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CmapTools software use for implementing Physics concept maps with Teacher Training Students

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Since the appearance of the first concept maps in teaching scientific literature by Novak and Gowin, they have been extensively used as a schematic resource representing a set of conceptual meanings included in a hierarchical structure of propositions and mainly based on a series of theoretical principles of the meaningful learning theory.

In this paper we try to review tentatively the various uses given to the concept maps in the field of Physics Teaching / Learning and in the different educational levels, from the design and presentation of didactic units up to as a methodology of evaluation through collaborative work among peers. Similarly, we will analyze the various modalities and possibilities raised according to the part of the Physics studied and the level of the course. Also, we refer to the CmapTools free software as an appropriate and easy tool for making concept maps. We implement also the use of the CmapTools software (free software developed by the Institute for human and machine cognition in order to help to construct concept maps in any field of knowledge). The topic chosen for it has been “Buoyancy and Archimedes Principle” because this topic is considered as crucial and basic in the field of Science Education for the understanding and assimilation of many other concepts as much in physics as in biology or earth science. Concept maps have proved to be an appropriate means of representing and organising knowledge in a graphical way, and its use can help the students to construct meaningful learning in an effectively way. Although students need time to be familiar with it, the use of this tool achieves to accelerate and make more interesting and playful the process. In this work we show the process of elaboration of the concept maps of the inclusive concepts: buoyancy, density, mass, volume, weight, buoyancy force. This useful tool can be implemented in any country at any level of the Physics education because the facilities offered include the possibility of sharing.

Keywords: Concept maps, CmapTools, Physics, buoyancy, Archimedes principle
Beliefs of Preservice Teachers regarding to the Implementation of Topics of Modern and Contemporary Physics in High School

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The objective in this work is investigate prospective physics teachers’ beliefs concerning the introduction of Modern and Contemporary Physics into High School education. Our research methodology is qualitative (Bogdan & Biklen, 1994), case study type, and our data collection instrument were structured interviews with future teachers. The interviews consisted of questions extracted and adapted from research results on epistemological, didactic-pedagogical and motivational teachers’ beliefs (Ruiz et al, 2005; Porlán; 1989; Beach & Pearson, 1998; Lumpe et al, 2000; Kagan, 1992; Pajares, 1992). Our sample consisted of 4 future teachers from the undergraduate course in Exact Sciences at the São Carlos Physics Institute of the University of São Paulo Brazil, who were interviewed on two occasions: at the start of a 40h training course based on Particle Physics and again following the application of the activities proposed by the future teachers to secondary students. The theoretical analysis and organization of data consisted of content analysis (Bardin, 1986) in regard to the goals of our investigation. We intended to establish some aspects which allowed us to group them in some categories revealing certain tendencies based on the statements of the future teachers. Among the principal aspects of epistemological beliefs regarding Modern and Contemporary Physics, we should highlight: abstract, artificial, applied, motivating content. In terms of didactic-pedagogical beliefs we should highlight: need to teach, difficulties to teach, possibility to teach, does not know how to teach, teach how to learn, teach with or without mathematical formalism and prerequisites. For the motivational beliefs we should highlight: feels capable of teaching, feels that the teachers are capable of teaching. Among the differences that marked the responses of the future teachers to the initial and final interview we verified a significant increase in didactic-pedagogical beliefs relating to teaching methods. Finally, we would highlight the increase in their self-efficacy beliefs regarding to the personal capability of introducing innovative content in classroom. Hereafter, we will seek to broaden our sample investigating the beliefs of teachers both in their initial and their in-service training.

Interactive online resources to teach Physics: quality criteria and teachers’ expectations

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Current reforms in Physics education call for the integration of digital technologies into teaching, advocating that students learn Physics content and processes through technology. (Dani and Koenig, 2008).

Many schools have already got good technical conditions to include online resources in classes and there are a lot of resources to teach Physics in the Internet (Eteokleous, 2008). Despite an often instinctive skepticism, many teachers consider that the Internet offers a rich source of potential learning resources (Richards, 2005), specifically interactive ones, which present different levels of abstraction and help students gain a better understanding (Altherr et al., 2004). However, some teachers simply are unaware of their existence. To others, there is a huge difficulty to select valuable resources and to understand how their pedagogical potential in formative situations can be optimized. In fact, one cannot expect most teachers to effectively find, evaluate, and use these resources, in addition to their already high workload (Mathelitsch, 2008).

To address this gap, we propose the development of a feasible list of criteria to evaluate interactive online resources, based on four contributions dealing with interactive materials evaluation from the perspective of their use by teachers (CEIMSC1, MER-
LOT2, MPTL3 and SACAUSEF4). We also show the results of a survey of a sample of Portuguese Physics teachers concerning the way they find, use, and evaluate the quality of interactive online resources. The proposed list of criteria for the evaluation of interactive online resources is compared with the results from this survey to find if they match the teachers’ needs and perceptions about this issue.

The results show that the ease of finding and accessing interactive online resources is a critical requirement to promote their use in the classroom. However, the most important condition for Physics teachers to select and use these resources as didactical tools is their submission to an efficient and pragmatic evaluation process. We also address the need for suggestions on how to implement the interactive online resources in teaching and learning. For this purpose, we present a list of evaluation criteria distributed in three general categories: quality of content, pedagogical effectiveness and user friendliness. Each listed criterion is further characterized by several central questions to help the evaluators to classify the quality of interactive online resources in a quantitative scale.

1 http://www.ceismc.gatech.edu
2 http://www.merlot.org
3 http://www.mptl.eu


Creative use of technology has a potential to enhance the learning outcomes, increase students’ satisfaction and, ultimately, improve the retention in Sciences and Engineering Programs. At Ryerson, we constantly experiment with various technologies to support our pedagogy. The electronic pen technology utilized in tablet personal computers, as well as screen capture technology open up new exciting opportunities in teaching Science, Mathematics, Engineering and Technology (SMET) disciplines. Thanks to the generous HP Educational Technology Initiative grant, we were able to create HP Multipurpose Mobile Physics Lab for our students in Sciences and Engineering Programs. Since fall 2008 the tablet PCs have been used in our second year Modern Physics and third year Electricity and Magnetism courses. In both courses during the tablet-based activities, each pair of students was provided with a tablet during the class time. The tablets allowed us to introduce collaborative studio-style environment blending together lecture and tutorial, where the students can annotate instructor’s lectures, collaborate on problem solving, run applets and simulations, share and submit their work, all in real time. Due to the lack of standardized tests for the material in advanced courses, we used in-house designed problems to monitor student progress. We will present the examples of students’ work. In addition, the volunteers participated in post-course interviews and/or filled out anonymous questionnaires about their learning experiences. The students filled out a Likert-scale anonymous survey, where ranging from disagree (1) to strongly agree (3 or 5 depending on the scale). In-class use of tablets significantly increases student-instructor communication. In addition, we use Camtasia Studio software that allows capturing computer screen activity as a video clip. We use tablet PCs to create mini-lessons on selected topics that are known to be particularly challenging for the undergraduate students. The mini lessons (shorter than 10 minutes) included a problem statement, diagrams, interactive quiz to probe student initial knowledge, detailed explanation and solutions, including derivation, as well as a final summative quiz. Selected activities will be demonstrated during our presentation. Encouraged by the positive feedback from our students, recently we have expanded the use of tablets to offer selected laboratory assignments. Presently the mobile lab is used in the Optical Spectroscopy lab in our Photonics Course for second-year Medical Physics students as well as for Video-Based Motion Analysis lab in a large Mechanics course for first year students in Engineering Programs.

This work is being supported by HP Innovations in Education Initiative.
Video-based motion analysis demonstrations and assignments in large introductory physics courses

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At Ryerson University, we are constantly searching for various educational tools that can provide our students with the opportunities to engage in an active learning. Activity-based hands-on approach and real-life connections are particularly important for engineering students as well as for other nonphysics majors. Video-Based Motion Analysis (VBMA) is the technique of extracting and analyzing motion data from recorded digital videos. It has become an established tool in teaching introductory physics [1,2,3].

In VBMA, the staged experiments or real-life events involving any types of motion are digitally recorded and analyzed using commonly available commercial or open source software packages. A camcorder or a webcam connected directly to the computer captures the event in real time. In addition to photographs, most modern digital cameras and even cell phones allow the recording of short video clips that can be later downloaded to a computer. The software allows obtaining motion data (both time and position) from each time frame (30 frames per second for a typical camera). The numerical data generated can be graphed, analyzed using spreadsheets, fitted and compared to theoretical models. VBMA offers feasible, cost effective alternative to live experiments when the equipment like motion detectors is unavailable, the motion is too fast to observe with the naked eye, or the events of interest take place outside of the classroom.

Based on our experience with VBMA, it has enormous potential to captivate and engage the students. VBMA can be used to turn traditional lectures into more interactive environment, and to extend student learning beyond the classroom by creating meaningful homework assignments based on live classroom demonstrations. This is particularly important for the introductory physics courses that do not have a formal lab component. Case studies of using VBMA in two large introductory physics classes for the students in Engineering Programs and for the students in all Sciences Programs will be presented. New classroom and homework activities based on the movies recorded by the instructor and the students will be demonstrated.

In addition, VBMA can be a very attractive option for the distance education courses delivered entirely on-line. Different ways of using VBMA for in-class demonstrations, in-class laboratories, as well as homework assignments will be discussed.

The author would like to thank the staff of the Activity Based Physics Faculty Institute http://www.uoregon.edu/~sokoloff/abpi.htm for introducing her to Video Based Motion Analysis.

Inquiry activities’ impact on students’ interest and perceptions about school physics

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Nowadays, it is widely recognized that the students’ lack of motivation for learning physics causes absenteeism and low achievement. So, it is important to develop measures to increase students’ interest for this discipline and, consequently, their academic success. In a constantly changing society, influenced by the development of science and technology, it is essential that physics teaching promotes the acquisition of competences that support students in taking decisions about the world around them, and ensures meaningful school experiences for all students, despite their characteristics and differences (Perret-Clermont, 2004). It is urgent to think and to implement new teaching approaches where students are the centre of their learning. Inquiry activities reflect the way scientists work and do science, emphasize questioning, problem solving, planning and implementing experiences, interpreting data, taking conclusions, communicating results and are student centred (NRC, 2000; Woolnough, 1998). As a result, students control their own learning and have autonomy over the process, and these activities increase their interest and learning. However, developing this type of activities poses an additional challenge to the teachers as it involves changing traditional ways of teaching by an innovative one (Levitt, 2001). This communication aims at illustrating how a new approach of teaching astronomy, based on inquiry activities, raises students interest about physics, engaging them in their own learning. In this study participated a physics teacher with twenty-three years of professional experience and his two 7th grade classes (N=50 students, of whom 20 are girls and 30 are boys). The dropout rates are high as well as school failure rates. Data was collected using interviews to the teacher and students, reflections written by the teachers and observation of students’ interactions (Patton, 1990).

The results suggest that the use of inquiry activities increased students’ interest for
learning physics. Students learnt not only scientific knowledge but also how to plan, experiment, research, share ideas and interpret. Students’ perceptions of school physics is associated with the characteristic of the teachers approaches. By making inquiry activities, school physics was no longer associated with the memorization of formulas, calculations and a set of laws, but was seen as an interesting science that students enjoy learning.


