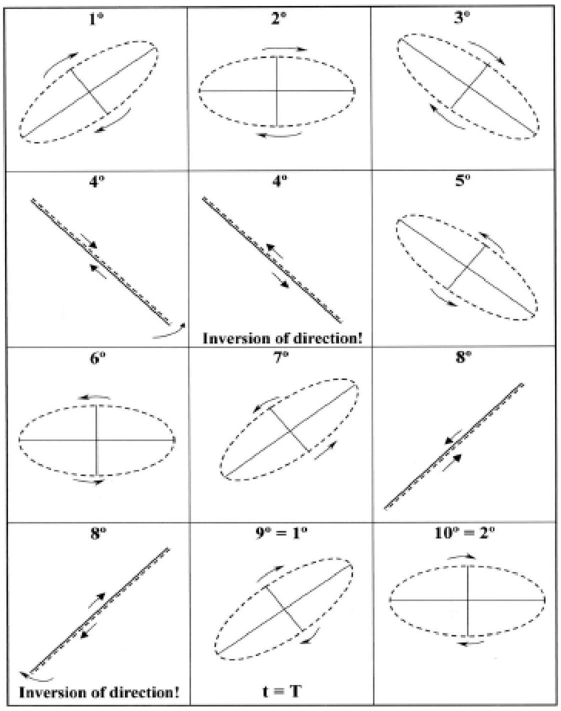

Figure 4. Superposition evolution of motions with near frequencies and constant phase difference

This behaves as if the two harmonic motions had the same frequencies with a phase difference $\psi(t)$, that is variable with the time, with this variation being as slower as lower will be the value of $\varepsilon = N-N_1$. With a slow changing phase difference, the tip of the rotor will describe an ellipse, which will slowly distort itself assuming all shapes already described above, with constant phase differences and same frequency (Figures 2 and 3). The same curves evolve with a frequency $\varepsilon = N-N_1$. Figure 4, steps one to ten, presents this evolution. The period of this evolution corresponds to the series of motions described from the first to the eighth frame, the ninth frame is already a repetition of the first frame, the tenth a repetition of the second and so on. One can observe the change in the direction of the motion when it goes through the figures, which happens in the straight line segments.

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Hence in the practical determination of the period the best precision is achieved taking the time interval $\delta t=T$ between two straight line segments, which is well defined.

Particle Oscillating Simultaneously in two Perpendicular Directions with Quite Different Frequencies

Let us suppose two orthogonal motions with their frequencies multiples of a fundamental frequency: N_1 = pN; N_2 = qN. The resulting motion will be a non sinusoidal motion with frequency equal to the fundamental N. The tip of resultant rotor will describe closed curves of sinuous shape. These curves are known as Lissajous figures. They are closed curves, which repeat identically at the same time intervals T, so the motion is a periodic one. One can illustrate the resulting motion graphically with two orthogonal motions:

$$y = 6 \sin 2\pi\, t/T \text{ and } x = 8 \sin(2\pi t/T - \pi/3)$$

With $\nu_1=2\nu_2$, $\nu_2=\nu$, where ν is the fundamental frequency. Analytically, we can obtain the motion graphics giving to t convenient values, i.e., multiples of T/12, and calculating x and y values for each value of t. The graphics points are then obtained from their coordinates. We may also use the graphical method with displacing circumferences x and y corresponding to arcs described in equal times with the phase difference ϕ=60º. The circumference C_2 is divided in 24 arcs and the C_1 in 12; meanwhile the rotor of C_1 completes two round trips while C_2 completes only one. Hence, the arcs described in the same time interval will be those with the same numeration and by composing the correspondent displacements the curve C can be obtained. So, one can compose the motions point by point thus drawing curve C. It is quite evident that this procedure is valid although laborious for other relations between frequencies. Up to a few years ago that was a method frequently adopted to treat this kind of problem. Indeed, we consider it important and opportune, as a differential to the learning, that the student draws a graphics based on that method. We think some basilar aspects for the physicist formation are implicated in here. On the other hand, we can visualize the motion superposition by using some appropriate software and its graphics resources. We used the software OriginPro 7.0 Server 7.0™ and Maple 7™ for the elaboration of graphics here presented (Figure 5). Figures 6 and 7 present the result of the superposition of two motions, with quite different frequencies, same amplitude and initial phase angle ϕ equals to $\pi/4$. Figure 6 shows the superposition of motions of frequencies at ratios of 1:2, 1:3, 2:3 and 3:4. The ratios for Figure 7 are 3:5, 4:5, 5:6 and 5:7. Clearly, the computational method allows for a much larger number of tentative experiments (....and if...?), which also leads to a better elaboration and elucidation of the experiment for the interested student.