Improving the Teaching of Experimental Sciences

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This work reports the development of an Educational Research Project, FSE/ CED/83453/2008, entitled “Improving the Teaching of Experimental Sciences”. Within this Project 19 University Professors, well acquainted with pre- and in-service teachers’ training, work together with 55 school teachers, teaching Physics and Chemistry, Biology and Geology or Mathematics. The aim of the Project is to develop, within Basic and Secondary School teachers, a guided reflective action attitude as creative practical educational researchers.

The Project started on the 1st of September, 2009. A workshop, WS1, on the 19th of September, with main subject “A Reflective Teacher as a Researcher”, was attended by every team member. Teachers were given some written notes on how to proceed so that they could develop what was expected from them within this Project. First of all, they had to choose a scientific subject among the ones they were supposed to teach during this curricular year. They were encouraged to form groups, each one with several teachers developing the same scientific subject at different school levels. As a result 15
groups were arranged. Prior to any teaching activity, teachers were asked to analyze critically the curricular Government Orientations and Programs, making notes about the way the chosen subject was supposed to be taught:

- Either along successive teaching levels – for instance, in Physics classes, what should students learn about forces and movements on 7th grade and how deeply, and what competences should be developed and trained, so that what is then learned can be used on 9th grade and later on, for the ones that want to proceed with scientific studies?
- Or within different disciplines of the same school level – at the same time, the students can be attending lessons on Physics, on Mathematics and on Geology. How is force dealt with in Geology classes? Shouldn’t teachers try to use the same words with the same meanings?

A second workshop, WS2, took place on the 16th of January 2010. Its main subjects were “Interdisciplinarity and Laboratory work”. Every group had 5 minutes to give colleagues an oral summary of what the group had already done. After that, a poster session was organized with places for the 15 groups’ panels, in which teachers should describe their recent teaching experiences within the selected topic.

A third workshop, WS3, is planned for the coming 17th of April. Its main subject is “Progressive development of scientific contents along school levels”. The Project groups have already been asked to organize summaries, posters and previous small oral communications evidencing new developments of their activities and presenting preand, eventually, pos-tests students’ results. In order to have a reference, the use of control teams was encouraged whenever possible. Some Guided Reflection Helping Documents were already developed by the University team, and sent to the school teachers to be used and commented. These comments will be received prior to the WS3, and will then be discussed, in order to improve future guiding documents.

A final Forum will take place in July, for which the whole science school teaching community will be invited. Final posters, with reflections, comments and conclusions, will be produced by the Project groups.

The three successive workshop presentations, compulsory to every group, force reflection steps on the preparation and development of their teaching actions. Group work was already recognized by teachers to be highly positive for the improvement of teaching activities. The written summaries and the successive poster contents will contribute to the assessment of the different group achievements.
Improvement of Physics Problem Solving Abilities whit a step-by-step strategy: two examples of knowledge bases

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Most of Physics examinations are based on problems, although many teachers don’t discuss with the students a methodology to solve them. So, in order to improve the abilities and skills to solve problems of first term students in an engineering school, we developed a teaching sequence based on Physics Education Research. We use a step-by-step methodology [1].

According to this methodology, the student can solve a problem in steps by performing certain operations that reduce the distance to the solution. For each step he/she requires a procedural and declarative base of knowledge. For this reason first we determined the bases and then we ensure that the student uses them perfectly with the help of a series of simple problems, this for every step.

To determine the bases first we analyze the results of students and then conducted clinical interviews to verify that bases contain the necessary knowledge. Then we analyse the standard problems to establish the steps to solve the problems. Every step has input and output. By input we understand, what the students perceived before starting with every step. And by output we understand, what students get after they have worked in a determined step with the problem. These steps begin with the interpretation of the problem, from a colloquial language towards a mathematical one, and ends with the integral solution of the equations and interpretation of these ones.

Basic statics and kinematics problems were divided into several steps, which at the end were assimilated into a final solution. We have to be sure that the students know every step before beginning the next step. During the development, the strategy has been tested and improved. After the class, the students work online with a number of elemental questions that they answer in a Learning Management System.

In this research, two groups were compared as follows: first we verified that the numerical abilities of all the students from each examined group were equivalent, after that, the results of the experimental group were compared with the ones of a control group. The analysis of the data let us know that students who used this methodology to solve problems had better results in their examinations.

The difficulty with this approach is that the steps we proposed not always represented the best way for all students. We must be attentive to individual cases to avoid creating unnecessary difficulties. This methodology is currently used in a b-learning environment with good finals results.

Mental representation in relative velocities

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When a student solves a problem of relative velocities in two dimensions, usually subtracts the vectors, nevertheless, we observed with qualitative questions that the student doesn’t understand the answer he/she gives. In this work we describe the algebraic and graphical reasoning of the students in relative velocity problems. The graphical part of the solutions is more difficult than the mathematical one, because it is linked with the representation that he/she makes of the movement, Shaffer and McDermott found¹ that the context is also important.

To understand the origin of the difficulty of these problems, we designed a questionnaire about relative velocity and applied it as a pre-test and post-test to analyze the student’s changes after the standard lectures on the subject.

We worked with the Basic Physics course students, that one of their topics is relative velocity. These students have already studied an introduction to vectors in two dimensions and know the meaning of vector addition.

The analysis of the answers show that in the resolution of questions that take into account relative velocity we have a clear difference between those in one and two dimensions and numerical and graphic questions. Almost all the students solved the numerical and syntactic questions in one dimension, but 80% failed in the graphical questions. In two dimensions only 15% of graphical questions were properly solved, after the standard lectures in relative velocities, the graphical index raises to 30% and 65% answered properly vector questions The answers show us that there is a deep problem with the graphical interpretation of the problem, the clinical interviews help us to understand that students have a mixed interpretation of relative velocity between mobile A and B. They mentally jump into the system A (moving system) and they interpret the movement of B not from here but from an inertial system with respect to which are described the motion of A and B.

When performing the vector subtraction operation implicitly uses an inertial frame of reference, this is the reason the percentage of correct answers raises in vector questions. In graphic questions we see no changes because in lectures the discussion on the interpretation from different observing systems is hidden under the mathematical formulas.

In the post-test, after the usual lectures of relative velocity the answers doesn’t show important changes in the graphical part, they can’t represent properly the direction of relative velocity in rectangular axis meanwhile from the point of view of vector analysis they really upgrade their performance. With this, is clear that the solution is not under-
Teaching Wave Aspects of Optical Phenomena in the Atmosphere

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Wave aspects of different optical phenomena in the atmosphere are hardly incorporated into physics textbooks and the teaching of physics. We present essential elements of the wave approach to the corona and the rainbow. Such approach is quite straightforward in the first case, where it is similar to ordinary diffraction and interference of light passing through a circular aperture, but rather sophisticated in the second one.

The description of two main experiments and their results are included. The corona is illustrated by generation of central disk and colour rings around it by white light scattered on a thin layer of small glass beads. The starting point in the discussion of the rainbow is a spectacular experiment in which a whole series of interference fringes is produced in the vicinity of the so called Cartesian ray (a ray of minimum deviation) when a pending water droplet is illuminated by a laser light source. This experiment deserves a wider attention than it has received so far.

We also briefly review the most important achievements in the theoretical description of scattering of light waves by water droplets covering the period from the very beginning of the 19th century, when Thomas Young explained supernumerary bows, till the second half of the 20th century, when precise numerical calculations, based on the solution of Maxwell’s equations for an electromagnetic plane wave incident upon homogeneous sphere, were performed. Even a short history of investigations leading to a better understanding of the rainbow clearly reveals the complex nature of this phenomenon. Interestingly enough, in both cases studied here, the crucial theoretical results are the work of one person: an English astronomer and mathematician, George Biddell Airy.
Contemporary particle physics is object of a growing interest both for Physics Education Research and for Communication of Physics. Such an interest is supported by: the requirements of secondary school physics curricula; the acknowledgment of some problematic issues in teaching Quantum Mechanics that enforce the search for new teaching paths on Quantum Physics; the greater success of public received in the last years by exhibitions, popular science books and extra-school activities devoted to the last frontiers of physics.

It is however evident that teaching or communicating contemporary physics presents a certain number of problems, firstly addressable to the unquestionable hardness of the involved formalism. Many of the existing teaching proposals, designed for secondary school students and of the communication strategies devoted to the general public, face the issue by recur to analogies or familiar images which, although understandable to students/people, are at risk of giving back a still very classical image of the microcosm. The contribution discusses the hypothesis that many problems stemmed from teaching and communicating particle physics show the need of a detailed and deep analysis on the foundations of contemporary physics: Such an analysis can indeed give a fundamental help in highlighting the conceptual nodes and in investigating the essential features of the way in which contemporary physics shapes the microcosm.

The hypothesis is argued by presenting the results of a study focused on the foundations of Quantum Field Theory (QFT) that allowed the individuation of criteria for pointing out critical issues that, in our opinion, have to be coped with in the design of strategies of teaching and communicating particle physics.

In more details, the contribution focuses on the critical issues related to the introduction of the quantum fields, considered essential in order to give back a “contemporary” image of a certain number of phenomena (interference patterns with matter beams, pair creation…). In the university textbooks for advanced courses on QFT, the introduction of quantum fields is usually tackled by recurring to the well known canonical quantization.
Canonical quantization is a powerful procedure to derive the core entities of QFT (quantum fields) from their classical, and more familiar, versions. The starting point, taken as paradigmatic case for developing the whole apparatus, is the classical electromagnetic field on which the following two formal steps are applied so as to obtain the quantum fields:

i) the elevation of the classical electromagnetic field to the quantum one;

ii) the construction of any other quantum fields by means of the formal analogy with the electromagnetic case.

Such a procedure has been analyzed from an educational perspective so as to point out the specific role played by the two involved formal steps, as well as to understand the implications of the general aim of removing the formalism or keeping it to an absolute minimum in order to reach a wider audience.

Working with high school physics teachers on the green house effect: from a research-based teaching learning sequence to the class work

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In the last years, while different approaches in the construction of teaching learning approaches have been suggested, research has shown that the implementation of innovative sequences in the classroom generally implies a transformation of the original proposals, sometimes with the loss of important aspects of innovation.

This contribution deals with a work carried out with a group of experienced high school physics teachers aimed to create a favorable context where to study in its different aspects the problem of transforming a research based teaching-learning sequence in a specific teaching action for a particular class.

A sequence dealing with thermal effects of the electromagnetic radiation and greenhouse effect, prepared by our research group, was chosen by the teachers among different possibilities as the one to analyze and to transform in a piece of the curriculum in their classrooms. In the study we focused on teachers’ reactions to the new proposal, on the construction of their own teaching path, and on its implementation. At the same time, we analyzed and discussed with the teachers data they were collecting on the students’ learning process: students’ initial reasoning on the topic, cognitive acquisitions and obstacles during the sequence, affective reactions, and retained knowledge after the sequence.

This double level of analysis allowed single out some problems concerning the relationships between the sequence project, the teacher’s choices and plan, the actual school practice and student understanding. The discussions within the group of teachers and
researchers often involved a critical analysis of the scientific content and of the usual treatments of the subject in textbooks. Teachers showed a need for a clarification of their own physics understanding and for restructuring their own view of the topic in the teaching perspective. It appeared that this process of personal restructuration together with a reflection on pupils’ learning processes constitutes a strong motive for accepting and actively implementing an innovative teaching proposal aimed at improving the quality of student learning.

In particular, our analysis has shown how the introduction in the traditional curriculum of a multifaceted topic such as the physical basis of the greenhouse effect, produces changes in teachers’ view of all thermal phenomena and of the teaching practices they generally use in dealing with this topic. An example is the change in the explanations of thermal equilibrium and stationary conditions when the framework of calorimetric phenomena is enlarged to consider thermal effects of radiation. In these changes an important role is played by the careful observation, triggered by the interaction within the group of teachers and researchers, of students’ reactions and reasoning during the activities carried out in the different classes.

The classes involved in the work belong to different types of school and have different curricula, social background and age. These differences led to slightly different teaching plans, but in the frame of a common elaboration, which produced a common core of objectives, contents, experiments and questions with some variable elements and different levels of abstractions and deepening.

**Learning Physics: a Competency-based Curriculum using Modelling Techniques and PBL Approach**

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As pointed out by the OECD Global Science Forum in 2006, in many countries, learning Science and Technology is less and less attractive for young people. At the same time, the overall needs for competences in scientific and technological fields are increasing. Changing the way Science and Technology is learned is becoming of crucial importance.

Besides these general trends, French “*Ecoles d’ingénieurs*” are now compelled to define the learning outcomes of their curricula in the form of a targeted knowledge, skills and competencies framework: the national accreditation body “*Commission du titre d’ingénieur*” proposed, as a reference since 2006, a general “capacities and competencies framework”; and it has now been completed by the European Qualification Framework initiative adopted by European Parliament and Council in 2008, which is supposed to be applied from 2010 onwards.

With the support of our Board, we have decided, in *Ecole d’ingénieurs* CESI, to address these issues in an innovative way, and to face a double challenge concerning our
curricula in Science: to define competency-based curricula, and to make learning more attractive by using modelling techniques and tools together with a Problem-based Learning (PBL) approach.

Within the scope of this project, “competency” has been defined as the ability to use cognitive resources (knowledge, skills...), operative resources (procedures, tools...) and monitoring indicators, in a given situation (context), to achieve specific outcomes. This allows a very detailed description of each part of the curriculum: each competency is described within a context of application, with the associated concepts and principles which should be mastered, the associated tools including mathematical expressions that should be used, etc. This description then facilitates the selection of an appropriate problem for each step of the learning path, allowing individualized learning paths according to the results of prior learning assessment tests.

This year, Ecole d’ingénieurs CESI has in total 2715 students registered for all its curricula in engineering and a few hundredths of teachers in Sciences. So, the new approach in Science has to be progressive, accepted by the teachers and carefully validated before being generalized. This is why the project team has decided to start with a first limited experiment involving a few teachers in Mechanics.

This experiment is monitored by the Learning Environments Design Laboratory (LED Lab), the Educational Sciences Laboratory of the school. The Force Concept Inventory (FCI) test will be administered in June to all the students in the school prior to starting the experiment. This will give a picture of the average level before any course in Mechanics at the school (students in 1st year), and after a course given in the traditional way (students in 2nd and 3rd years). This test will be used again after the course in Mechanics to measure the gains of the experimental course and to compare them with those of traditional courses given in parallel.

The final paper will present the rationale of the methodology used to design the experimental curriculum in Mechanics and will provide some detailed examples of learning situations and problems designed in order to acquire given competencies.

Inquiry-based physics education in French middle school

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Developed countries are facing a long-standing phenomenon of students deserting science studies. In response, many international reports have been published to improve
science education in compulsory schooling (High Level Group, 2007). They often encourage important evolutions regarding the final objectives for science education (Osborne & Dillon, 2008). Thus an understanding of the nature of science and its practices in classrooms holds a significant position, as does the learning of scientific knowledge. These changes have shaped the role of experimental activities, leading to science teaching through scientific inquiry in the 60s in the United States.

In France, inquiry-based science education (IBSE) was introduced with “La main à la pâte”, a program launched by the French Academy of sciences in 1996. Tasks relating to scientific investigation are encouraged, aiming to develop a scientific literacy for all and raise students’ interest in science. Specific teaching models such as socio-constructionism are used (not always explicitly), calling upon real-life contexts. In 2000 a national renovation plan in science education aimed to generalize IBSE in primary school. Since 2005, French curricula have evolved in middle school to encourage inquiry-based approaches where pupils should become active learners.

Recent research studies analyze these new directions. Some are more concerned with the explicit meaning of IBSE in curricula. Others intend to evaluate the effect of such teaching procedures on pupils’ learning and teaching practices. The benefit of IBSE on pupils was shown, both in terms of scientific knowledge acquisition (Hofstein & al., 2005) and regarding their attitude towards science (Gibson & Chase, 2002).

In this paper, we present and analyze examples of classroom sequences produced by researchers in science education. A diversity of procedures was encountered: problem solving, open problem solving, PACS (Prévision Argumentation Confrontation Synthèse), games or other out-of-school contexts, modeling etc. From the analysis we define a structure shared by all of these teaching sequences. A common characteristic is to assign pupils a succession of tasks, we called ‘series of tasks’ (Morge & Boilevin, 2007), underlining the fact that task T+1 depends upon the knowledge available and constructed throughout task T. Hence, we propose a model for carrying out an IBSE sequence. We believe this constitutes a tool for teachers to analyze, compare, choose, create and conduct inquiry-based science classroom activities. The model also allows one to define criteria to identify IBSE approaches from within the wide range of teaching strategies. Analysis of these systems highlights a high level of homogeneity with regard to pupils’ learning position, the importance attributed to scientific argument and debate, or the importance of the teachers’ role in managing these teaching patterns.

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Foucault dissipation of a magnet falling through a copper pipe studied by means of a PC audio card.

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This work presents an experimental learning path on magnetic induction, centered on Foucault’s eddy currents. Proposed experimental activities are based on various measurements on an Atwood’s machine, one of whose masses is constituted by a permanent cylindrical magnet falling through a plexiglass pipe. Hollow copper cylinders of different heights are available, whose inner diameter just fits the external one of the plexiglass pipe. These copper cylinders can be externally fixed, at will, around the pipe. In this way, the magnet drop through a conductive guide can be studied, by varying the guide length, the magnet acceleration and the magnet falling height with respect to the conducting copper guide.

The measurements (of both magnet position and speed) are performed by employing self-made induction sensors connected to a PC audio card. Freely available acquisition software is used, allowing to utilize the PC as an oscilloscope. This setup permits the study of energy dissipated by Foucault’s currents both when guide length and in-guide magnet speed are changed. This, in turns, allows teacher to give and quantitatively discuss an explicit example of a system in which energy dissipation depends on speed.

The proposed learning path is under evaluation in some high school, within the Project “Lauree Scientifiche” promoted by the Italian Department for Education.
An experimental learning path to introduce clean energy in the primary school.

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The topic of clean, renewable energies is of extraordinary importance, both for environmental protection and for economic reasons. From an educational point of view, the treatment of this topic allows to introduce and to deepen various questions regarding the inter-conversion of the energy among its various forms (i.e., gravitational, electric, radiant and so on). This may be done at various levels: from a simply qualitative one (suited for a primary/middle school level) to a quantitative treatment (to be proposed in the high schools).

In this context, we present an experimental learning path on clean and renewable energy for primary school, that can be divided in two different parts: the first one is a problem solving activity appropriate to introduce electromagnetic induction, the second one is an activity by artefacts through which children can analyze the functioning of two different energy-conversion devices proposed as applications of electromagnetic induction. The two employed devices, built by using easily found and low cost materials, allow pupils to understand the functioning of a wind generator (Savonius turbine) and of a hydro-electric generator. All of these devices are visually and interactively illustrated, as well as the outstanding physical principles.

Promoting Effective Science Teacher Education: An Investigation into the Effectiveness of a Targeted Pre-service Physics Module in Ireland

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In Ireland there has been a steady decline in the number of students studying science subjects and in the context of Ireland’s technological society and economy, students’ interest in the physical sciences is of utmost importance. The demand for science graduates in these economic times has made high-quality schooling more important than ever. The literature highlights several factors that influence student learning, including
attitudes, student skills, expectations and teacher knowledge. Many papers document a growing dissatisfaction with the quality of physics teaching and learning, which has resulted in widespread changes in the practice of pre-service teacher training (Aiello-Nicosia and Sperandeo-Mineo, 2000). This paper reports on one such change in practice which took place in the University of Limerick, whereby third year undergraduate education students experienced teacher training which was designed to target ill-equipped pre-service physics students.

Pre-service science teachers are affected by their prior experience of physics, which can often be limited and consequently poor. As a result this can lead to a low sense of self-efficacy to teach science (Sherman and MacDonald, 2007). To satisfy the needs of the students the structure and content of the course must be both organised to improve the students’ confidence in their teaching and also to prepare them to carry out the teaching tasks during their own teaching experience. Within this study this approach involved substantial modifications to the previous years, including the teacher’s role and teaching methods employed.

The cohort of students (N = 24) included a wide variety of abilities from two courses, biological science education and physical science education. The students’ timetable for this module consisted of a six-week teaching block including a two-hour lecture and a two-hour laboratory weekly. The students’ tasks were designed to facilitate inquiry based learning. During the twelve week semester the students were asked to complete three assignments: a scheme of work, ‘physics snaps’ and a mini-project. The initial assignment was divided into two where the students were asked to develop two schemes, each on different topics. The ‘physics snaps’ assignment involved the individual students capturing a real life situation on a photograph that relates to a physics law, principle or phenomenon. The students were then required to explain the ‘physics behind the photograph. The mini-project required much more from the students. This project revolved around pre-designed physics questions which the students were asked to solve using an inquiry-based approach. The students worked in pairs with each completing an individual report. The pre-service teachers were surveyed prior to, and following completion of the six-week teaching block. Preliminary analysis of the data indicates that the inquiry based approach increased the pre-service teachers’ attitude towards physics but also their confidence with regard to teaching secondary level science and physics.


STEPS TWO Academic Network use the partnership and expertise of EUPEN (European Physics Education Network) Consortium [1], in order to provide universities with a support in implementing reforms in physics education and to respond to lifelong learning priorities. In the process of reconsidering their traditional curriculum, universities need to give a higher priority to mobility, to interdisciplinarity and transdisciplinarity. The principal aim of STEPS TWO academic network is to provide Europe with increasing number of well trained Physics graduates, among them the Physics teachers.

One of the main objectives of the STEPS TWO project is to sustain the Physics Teacher Education in universities, notably with regard to the trends in European Teacher Education, in order to reinforce the study of physics subject before university. To attain this objective, one of the most important line of action is developing policy recommendations and offering solutions for concrete strategies in Physics Teacher education.

The network partners are using their wide experience in enquiring, analyzing, mapping and disseminating the results, taking the advantage of a long term fruitful cooperation. In order to get a picture of the ‘pre service” and “in service” Physics teachers training the questionnaire was organized in four parts. Part AA containing 5 questions with multiple responses was designed in order to collect information about the respondent (university, department, activities in training teachers, fields of interest in teachers training, researches in teachers education, main problems encountered in physics education and interest in project activities. In the 8 question of the part A was addressed the problems of Physics education and teachers training at university level (requirement for employment, teachers assessment, in service training). The part B was the most consistent and contained 23 questions addressing the problems of Physics education at the level of low and high secondary school (curricula, subjects, routes in teachers training, teacher assessment, in service teachers training, etc.). The last part C contained 8 questions related to the Science education in primary school (curricula, “pre and in service” teacher training, teacher assessment).