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Particle Oscillating Simultaneously in two Perpendicular Directions with Frequencies Multiple of Almost Equal Frequencies ν_1 and ν_2

Supposing the two motions have frequencies, which are multiple of frequencies ν_1 and ν_2 and these are not equal but almost equal, that is, they differ by a very small value ε. For example, $\nu_1=2\nu'$ and $\nu_2=3\nu''$ and that $\nu''-\nu'=\varepsilon$ and the ε being small enough to the proposal of our experiment.

In order to illustrate this case let us suppose $\nu_1=\nu'$ and $\nu_2=2\nu''$, with a very small $\nu''-\nu'=\varepsilon$. Clearly the resulting motion will not present only one Lissajous figure like those presented in the Figures 6 or 7, but it will evolute passing by all configuration kinds in which the both motions have frequencies multiples of the fundamental one: $\nu_1=\nu'$ and $\nu_2=2\nu''$; but with a slowly time varying phase difference. In this case, the motion evolution occurs among the different cases of which a few are illustrated in Figure 6 and 7. The resultant motion frequency is now: $\nu''-\nu'=\varepsilon$ and $T=1/\varepsilon$

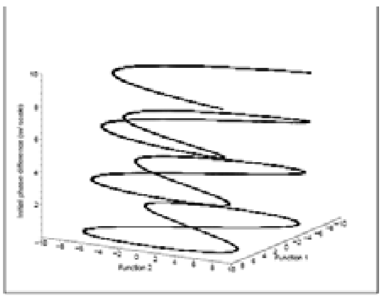

Figure 5. Tracks described by the pendulum mass with the coupling of two orthogonal motions with quite different frequencies (ratios 1:2), equal amplitudes and initial phase angle ϕ varying from 0 to π/2 (0, π/6, π/3 and π/2)

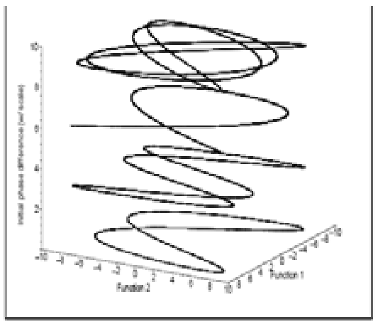

Figure 6: Tracks described by the pendulum mass with the coupling of two orthogonal motions with quite different frequencies (ratios 1:2, 1:3, 2:3 and 3:4), equal amplitudes and initial phase angle ϕ=π/4

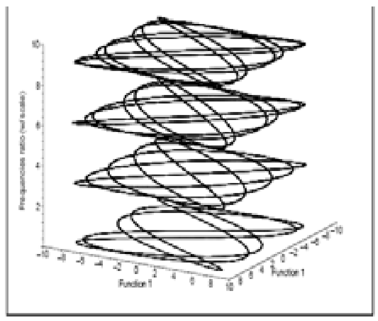

Figure 7: Tracks described by the pendulum mass with the coupling of two orthogonal motions with quite different frequencies (ratios 3:5, 4:5, 5:6 and 5:7), equal amplitudes and initial phase angle ϕ=π/4

Particle Oscillating Simultaneously in two Perpendicular Directions with Frequencies neither Multiple of Almost Equal Frequencies ν_1 and ν_2 nor Divisible by a Common Factor

The relation $\nu_1/\nu_2=T_2/T_1$ is incommensurable, that is, ν_1 and ν_2 are not divided by a common factor neither are multiple of almost equal frequencies like those in the preceding case. In this case the resulting motion is not periodic and describes open curves never reproducing themselves identically and translating continually among the various types.