40 respondents from 26 EU and associate countries contributed to the survey concerning Science and Physics Teachers Education, confirming the subject importance. “In service” teacher training is considered as a crucial action to be conducted in the educational system [2].
The teacher education is confronted with many problems and the most important seems to be the school Curriculum, changing continuously in most of the European countries. The second problem is the shortage of the teacher initial training and the low level of the subject knowledge of the initial appointed teachers. Another problem is represented by the low level of modern teaching tools and laboratory facilities harming the efficiency of the instructional process. Half of the survey participants claim the quality of the teachers training programmes, referring both the ‘pre service” and “in service” training programmes.


Active learning strategies for developing pupils’ creativity in Physics

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Nowadays in our knowledge based society was shown an increasing and general interest, refereeing the act of creation, the modalities in identifying and developing creativeness. The creativeness is a fascinating theme, beyond psychology and scientific domains. The identification and cultivation of students’ creative behaviors during Physics classroom activities must equally address all types of creativity (traits): fluency, flexibility, elaboration, originality, complexity, risk-taking, imagination, curiosity. The same importance must be paid to the four traits groups: scientific thinking (special abilities), creative thinking, intrinsic interests and multiple intelligences profiles.

Gardner stated for early exposure of the pupils to various learning contexts and tasks. The pupil’s intellectual skills and intelligence profiles are improved by problem solving process materialized in different practical situations. To educate the students’ exploring competence and communicate performances in “their intelligence code” imposes the teacher to create adequate learning situations.

The students are different by their native intelligence profiles and also by their developing paths. The teachers are asked to open all the ways, encouraging pupils to improve their intellectual skills by providing individual and group tasks, encouraging student’s liberty of choosing actions. Contextualizing the assessment as pedagogical
model adjusted to the multiple intelligences profiles, the teacher must address student, capacity to wield cultural symbols and to carry out creative activities.

The objectives of this research are: to identify and practice some active learning strategies; to conceive some flexible strategies of using the active learning techniques in Physics lessons; to publish a methodological guide for the Physics teachers. For a better correlation between the objectives and the teaching activities we have adapted the contents so that we can exploit what the pupils already know, to lead them to discover new things or to correct through research and investigation what is unclear. Throughout the academic year the pupils have done the following things: devices, drawings, scientific and literary essays, projects, games, worksheets. They have studied Physics at home, in the laboratory, in nature, working in groups, individually or in pairs. To observe the impact of the project upon the pupils we have realized a study case using the following instruments: questionnaires - which were applies periodically, evolution graphics for each pupil and each class involved in the project, evolution graphics for every pupil and every class that were not involved in the project, a comparison analysis of the two classes, the growing number of the pupils taking part in school competitions in Physics and their performance.


Students’ motivation and context based approaches

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The motivation is essential in improving students’ performances and the context is especially emphasized in context-based approaches. In these approaches contexts and applications of science are used as the starting point for the development of pupils’ scientific knowledge. Pupils could become interested in sound and ultrasounds subject if the teachers start the classroom activities with musical instruments or medical techniques for diagnosis. The approach is different from the traditional one in which the teacher starts with theoretical aspects and ends by mentioning the applications [1].
The specialist classified motivation in intrinsic and extrinsic. The intrinsic motivation leads to intensive and persistent studying activities improving the quality of learning [2]. Intrinsic motivation has its source in the instructional activities and is satisfied during it determining the students to become involved in action for his self-satisfaction and pleasure without external constraint factors. Instructional activities motivated by intrinsic motivation are explained by their appeal of novelty, challenge and passion for the subject.

The extrinsic motivation has its source in external factors as incentives (grades or prizes, and advantages). The involvement within the activity is perceived as tool in attaining the goal. The learning activity is performed as a response to a conditioned task without pleasure, satisfaction and with voluntary efforts. If Extrinsic Motivations become the primary incentives that motivate students to perform their work, the children will develop poor habits and miss out on the self-satisfaction that comes from hard work. If extrinsic motivation changes in intrinsic one the student could become interested in the subject [3].

In order to identify the type of low secondary school students’ motivation and how the context-based approaches can influence it was designed and administrated a questionnaire. The questionnaire has been prepared through cooperation so that the findings could help teachers to make their classroom activities more interesting. The questionnaire was distributed in 2 schools with different cultural contexts and more than 1000 students answered. The survey contains open and closed questions. The students’ answers are correlated with their scholar performances. The identification of the real motifs of learning supply teachers approaches in order to ensure students’ performances improvement.

Using ICT and Physics laboratory practice in increasing students’ motivation

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Physics is a difficult subject not only for most people but also for students highly interested in understanding nature and everyday life. The difficulties arise for a teacher when having to accurately and concisely explain to students conceptual representations in Physics in order to lead them to a deep understanding of phenomena and laws of Physics. Both teachers and students could have difficulties in explaining Physics concepts or experimental activities clearly and concisely. Physics knowledge is gradually built and developed in the student/teacher relationship in the classroom during the classes. The main aim of the practical activities is to develop student competences and skills with a view to supporting students’ professional insertion.

The inquiry-based strategies and interactive methods supported by information and communication technologies used in Physics classroom and laboratory activities are not new. In most of the cases ICT is used to familiarize students with physical phenomena which are hard to be reproduced in the laboratory, very rare in the natural environment or difficult to be noticed due to their short length of occurrence.

A very enthusiastic group of physics teachers started the PhysTech project, benefiting from the school laboratory with computer networks and touch screen table, and being assisted by the Advanced E-Learning system (AEL). The project is now in the third stage. In the first stage when the multi touch screen table was installed the teachers and students became familiar with it and discovered the table’s usefulness in analyzing experimental data, phenomena, physics laws etc. In the second stage the computers network was installed so the students and teachers used the Intra and Internet facilities offered by AEL system. Now the project is in the third stage in which students and teachers contribute to the software collection and application supporting the teaching/learning activities.

The “new face” of the laboratory of physics has changed the students’ attitude towards Physics topics and subjects. Attracted by computers, screen and moving images students have become more motivated and confident in discussing physics phenomena and experimental set-ups. Virtual instrumentation and data acquisition will become the fourth step of their activities in the laboratory. Physics is no longer a boring subject. Some of the students have increased their performance, interest and self esteem. Students with a high level of performance have been paid special attention. As a result, the learning process has been individualized and students have received personalized tasks.
In our Physics laboratory the computers network is used in data acquisition, physical measurement, data processing, phenomena simulation, dynamical models demonstration. The computers are sometimes used in assessing the students’ performance or/and in solving problems.


Physics Teaching and Brazilian Sign Language: the “Signing Physics” Project and a movement towards scientific education

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Deaf education, all around the world, presents the same problems and situations, despite local culture and history. We found teachers of deaf students that are often not well-educated on the subject and educational materials just adapted and not designed to suit students needs (MARSCHARK; LANG; ALBERTINI, 2002; ROALD, 2002). Brazil has adopted Brazilian Sign Language (Libras) as a second official language, besides Portuguese, but deaf education still has problems because Law cannot supply, at least in a short period, the necessary amount of qualified teachers, specially on sign language. When dealing with science education for deaf or hard hearing students, we find another obstacle, the absent of technical and scientific signs. A similar situation took place the United States (LANG, 1996) and in Norway (ROALD, 2000) at the 1970s. In 2008, we have started the “Signing Physics” Project at Mato Grosso Federal University (sponsored by FAPEMAT - Fundação de Amparo à Pesquisa do Estado de Mato Grosso), which aims to research Physics teaching through Libras. At first, this project found on the literature, as expected from earlier readings, just a few signs dealing with Physics terminology and we have questioned ourselves: “how could deaf students learn Physics and/or Science if there aren’t enough signs about these subjects?”. Then, trying to help teachers, students and interpreters, we have decided to compile some of the main concepts for teaching Physics and assign them a sign from Libras or even from another sign language as ASL, BSL or NSL, when they seem to fit our necessities. Sometimes we have just created new signs based on our understanding about the concepts, or modified existing ones that could be related to the concept in question. As an example for the
last situation, we could mention our sign for “phenomenon” (figure 1) that came from
the Libras “to happen” sign (figure 2), both having the same movement, but different
hand configurations. Finally, we have elaborated a vocabulary for Mechanics and we’re
finishing two others, one for Thermodynamics and Optics and another for Electricity
and Magnetism. These books could be found at www.ufmt.br/sinop/sinaisdafisica be-
because we think the access to information and to the literature is a cornerstone for deaf
education. We also want to receive suggestions, corrections, new signs and questions
about our work. Finally, by showing our materials and what we have done so far, we
hope to help Brazilian deaf students to improve their knowledge about Physics and
about the relation between Science and their lives, which we consider important to eve-
ryone who wants to become an active citizen.

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MARSCHARK, M.; LANG, H. G.; ALBERTINI, J. A. Educating Deaf Students: from research

ROALD, I. Terminology in the Making: Physics terminology in Norwegian Sign Language, The
Deaf Action Committee for SignWriting. URL: http://www.signwriting.org/forums/linguistic/

ROALD, I. Reflection by Norwegian Deaf Teachers on Their Science Education: Implications for
Optical tweezers: approaching research topics in photonics to undergraduate students

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Optical tweezers (OT) are highly-focused light beams which are able to trap and manipulate small particles by taking advantage of the radiation pressure effect [1]. Moreover, OT also constitute an useful technique for measuring forces in the microscopic world. Recently, several experimental methods have been developed to measure the force exerted by a light beam [2]. Optical trapping experiments are being introduced into some undergraduate and Master’s programs in Physics, Photonics or Nanotechnology. OT currently represent a multidisciplinary area of study suitable for advanced students with a knowledge of a wide range of fields. For instance, building an OT set-up involves microscopy, electromagnetism, laser technology, signal processing, hardware control, etc. Related to this, some papers have been published pointing out the usefulness of OT as an educational tool [3,4]. In our opinion, considerable knowledge of the underlying theories is necessary to make the most of OT experiments but, as the number of papers in this field is huge, students will have to access a large amount of reference work.

In order to provide comprehensible information to the students, we have developed a Java application that simulates the behavior of a spherical dielectric particle trapped by means of a focused laser beam. This program illustrates a wide range of theoretical results in the Mie and Rayleigh regimes [5]. Instructors can propose different tasks that can be carried out using the applet. A simple exercise is included here as an example:

Design an OT system that can trap dielectric spheres (n=1.58, radius=4 μm) in water at T=300 K using a HeNe laser. Discuss which available objective is more convenient and the most suitable combination of overfilling ratio and laser power. Determine the stiffness of the trap and the trapping position.

Figure 1 shows the Force Analysis panel of the application corresponding to the solution of the exercise. Some more examples and further discussions can be found in reference [6].


Figure 1: OT simulation main window
Argumentation has recently become a common topic of research in science education. On the other hand, the interpretation and construction of graphs is a classic topic still present in science education research. In contrast, research on learning to construct and interpret tables is very scarce. Still less common is to find research that deals with the use of tables and graphs as evidence to justify a given argument.

The present work analyzes the use of Tables vs. Graphs to justify a given claim in an argumentation written task about an energy dilemma and also to infer about the quality of argumentation of those students’ written texts.

A dilemma about two sources of energy was presented to fifty 13-to-14-year old students. The task performed by the students, individually, had two parts. In the first part they had to decide about the dilemma and to justify in a written text on the base of the information given to them as a verbal text. In the second part, the data (graphs or tables) were given to students and they had to write a second text confirming or changing their previous position with the support of the data.