Experiment

The apparatus used in order to observe the Lissajous' figures is very simple and one can find it elsewhere in literature [2, 3, 4, 5], it is a double pendulum, in which

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one of the motions occurs in one plane and the other is in a plane orthogonal to the first one, as can be seen in Figure 8 and Figure 9. The mounting should be quite rigid in order to prevent unwanted oscillations disturbing the expected results. Figure 10 introduces the real apparatus used to arrive at the results. Using the mountings presented in Figure 8 and 9, one can calculate the frequency as follows:

$$v_1 = (\tfrac{1}{2}\pi)\sqrt{\frac{g}{l_1}} \quad v_2 = (\tfrac{1}{2}\pi)\sqrt{\frac{g}{l_2}}$$

and observing that

$$\frac{v_1}{v_2} = \sqrt{\frac{l_2}{l_1}}$$

then, in order that $v_1=2v_2$ it is necessary that $\sqrt{l_2} = 2\sqrt{l_1} \Rightarrow l_2 = 4l_1$. So, if l_1 =14 cm then l_2 =64cm.

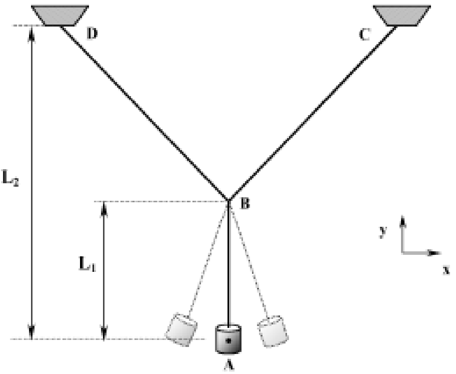

Figure 8. Mounting, plane *xy* view

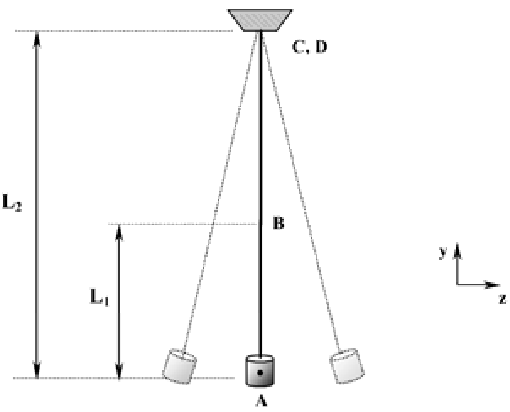

Figure 9. Mounting, plane *yz* view

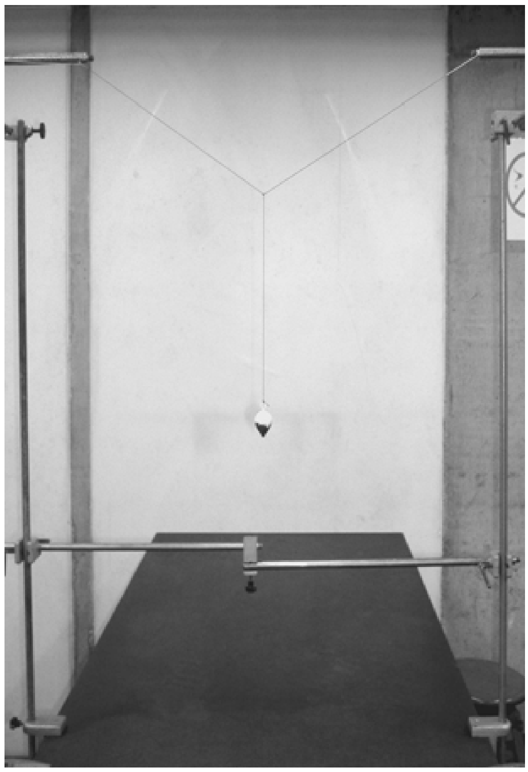

Figure 10. Photography of mounted apparatus

In this case, one obtains only a Lissajous figure with a shape depending on the amplitude of the two motions as well as on the phase difference between them,