The Analysis: In the first part, the students’ texts were coded according to 1) the option they choose; 2) the types of arguments used by the students and comparison with the arguments given in the dilemma and 3) the quality of argumentation, which is defined by: a)evidence that supports the claim only, b)evidence that supports the claim with rebuttals, c)evidence that supports the claim plus evidence against the alternative, d)only evidence against the alternative.

In the second part of the analysis, the students’ texts were coded according to: 1) keeping or changing their position, 2) giving the same arguments or adding new arguments in the second text in comparison with the first text, 3) using the tables or graphs to defend their positions and/or to disconfirm the alternative position, 4) the general strategies used to construct the arguments, 5) the specific strategies used to integrate the tables or graphs into their arguments.

Results: In the first text, approximately the same percentage of students (40%) chooses the thermal station or the nuclear station. There is also a quite significant percentage of students that choose an alternative source of energy. The majority of students argue using the reasons given in the dilemma. Most of the students use only supporting arguments to their claim, but also a significative number of them use arguments to refute the not chosen option as well. We have found some students with high quality argumentation.
In the second text, the majority of students not only don’t change their chosen option in the first part, but they seem to use the tables or the graphs as evidence for their previously chosen option. Students can be categorized into several groups according their general strategies using graphs or tables in their arguments that go from a simple reading or commenting the data to the integration of this data into the arguments, and also in relation to the specific strategy coming from the way they interpret tables or graphs to its integration in the arguments. These strategies are related to the condition of having tables or graphs.

Implications for science education and references will be presented in GIREP 2010.

Learning «without Teaching»: Lab Activities and Self Awareness of Physics Competencies to increase Motivation and Disciplinary Reasoning

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We report the analysis of several Physics laboratory activities based on a teaching/learning strategy developed in the last years for the University course “Preparation of Didactic Experiences” held in Milano for graduate students in Mathematics. The aim of the approach is to promote Physics understanding through the development of self-made inquiry activities of the students involved, without any prescription except for minor hints given by the Professor. In fact the only request is that students, working in groups of three or four, make their own investigation «inspired» by the material proposed on their bench-tables. Questions asked by the students are answered only if «well-posed» while pedagogical seminaries on the construction and meaning of the physical world and theories are held «when needed». The goal of this approach is to make students well aware of their disciplinary (or lack of) knowledge and to bring them to a personal reconstruction of basic concepts and methods.

The University course has been attended by 18 students who had previously followed at least two University Physics courses in Classical Physics (most of them had also studied Physics in Secondary School) and has been held by a Physics Professor with the help of a Pedagogist, a lab Assistant and a Secondary School Teacher.

The analysis we report on has been made i) following the strategies and the activities of the students during the course, ii) comparing the outcomes at the end of the lab with students’ knowledge before the course, and iii) comparing students’ final results with the aim of the course.

This approach has been proposed, with due differences, also in a Secondary School class composed of 19, 16 years old, girls who had often worked in collaboration with 40
Primary School pupils. The aim has been to make the students aware of the “meaning” of a physical laboratory experience, “conducting/driving” them to explain a phenomenon using an appropriate and correct “theoretical model”. A highly interactive method has been used in order to stimulate students’ creativity and intuition. The students have been given different sets of laboratory kits, and have been asked to realize an appropriate experiment which had to be properly described in a report. All students’ work has been carried out in groups and most of it has been object of monitoring.

In both (University and Secondary School) contexts, in spite of the different knowledge and working level of the students, some common results (such as an increasing motivation and enthusiasm, and a number of interesting intuitions) have been observed, together with a final «dramatic» non progressive shift from common sense to scientific disciplinary reasoning in a large number of students.

**Effectiveness of Real-life Context Based Approach Integrated with 7E Learning Model on High School Students’ Science Process Skills**

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In literature, there are many studies about context based approach and 7E learning model. In this study, to research students’ science process skills real-life context based approach was integrated with 7E learning model.

The purpose of this study is to investigate the effect of the real-life context based approach merged with 7E learning model on students’ science process skills which are identifying variables, formulating hypotheses, controlling variables, interpreting data and graph, recording data and constructing graph. In this study, pretest-posttest design with control group was used.

The test is consisted of 16 multiple choice and 6 open end items. Identifying variables, interpreting data and graph formulating hypotheses and controlling variables were investigated by multiple choice items. Constructing graph and recording data were investigated by open end items.

To find the reliability of this test, 331 high school students were selected for pilot study. Using the Kuder Richardson formulation (KR-20) reliability coefficient of 16 multiple choice items was found as 0.80. To find the reliability of open end items 100 students were selected randomly and students’ answers of the open end items were assessed with the analytical rubrics by three referees. The correlation of scores was investigated by Spearman’s rho correlation coefficient and positive correlation was found between referees’ assessment.
Experiment group consists of 50 students; control group consists of 45 students from two different schools. There was no significant difference between the control and experiment group students’ pre-test scores.

Based on the 7E learning model, four different lesson plans were prepared by the use of real-life context-based approach. Science process skills were integrated with 7E learning model. Worksheets were prepared for experiment group. First part of the each worksheet includes a text which describes the context. Each worksheet has an experiment about a type of “energy”. Science process skills are especially emphasized in the explore and explain stages of 7E learning model. In the explore stage of 7E learning model, students made the experiments. In this stage, students identified variables, formulated hypotheses, estimated and recorded data about experiment. In the explain stage, students constructed graph and interpreted data and graph. For two months period, these lesson plans were applied to experiment group. For the control group, traditional approach was applied. How formulate hypotheses, record data and construct graph were given for control group.

Results of the analyses showed that there was a significant difference between the students’ science process skills scores in pre-test and post-test for experiment group. For control group, there wasn’t significant difference. The findings of this study showed that the real-life context based approach integrated with 7E learning model was more effective than the traditional approach in terms of students’ science process skills.

**Experiences from the new subject for the first year students – Physics and Nature**

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Can the ongoing scientific research in physics be introduced to novices in physics, the first year students or the students in the last years of high-school? Our aim was to construct a subject that gives the positive answer to the question stated above. In addition, we hope that the subject also increases the motivation for physics. Such subject should work positively on the motivation of students who already enrolled the study of physics as they can get an idea about the possible research problems in the future. Some topics developed within this subject can be taught in the high school and may become the crucial point in a student’s decision of future studies, we hope.

Topics taught in physics courses in high schools and in the entering courses at the university level are often considered by students as boring. The reasons stated are that
physics is often taught at the rather abstract level using various assumptions (Who does not use negligible friction, rigid body, weightless string, etc.?) leading to results that are never found in everyday life. The topics usually include “old” physics, known for two hundred years or more. Examples from nature are avoided as they are complex and have many uncontrollable variables. Last but not least, the teachers are usually not informed about the ongoing scientific research well enough to be able and willing to make difficult adaptations for students, having little knowledge of physics.

The subject Physics in nature is taught in the first semester of study. Each week it includes a 90 minutes lecture and a laboratory exercise of the same duration. In addition, the students prepare a seminar, where they present their small research problems from everyday life.

The topics considered are:
- Earthquakes and buildings;
- Magnetism and superconductivity;
- Density, buoyancy and underwater world;
- The body temperature of leaving species;
- Diffusion, osmosis and life processes;
- Surface tension;
- Water transport in high trees;
- Light, polarizers and colours;
- Liquid crystals;
- Physics of sports.

In the contribution we present in more details the philosophy of the subject, the criteria for choosing the topics, the activities done during the lectures and laboratory work and the results of the course evaluation. The evaluation of the acquired knowledge was done by a comparison between the pre-test for each topic and answers to questions at the written exam. The qualitative study of students’ interest or lack of interest for different topics was also performed. In spite the careful selection of topics, we still assumed that some topics will be less interesting for all students. Surprisingly, we found that for each topic there were students, who found the topic as their favourite one. Not so surprisingly, most of the topics were considered as non-interesting by a few students as well.
At 1st of January 2002 the Euro becomes a common currency in eleven European countries. Few years later, at 1st of January 2007 Slovenia joined to the ECU (European currency unit) as a thirteenth member. At that time the national currency tolar was exchanged for Euros within two weeks. As coins of different European countries have different heads, the coin’s origin can be straightforwardly recognized. When the new coins with Slovenian motives were released, a unique possibility to follow their mixing with Euro coins from other countries appeared. We followed the mixing of coins for two years. The study was performed at the Faculty of education involving the volunteers (mostly our students) who were willing to take part in this long-lasting study.

We tried to find answers to the following research questions:
- What was the percentage of foreign coins at the introduction of new Slovenian coins?
- Is the time dependence of the Slovenian share exponential?
- If so, what is the characteristic time?
- Which foreign Euro-coins are most frequent?
- What are their characteristic times?

The Euro coin mixing is an example which can be analyzed using the diffusion as a model. The collected data can be used as an exemplary experimental result for a sociological study in undergraduate courses. The estimations of expected results are a classical examples of Fermi questions. In addition, physicists are often employed in social sciences and other professions where they work in statistics, designs of public opinion measurements and similar. The presented study can be a good example of the problems which may occur when ”measurements” are performed in society. A lot of attention is needed to collect the “real” and not the “fake” data. The long term study in society can fail due to the decreasing motivation of volunteers etc. It is also a good example of showing students that in society circumstances that are interesting to be observed are often unique events. They have to be observed at the time, when they are present and they cannot be reproduced or modeled in a laboratory as we are used in physics.

The results are also interesting for future studies. They could stimulate newcomers to the Euro region to study the migration and mixing of their coins as well and to answer few questions which we did not consider. Finally, the coins in the Europe are not mixed yet. It is still worth to follow the presence of foreign coins and the share of the domestic coins from time to time. For such an in-situ measurement, the school and the university is the best place.
We developed several online diagnostic activities intended to improve students’ conceptual understanding and reflective habits in physics problem solving. The activities provide opportunities to explicate alternative interpretations for physics concepts and principles and negotiate meaning during several learning cycles. It involves as a 1st step the e-tutor “mimicking» a novice - presenting a mistaken solution that the student is asked to diagnose, and as a 2nd step the e-tutor modeling diagnosis for that same mistaken solution, and the student is required to compare it to his own diagnosis and reflect. Then the student is provided with an additional isomorphic mistaken solution and has to repeat these steps.

In this presentation we focus on the topic of electro-magnetism. The mistaken solution, is designed as an answer for a problem taken from published diagnostic questionnaires. The answer includes both a mistaken prediction and a mistaken reasoning leading to that prediction. For example: one of the items involved two parallel wires I and II that are near each other and carry currents i and 3i both in the same direction. The students were asked to compare the forces that the two wires exert on each other (item 24, CSEM, Maloney et. al., 2001). The mistaken answer provided included a) a wrong prediction: «wire II exerts a stronger force on wire I than I exerts on II…» (reported as chosen by 45% of the students), followed by b) wrong reasoning «… since the first wire carries triple current, so the force it exerts is 3 times larger». In the 1st «diagnosis» step the students were required to 1) Identify the wrong part in the answer. 2) Explain the nature of the mistake. (3) Suggest a correct answer. In the 2nd step the etutor provided explanation for the nature of the mistake and a corrected answer.

The activities are aligned with the four components identified by Linn & Eylon (2006) as necessary in «re-organization of knowledge»:

1. Eliciting: 1st step - Students think how they would solve the problem.
2. Adding: 1st step - pointing out the solution involves a mistake; 2nd step - providing sample diagnosis.
3. Evaluating: 1st step, students diagnose the mistaken answer; 2nd step - students compare their work to that of the expert.
4. Re-sorting: 2nd step - students state what they have learned, then they repeat the
task with an isomorphic mistaken solution.

Former study showed that

1. Students’ conceptual knowledge did not deteriorate following exposure to common mistakes, as some instructors suspect.

2. Most of the students who did not realize the mistake in the first mistaken solution, did realize it in the isomorphic mistaken solution.

In this paper we will focus on the content area, following how students’ conceptual understandings evolved along the activity. In particular, how students performed in identifying, explaining and correcting their mistakes, and how their conceptions changed after reflecting on the e-tutor modeling.


A story as innovative medium for science education in primary school

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Science education researchers are working on theoretical and methodological foundations for constructing and using stories in science teaching. Following this challenge, a story has been integrated in an educational path for primary school together with the Prediction-Experiment-Comparison cycle, and group discussions guided by the teacher. This methodological choice derives from the consideration that an effective learning is achieved if children are involved both cognitively and emotively, and from the importance of an interdisciplinary perspective, not only inside the experimental sciences, but also towards the human sciences. The effort has been addressed to identify the peculiarities of a story and of its characters to be relevant for science education, as well as to design its integration with experimental activities and discussions.

An experimentation with 8-9 years old children has been performed about the subject of water in equilibrium and in motion to identify the level difference as driving force for water flow, the relation between pressure and current, and the role of the pipe connecting two vessels in terms of resistance. In this paper we summarily illustrate the story
about the adventures of a character named Leo and his friends and the way it has been employed. In addition we discuss the results of the experimentation, obtained from the drawings and the writings produced by children during the path. The analysis gives information about the interaction between imaginary and real world; the inclination of children to describe, to make hypotheses and to interpret phenomena; the differentiation and clarification of the basic physical concepts; the abstraction ability.

Conceptual images and analogy in Physics formation of primary school teachers

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Primary school teachers need a formation in physics robust enough to enable them to interpret phenomena and new and complex situations they encounter as well as to meet the children’s questions. At the same time they need basic and elementary knowledge that enable them to design teaching activities for children and to engage physics teaching with other disciplines, scientific or not. In initial teacher education, it must also be taken into account the limited scientific and mathematical background of students enrolling in university courses.

The approach, that starts from an analysis of the misconception to construct a formal knowledge that teachers need to make then non-formal to teach children, is ineffective. One way more appropriate seems to be that based on research in the fields of cognitive linguistics and cognitive sciences that focuses on the simple structure of imagination that are used to interpret everyday phenomena.

From this point of view, the contents of the course of Physics of the Degree in Primary Education of the University of Modena and Reggio Emilia have been restructured in order to highlight the common conceptual structures, and maybe the specific differences, between the various contexts of the discipline [1]. The students’ teaching was first focused on the clarification and the differentiation of the basic concepts for interpreting the processes such as substance, storage, capacity, potential, current and resistance. These basic concepts have not been built, as often happens, in reference to a specific disciplinary context (i.e. fluids), but qualitatively though rigorously from a series of examples taken from everyday experience and known contexts, to recall and clarify the conceptual images own by students. The analogy was heavily used in the next study of the disciplinary contexts of fluids, electricity, motion and heat, but not as a bridge to project a context domain to another, but as a result of the use of the same conceptual images to interpret phenomena and processes [2].

In this contribution we present the structure and the contents of the course according to this approach, and the results of the analysis of the cards compiled independently and individually by students during activities of experiment interpretation in the particular
contexts of fluids, electricity and motion.


Resetting the Teaching of Energy with the Gibb’s Legacy

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The problem of energy is not a new one, but the contemporary debate on climate change has added to it highly emotional contents. The science and technology challenge for environment friendly energy sources, should have at least brought some benefits to our community. What else could help if not the knowledge of the natural sciences, beyond the good will, of course. Instead the popularity of physics among students has been low and the enrolment has declined, as the theme of the conference laments.

I believe a little self-criticism is needed here, looking for the reasons in the very house of the teachers. If we look in the media coverage of the climate change, we find only two words from the physics vocabulary: energy and temperature. And most textbooks use only these two quantities to explain thermal phenomena. But with only two quantities it is awkward and inapt to teach any area of physics. Thermodynamics without entropy, mechanics taught with forces and energy, almost without momentum, are unnecessarily complicated, as well as chemistry without the chemical potential: please compare with the more modern and logical didactic and cultural layout of electrodynamics. The energy is at the center of the stage of contemporary life since many years, but dressed as it was at the end of the XIX century after its tortuous and difficult invention. Although it has become the star of the physical quantities during the tumultuous developments of modern physics, the deficiencies of its didactic and cultural layout are still evident.

I’ll argue against the “forms of energy” as an infelicitous cut short for above mentioned need of three physical quantities: we need new words, and more words again to use less math. But these words contain the cultural heritage of the impressive synthesis of the macroscopic physics made by G.W. Gibbs, a century old but still almost unknown. In my opinion it could dramatically change not only the teaching but also the public understanding of hard sciences. And this is the change we need.
Faraday’s law and magnetic damping: Quantitative experiments with MBL sensors

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When a conductor passes between the poles of a magnet, an electric field is induced, and circulating currents called eddy currents are generated as the conductor enters and leaves the field. As a result, a magnetic damping force is produced on the conductor which opposes its motion.

This work starts from the observation of an eddy current pendulum, also known as Waltenhofen’s Pendulum, with the aim of motivating students to investigate the magnetic induction and the crucial role of eddy currents in establishing the mechanical equilibrium.

A set of experiments is presented suggesting a path in which the damping of the eddy current pendulum is strictly correlated to the exploration of the electromagnetic induction phenomena for magnets oscillating into a solenoid or for coils oscillating into a permanent magnet. The problem is tackled by the energy point of view and the role played by the intensity of the induced current in determining the damping of the pendulum is stressed by substituting the Waltenhofen’s Pendulum with a coil oscillating in the magnetic field and connected to an external circuit with a variable resistance. Students observe how the damping of the oscillations of the coil increases when the circuit resistance decreases and can relate the variation of the mechanical energy of the pendulum to the resistive energy dissipation in the circuit. The interpretation of the experiments allows students focus on the relation between the value of the resistance in the circuit and the Joule dissipation when the value of the electromotive force in the circuit is given. This helps them to deepen their understanding of the relation V = I2R they generally use to explain what happens in a circuit without taking into account that I depends on the value of R.

The experiments, which can be performed in college and undergraduate physical sciences laboratory courses, has been tested with high school students and in a post-graduate course for physics teacher education. The computer based laboratory activities proposed need equipments and tools usually available in a well-equipped teaching laboratory.

A numerical simulation, based on the evaluation at each step of the energy of the system, is proposed. Its implementation allows student to compare theoretical and experimental results.
Exploring students’ understanding of reference frames and time in Galilean and special relativity: a framework to design learning scenarios for the implementation of the EVEILS project.

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This research takes place within the context of the EVEILS research project (Virtual Spaces for Scientific Exploration and Education). This project aims at exploring the innovating potential of Virtual Reality (VR) in several domains of sciences through an interdisciplinary approach. The project exploits advanced interfaces in order to ‘immerse’ a student in the middle of unusual phenomena otherwise inaccessible to human experience. The exploration of the cognitive modifications and pedagogical advantages associated with the ‘immersion’ is part of the main goals of EVEILS. This educational aspect makes EVEILS quite specific among the research programs devoted to computer simulations associated with VR [1].

The relativistic structure of space-time cannot be grasped through direct, sensible human experience. Thus, we decided to apply VR to the domain of special relativity by favoring the understanding of perceptible relativistic effects and the construction of relativistic concepts thanks to appropriate learning scenarios.

Investigations of students’ understanding of relativistic situations and concepts are not very numerous [2]. After all, it has been shown that most of the difficulties spotlighted by researchers are consequences of misunderstandings of the principles of the Newtonian kinematics [3], [4]. From these results we developed a pencil-and-paper test in order to identify and characterize the conceptual and reasoning difficulties that students encounter in the study of classical and relativistic situations. We targeted difficulties related to the invariance of the speed of light, to the notions of the reference frame and event and to the non-conservation of simultaneity of events in a change of reference frame.

The analysis of the first answers to the test indicates that, even after instruction, more than half the students surveyed are unable to use the invariance of the speed of light. Moreover, most of them associate the time of an event with the time at which an observer receives a signal from that event although our test explicitly distinguishes between these two aspects. Furthermore a reference frame is often confused with a single observer. This inquiry was conducted in order to characterize cognitive obstacles targeted in
the learning scenarios implemented in the virtual space. At a later stage we will develop tools to evaluate the cognitive impact of immersion in VR for the understanding of relativistic situations and the construction of Galilean and relativistic concepts of kinematics through the implementation of our dedicated scenarios.


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**The Virtual and Remote Laboratory for Snell’s Law at the FisL@bs Portal**

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FisL@bs is a network of remote and virtual laboratories for physics higher education via the Internet. The network is distributed between different Spanish universities and it offers to students the possibility of performing hands-on experiences in different fields of physics from their homes in two ways: simulation and real remote operation. These laboratories are all accessible for anyone with an Internet connection and a Java compatible web browser.

Traditional laboratories may sometimes present a low ratio between their use and their costs. By allowing a remote access to these laboratories their frequency of use can be increased thanks to the creation of networks of schools interested in the same shared experiments. Although the economical aspect is important, there are other benefits tied to these laboratories. The most obvious one is their improved accessibility with respect to their traditional counterparts: since they can be used from students’ homes, anybody can access to them, even handicapped people. Another advantage of remote laboratories is their increased availability thanks to their capability to operate 24 hours a day without constant supervision. Finally, the safety of the laboratory devices is also guaranteed due to the software-controlled remote use of these resources.
Therefore, FisL@bs not only reduces the necessity of students to travel to real laboratories in distance education courses but it also expands the experimentation possibilities of traditional laboratories thanks to the sharing of network’s resources as well as to their fulltime operability. Since the didactical setups at FisL@bs can be used by students from any university, laboratories implementation and maintenance costs are drastically reduced. Both the virtual and the remote laboratories provide students with some experience and skills they can take advantage of when facing related laboratory experimentation in person for the first time. Finally, since students perform each experiment twice (in simulation and in remote), they can check the differences between the theoretical model and the real system and search for a plausible explanation for any observed discrepancy.

This paper presents a well-known experiment in optics: Snell’s law of refraction. As for every other web-lab at FisL@bs, Snell’s law experiment consists of four components: a Web-based learning environment (eMersion), a Java applet, a didactical setup for the considered experiment, and a LabView application. eMersion provides student/professor communication links, makes references, theory and exercises accessible to students, and offers a file management system for the saved data obtained during the experimentation sessions. The applet (made with Easy Java Simulations) carries out two functions: 1) the control, visualization, and evolution of the experiment in simulation mode, and 2) to act as user interface for the experiment in remote mode. The third component is the real physics experiment setup while the LabView application is a program used to control it.

Fig. 1 shows two snapshots of this web-lab working for air-water media in both modes: simulation and remote.

(a) Simulation mode  (b) Remote mode

Figure 1.