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nevertheless if l_2 is larger or smaller than 64 cm, then the two motions will not have the same fundamental frequency, or their frequencies will differ by a very small amount ε, so the resulting curve will evolute among the different types of configurations resultant of the composition of two orthogonal motions where one of the frequencies is the double of the other Figures 11 and 12 show a graphical result obtained from the double pendulum real mounting presented in Figure 10. Figure 11 was obtained by photographing the displacement of a laser spot from a small laser pointer attached at pendulum mass. Figure 12 was obtained in an slightly older fashion by photographing the pendulum mass from top with the help of an stroboscopic flash (Nikon™ F90X photographic machine with Nikon™ Speedlight SB26 flash).

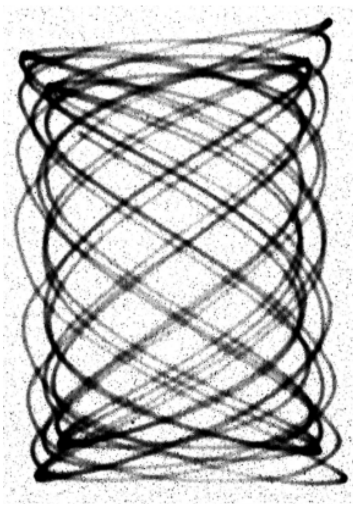

Figure 11. Photography of Lissajous figure generated with the double pendulum and a small laser pointer

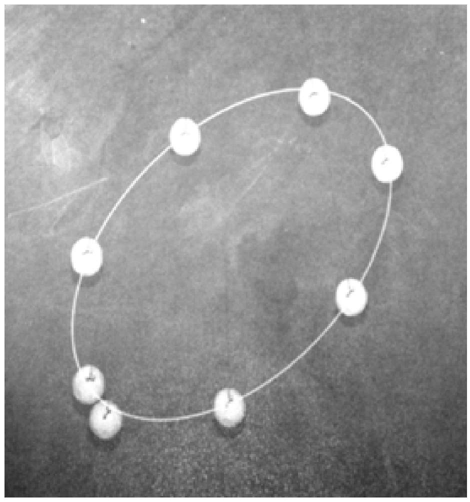

Figure 12. Photography of Lissajous figure with stroboscopic flash (white line was superimposed through digital processing of original snapshot)

Conclusion

The point of writing this paper is to argue that it is possible and important to observe physical phenomena in a variety of apparatus and environments. This diversity contributes strongly to the understanding of the essence of phenomena under observation. In particular, we focused on a mechanical realization of Lissajous' figures. The experimental setting is very simple and can, therefore, be easily reproduced in any laboratory and/or classroom. One does not need expensive electronic equipments to observe the physics behind the Lissajous' figures. Furthermore, since the apparatus is built from scratch by the students, it is a bonus that they can understand the effect of parameters change on the results obtained and can analyze fully the agreement (or not) between theory experiment. This by-product of the experiment here suggested is incredibly valuable to the education of the future scientist. We would like to point out that experiments presenting these characteristics should, therefore, be more frequently pursued.

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References

[1] Sears FW, Mechanics, Wave Motion and Heat, Addison-Wesley: London, 1965.

[2] Pinkerton KD, Laser Light Fantastic Lissajous Figures, The Physics Teacher, 29: 168-169, 1991.

[3] Herrera O, Mechanical Device to Draw Lissajous Figures, The Physics Teacher, 29: 284-285, 1991.

[4] Greenslade TB, All about Lissajous Figures, The Physics Teacher, 31: 364-370, 1993.

[5] Ballegeer DJ, Drumheller JE, Kirkpatrick LD and Rugheimer M, Demonstration Experiments in Physics, Sand Pendulum for Compound Wave Form and Lissajous Figures, The Physics Teacher, 20: 415-418, 1982.

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