Other laboratories at FisL@bs that are already operative or still under development are:
a couple of experiments on Hooke’s law and radiation, a motorized optical bench for
the determination of the focal length of a thin lens, and a sensor whose XY position can
be remotely controlled to measure the distribution of potential over a resistive sheet of
paper with different electrostatic fields.

**Babies’ Response To Magnetic Interaction: An Exploratory Study**

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As early as at 7 months, babies show signs of surprise when they see that a magnet
pushes another magnet without touching it. This does not happen when they are shown
a box pushing another one. This result from our research may prove to be useful as we
are looking for events from the physical world that interest very young children. They
may indicate contents of particular interest in teaching physics.

Former experiences that used films, simulating two bodies interacting both by contact
and at a distance, have been studied in relation to the study of causality (Cohen and
Amsel 1998).

We know that magnets are fun objects to play with at almost any age. Children and
adolescents may have learnt about them through varied sources (toys, Internet, classes,
etc). In Argentina it is hardly ever studied in primary school and when it is, usually no
experimental activities are done. However a very high percentage of children know that
magnets interact at a distance before having had any high school physics classes (Dibar
et al 2009). At the same time, when students of this same level are asked to choose from
different explanations for the force of gravity, several of which are correct, many choose
an answer which states that the cause of gravity on earth is the existence of a magnet at
the centre of the earth. These results stress the importance that magnetic forces have for
them, probably related to the early interest to action at a distance.

In this first phase of the work, we have chosen to study few cases and have modified the
interview slightly during the process. This is one of the characteristics of exploratory
and qualitative methodologies commonly used in the social sciences.

We have carried out interviews with 6 babies, 2 boys and 4 girls aged between 5 and 10
months, to study their reactions to magnetic repulsion. A special effort was dedicated
to plan interviews with concrete material and in situations that were familiar for the
babies. We focalized the analysis on the babies’ reactions through their gestures and
the time they looked at both events (interaction between boxes and between magnets)
which were repeated two or three times. The interviews which lasted about 7 minutes
were videotaped and then analysed by impartial judges.

Three of the babies reacted differently than the others. Lar, a girl aged 9 months and 4 days, stared with only some interest at the box pushing another and then raised her arms and gave a little cry when the magnets interacted. Lau (7m8d) and baby boy Sa (7m25d) looked more intently at the magnets than at the boxes.

These preliminary results show precocious reactions and interest in magnets. They point to a promising content for activities in physics with children at pre-school level and further.


Dibar, M.C, Aleman, M.A. y Montino, M. (2009), Aprendiendo sobre imanes, II Jornadas de Enseñanza e Investigación Educativa en el campo de las Ciencias Exactas y Naturales Actas II, La Plata, 10-17

**New experimental seminary for bachelor study**

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The implementation of the Bologna process in the university teaching has various impacts on the teaching process. Dividing of the study program of the future physics teachers to the two parts – bachelor level and master level in our country was connected with some rearrangement of the study content. There are more physics subjects in the bachelor level and more didactically oriented subjects in the master level. The eligibility of such changes could be widely discussed. Recently wide-ranging discussion came about – for instance during the EUPEN-BPP meetings.

Students of the bachelor level (those, who are preparing themselves for schoolmasterish career) need also some practically oriented seminary. Such a seminary appointed mostly for bachelor students provided by our department is called The Development of the Physics Experiments. There were several reasons for developing of such seminary. We would like to cultivate creative attitude of the students to the school physics experiments. Very useful is also obtaining of certain manual skills. The ideal result will be if the students are able to devise appropriate aids, manufacture them and prepare suitable didactical and methodical materials related to the selected physics experiment.

The aim of this contribution is to describe our experiences obtained during test run of the seminary The Development of the Physics Experiments. First results are described
as well as the examples of new developed aids and simple apparatus. The emphasis is placed on the creativity of the students and on the applicability of the developed aids and apparatus to the physics teaching. Description of such aids and apparatus is included in the paper.

**Simple quantitative electrostatic experiments for teachers and students**

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Students often have nearly no idea about the values of charges of some things around us, e.g. charged plastic rods, straws or even people themselves, for example when walking in shoes with rubber soles at plastic flooring. This lack of knowledge concerns not only high school students but also future teachers and physics teachers in schools. Even for them it is not easy to estimate the value of charge of plastic straw after being rubbed with a piece of cloth. Of course, it can be measured by a charge meter. But do teachers and students understand such measurements? How many of them could explain the principle of a charge meter? One can worry that quite often this special instrument is perceived rather as a “black box” somehow providing some results that cannot be checked in a different way.

Yet, charge is one of the most basic concepts of electrostatics and the whole area of electricity. So it is perhaps worth for teachers and students to know at least the order of magnitude estimates of charges in some concrete situations – and to be able to support and verify these estimates by simple and understandable quantitative measurements.

Several such measurements will be presented in the talk starting from the simplest observations to more refined (yet still low-cost) experiments using reasoning both at high school and introductory university level. This series of experiments can be regarded as an example of “multilayered experiments”, the idea of which was described at GIREP 2009 [1]. Apart from the method using Coulomb’s law (and also, at a more sophisticated level, Gauss’s law), the method using a capacitor and an ordinary multimeter will be presented. The latter method is also useful for understanding the principle of charge meters and for measurements of charges that are above the range of charge meter sensors provided for schools e.g. by Vernier and other companies.

The experiments presented here were already used both in pre-service teacher training (in the seminar “Electricity and magnetism step by step” for future physics teachers at Charles University) and in in-service teacher training of Czech physics teachers (at the workshop at the conference “Heureka Workshops 2009” [2]).

[1] Planinsic G., Dvorak L.: Multilayered simple experiments: an approach with increasing co-
LEDs in Water: Hands-on Electric Field Lines and Electric Potential

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It is well known that concept of electric field and electric potential and relation between them are one of the hardest to grasp at secondary level and even at university level. Simple experimental setup using LEDs offers possibility to get hands-on experience about a spatial variation of electric filed and electric potential in various two dimensional configurations. The example will be presented as a multilayered simple experiment, an approach with increasing cognitive demands, proposed by the authors at the last GIREP-EPEC Conference. [Planinšič G., Dvořák L.: Multilayered simple experiments: an approach with increasing cognitive demands. In: Proceedings of GIREP 2009. In print.]

At the lowest level it may be just a “miracle” for children: They see that LEDs with bent leads thrown into a fish tank filled with ordinary water can glow (when voltage of several tens of volts is applied to electrodes at the opposite sides of the fish tank). At a slightly higher level we can discuss how the current flows through the water and which orientation the LED should have to glow. (It was at about this level when one of us saw this experiment at a conference of Slovak physics teachers in Bratislava several years ago.) At still higher level the experiment enables to map, at least roughly, both electric field lines and equipotential surfaces for different positions or shapes of electrodes. It is just this level that can be useful for both physics teachers and students even at introductory university level. Of course, further challenges exist for those who want to dive deeper. For example: Should we isolate “inner” parts of LED’s leads? It seems to be useful but surprisingly it has nearly no effect. Or: How does the LED distort the electric field in the water? Such questions can provide nice motivational problems even for the area of classical electrodynamics.
This study aims to investigate the effect of textbook style and reading strategy on 9th grade students’ achievements in and attitude towards heat and temperature. Textbook style was taken as a textbook based on conceptual physics (physics free of advance computations, teaching the concept by daily life, logical reasoning and critical thinking) or a textbook based on computational physics (textbooks that are used currently as a textbook). Conceptual physics is defined simply as putting concept before computation that is the way of teaching without relying on mathematical terms (Hewitt, 1990; 1994). The reading strategy was taken as KWL (Ogle, 1986; Sampson, 2002) vs. Non-KWL, which is without using KWL. KWL (What I Know, What I Want to Learn, What I Learned) is designed to help students learn from expository text in any content area. It has three steps: brainstorming and categorizing, questioning to set purpose to read, and examining answers to those questions. Each step is recorded on the related column of KWL chart. The first step is for the students to tell or write what they already know about the topic in the first column, the K column. When all known information has been recorded in K column, the information is categorized to indicate what types of information that will be found during the learning phase. And the second step is to generate a list of questions that reflect what the student wants to know about the topic. At the same time, these questions are listed on the W column of KWL chart. This list then becomes a guide for the upcoming reading. Then text material is read with the purpose of seeking answers to the questions listed. The last step is to list the information learned about the topic. The student may have discovered answers to all questions asked, or may find that some still need to be answered.

A factorial design was used to investigate partial and combined effects of these methodologies. Study uses convenience sampling and the participants were 123 9th grade students at Zonguldak Ereğli Super High School in four different classes. The selected intact classes were randomly assigned into four groups. The groups were conceptual physics text with KWL reading strategy, conceptual physics text with Non-KWL, traditional physics text with KWL reading strategy and traditional physics text with Non-KWL. The developed Physics Achievement Test and Physics Attitude Scale were administered before and after the treatment. Cronbach’ Alpha reliability coefficients were calculated as 0.855 and 0.934 in the post-test, respectively. The data were analyzed by Multiple Analysis of Covariance (MANCOVA) to find out individual and combined effects of conceptual physics texts and KWL reading strategy. The results has shown
that conceptual physics texts were effective in increasing students’ attitude, KWL was effective in increasing achievement, and their combination was effective in increasing both achievement and attitude of the students.


**The Effect of Instructional Comics**
**on Sixth Grade Students’ Achievement in Heat Transfert**

Erdoğan, Günsel, & Gülciçek, 2003; Sözbilir, 2003). The present study offers the use of comics in science instruction claiming a better leaning environment for this problematic concept. Since ancient times, people have used stories and tales to transmit knowledge and to teach socially acceptable behaviors to their children (Hadzigeorgiou & Stefanich, 2000). In modern times, stories are still being used in various formats, such as, storybooks, cartoon animations, movies etc (Cheesman, 2006; Keogh & Naylor, 1999; Rota & Izquierdo, 2003). Comics are one type of the modern stories. Traditionally, comics usually have some messages to children, such as, solidarity, friendship, honesty and so on. As mentioned above, comics have played an important role in non-formal education. However, one may wonder if comics can be effective instructional tools in formal education. The purpose of this study is to investigate the effects of instructional comics on sixth grade students’ achievement in heat and temperature, enjoyment and perception of success in science when some variables are controlled.

The sample of the study was 113 sixth graders from three public elementary schools in Yüzüncü Yıl district. In this study, a series of comics was used as instructional activities in treatment group. In addition, an achievement test was used in order to measure students’ achievement. Also, a treatment checklist to check authenticity of the treatment, a student questionnaire to learn students’ opinions about comics and a teacher question-
naire to learn teachers’ opinions about treatment were used. In addition, lesson plans were used as supplementary materials. In the beginning of the matter and heat chapter of science and technology course, the implementation started with the pretest. Then, a series of comics were implemented to the students for two weeks. Then, the implementation ended with the posttest. Data were analyzed through MANCOVA where the independent variable is the treatment implemented to the students. The dependent variables are students’ achievement in heat transfer, enjoyment of science and perception of success in science.

It was statistically found that there is no significant effect of the treatment on the combination of the dependent variables. However, when the effect of the treatment on the dependent variables is investigated separately, it was found that students in the treatment group got significantly higher scores than the students in the control group. On the other hand, it was also found that there is no significant difference in students’ enjoyment of science and their perception of success in science between the groups. In addition, it was observed that instructional comics increase the participation of reluctant students.


Human as a Context in Learning Physics: a Guide for Textbook Authors

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Turkish high school physics curriculum was developed in 2007 on context based approach with a spiral curriculum design. Most of units, all grades and other disciplines were connected in a spiral structure. The answer of the question whether there is a context which is appropriate for all units, all grades and other disciplines is one of the main points of this study. Other is about how physics textbook authors may use this context in their books according to Turkish students’ interests.
The context suggested in this study is human being with biological and social dimensions. In any biophysics book, some relations like eye and optics or axons and charge distribution can be found (Stanford, 1975). In this study, these relations were enlarged with other examples which were chosen according to Turkish physics curriculum objectives and presented to three lecturers who are expert in biophysics. Revised examples were used in a questionnaire which investigates what kind of relations between human and physics students want to see in their course book. The results of 150 students’ questionnaires from different high schools and degrees would be discussed.

The units cited in the questionnaire are nature of physics, energy, matter and properties, force and motion, electromagnetism, waves, modern physics, from atoms to quarks and from stars to quasars. Connecting the last unit with human body was difficult. Therefore, the social dimension of human with analogies, life of a star, family and sun system or nations and galaxies, was selected.

Although some contexts like hair dryer may be more attractive for one gender, human context may be appropriate for both male and female students. Additionally, learning physics via their body and their social positions may help to develop their meta-cognitive skills. Compatible structure of human context with near-to-far educational principle makes it usable for textbooks. Writing a physics textbook about human may link two units, from atoms to quarks and from stars to quasars, in meso-level which positions between micro (particle physics) and macro (astrophysics) levels (White, 1998).

Similar to physics, using human context for other disciplines is also possible. Golden rate on the face for mathematics, balance on different body parts for physical education or acids in the stomach for chemistry may be given as examples in interdisciplinary human context. For meaningful learning, interdisciplinary relations are necessary (Cone, Werner, Cone & Woods, 1998). Therefore, this work may be the first step for human based high school curricula.

It is hard to reach all objectives written in the physics curriculum by one context, so the physics textbook authors should be aware of this disadvantage. Although teachers may gain time by using one context throughout the whole units, students may misunderstand that the subject matter is only related with that context.

Interactive e-learning content for physics

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Nowadays, internet and multimedia are important sources of information. Teaching processes have to adapt to these, but information-communication technology (ICT) also offers the chance to develop new teaching methods that are specifically designed to exploit the advantages of ICT over traditional methods, rather than trying to convert traditional methods to an ICT form.

There are several types of e-learning materials. Our group approached the task by adopting a few basic guidelines:

- Learners should be active while using the material;
- Teachers should get a detailed feedback on students’ solving procedures;
- The material should include examples from the «real world» which is close to the learners’ perception. Where possible, materials should include measurements of actual experiments or events from everyday life.

In accordance with these guidelines we focused on designing e-learning materials with emphasis on interactivity. Our team developed tools that enable the user to measure distances, angles, draw vectors, polygonal and freehand lines on pictures and videos, use a star map, analyze graphs derived from data from real measurements, etc. We wanted to exploit the possibilities that e-learning offers compared to traditional methods. One important possibility is the dynamic adaptation of the task’s difficulty and pace according to the users’ abilities.

An important characteristic of the material is that the feedback and the next step depend on the input from the user on previous steps. If the user fails to answer correctly in the first attempt, she is provided with hints and asked to try again or is led along a longer step-by-step route to the desired solution. The task can thus be solved either in just a few steps (by more gifted students) or through a longer, step-by-step, guided route for those who need or desire more help. Feedback to the user, in addition to information whether a particular answer is correct or not, also provides a short explanation of the solution, so that she can either receive confirmation of her line of thought or, alternatively, learn from her mistakes. Feedback on students’ performance is provided to teachers, who can choose how detailed they want this information to be. If they want, they can receive the entire history of students’ solving procedures.
The material is comprised of blocks (individual, independent short tasks). A teacher can choose to build an e-learning worksheet from these pre-designed blocks and can arrange them in any order she wants. She can also build a task from scratch. The design of the content is entirely separated from the technical aspects, thus enabling the author not to care about the technical implementations, but rather focus on the content itself. Our team is developing a software platform based on common and free internet technologies: HTML, JavaScript (AJAX), and Flash, and the tools that are required to provide the desired interactivity. Furthermore, the team is developing tools for building such tasks in a visual environment (currently a wiki-like code is used). The material can also be exported as a SCORM package.

Materials can be used in several situations. For example, to allow learners who were absent from a school-lesson or maybe less vigilant to master the activities carried out in the classroom. Materials can also be used for repetition and consolidation of the knowledge. They allow the teacher to actively control individual tasks and compose individual tests for testing and evaluating knowledge.

**An Inquiry-Based Approach to Physics Teacher Education: the Case of Sound Properties**

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The design and validation of new models for pre-service and in-service Science teacher education is a key subject in today’s Science Education Research. Many literature results show the pedagogical efficacy of extended inquiry-based models, where teachers work in special-designed teaching/learning environments, concentrating on laboratory and modelling activities. Here, we describe an approach to Pre-Service Physics Teacher Education that built on the inquiry-based model in order to develop a “Pedagogical Content Knowledge” (PCK) in Trainee Teachers (TTs). The main focus of the approach is in stimulating a problem posing approach, where TTs are guided in testing on their own understanding the same teaching tools they are supposed to use with their pupils. In particular, it is analysed how the approach supports the understanding of content, the development of enquiry based competences, as well the building of appropriate PCK. The experimentation has been performed with a group of non-Italian TTs engaged in one-month mobility activities at University of Palermo, in the framework of the EU Project “Move’in Science”, focused in Physics and/or Mathematics Pre- Service Teacher Education. Relevant phases of the Project have been the Partners’ cooperative building of Teaching/Learning Units (TLSs) on specific subjects of Mathematics/Physics, with a special look at PCK competencies to be developed during actual TLSs’ activities, and the subsequent TLSs experimentation during in-presence workshop and apprenticeship activities of TTs in mobility. We discuss the results of a TLS about Mechanical Wave propagation, developed at University of Palermo and experimented, during TTs mobi-
A Student-Centered Active Learning Environment for Introductory Physics

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Studies of undergraduate science education have shown that students must be actively engaged in the learning process for it to be effective. Passive lecturing (“teaching by telling”) is known to be ineffective in developing critical thinking skills. One of the first collaborative group-learning environments (“studio physics”) developed by Wilson in the mid-1990’s addressed this issue — students work together in small groups and the instructor serves as a facilitator or “coach” instead of a lecturer. A critical aspect of the studio approach is the integration of laboratory activities into the classroom — in this manner, class time consists of a seamless progression of activities, ranging from group problem-solving exercises to lab experiments to short demonstrations to mini-lectures. By merging the collaborative approach with the integration of various pedagogical activities, a dynamic collective learning environment is created.

A practical limitation of the studio method is the small class size — it is not possible to staff multiple sections of a course with limited faculty resources. Beichner at North Carolina State University pioneered an extension of the studio approach, called SCALE-UP (Student-Centered Active Learning Environment for Undergraduate Programs), which adapts the method for larger classes (e.g., up to 99 students). In this scheme, round tables accommodate 3 groups of 3 students for all classroom activities. For a class of this size, one instructor and two Teaching Assistants are sufficient to cover the questions and promote useful discussions.

We have implemented the SCALE-UP approach at George Washington University for our calculus-based introductory physics class and the first semester of our algebra-based class. We have redesigned a classroom with 6 round tables, accommodating a total of 54 students. Each group of 3 students shares a laptop computer and has a portable white board to facilitate their work together. The classroom walls have large white boards on which students can display their work, 4 large LCD screens for image projection, and storage cabinets for lab equipment.

We instituted SCALE-UP in Spring 2008, and at this point, we have 5 semesters of experience. The class meets 3 times a week — 2 hrs on Monday/Wednesday and 1 hr
on Friday — with a weekly 15-minute quiz every Friday. Groups are carefully arranged by the instructor, and guidelines are clearly outlined in a “group contract” that is prepared by each group. In class, students work collaboratively on conceptual questions and numerical problems (“ponderables”), in addition to short hands-on activities and longer laboratory experiments (“tangibles”) using real-time data acquisition. With lecture reduced to a minimum, class preparation is quite important for students. To gauge their understanding and to motivate their preparation, pre-class “Warmups” are available online for students. Student engagement is high in the SCALE-UP environment, and students gain a greater facility with the physics material in this collaborative mode compared to a conventional lecture-style approach.

We have acquired data on the Force Concept Inventory (FCI), as well as the Colorado Learning Attitudes about Science Survey (CLASS) to examine student attitudes. In some semesters, we have had a large (concurrent) conventional lecture section take the same assessments for comparison purposes, and in some cases, even common exams. Results from the FCI and common exam questions indicate that students are performing better in the SCALE-UP class. We will describe the SCALE-UP pedagogy, summarize the particular features of our implementation, and present our data analysis results based on the FCI, the CLASS and common classroom exams.

Fun and Joy with Researching and Ruminating –
The Erlangen Student Research Centre
(‘Erlanger Schülerforschungszentrum ESFZ’) for Bavaria

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‘Fun and joy with researching and ruminating’ is the motto for the Erlangen Student Research Centre (ESFZ) for Bavaria which was founded in spring 2009.

The ESFZ (→ www.esfz.physik.uni-erlangen.de) offers special support for students who are interested in science and technology. Unlike many other advancement initiatives, the ESFZ fully concentrates on the initiative and creativity of its participants: The students attend a one-week science camp in Erlangen; during this week they carry out projects they have thought up themselves.

Erlangen University provides the premises and the equipment for this ‘project work experience’ for the ESFZ, which is a form of practical training for students of physics that is unique in Germany. On top of the excellent facilities regarding appliances and methods, former students of the project work experience act as tutors, motivating the
activities of the students and supporting them competently. Furthermore, where this is requested by the students, professors and scientists of the university provide subject-specific support.

The ideas for research come from the students. While some of them arrive at the science camp with their project ideas already prepared in their minds, others use the opportunity of joining up with fellow students at the science camp and start discussing there and then what subject they would like to delve into. There are ‘lone wolves’, as well as groups of up to four students working together. Some of the projects are completed within the week, but many others take longer and are continued at home, or the students may indeed come back to the next science camp or in between camps. Many students intend taking part in competitions like ‘Jugend forscht’ with their work.

In the lecture, the objectives and contents of the ESFZ are introduced in detail; the run of events during the first year of the Erlangen Student Research Centre is chronicled.

**Music as an analogy for understanding the concepts of quantum physics**

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Pupils experience problems in understanding the concepts of modern quantum physics. Hobson (2007) showed that wave-particle duality is a rather unfruitful paradox in teaching quantum physics. He proposes a more unified view as given by Quantum Field Theory (QFT) where photons and matter are understood as quanta of waving fields.

It was the French physicist Louis De Broglie (1924) who introduced the concept of waves in quantum physics. He applied the analogy of standing waves on the physics of electron waves and gave Bohr’s quantum conditions physical ground.

**Fields and quanta of fields**

Like Feynman we start with the double slit experiment. Since a particle cannot go through both slits at the same time, the double slit experiment contradicts directly the particle model of matter. In QFT physicists suppose that fields can spread out and can go through 2 slits. We introduce the electron matter field and the quantum EM-field. Both carry their energy in the form of waves, much alike sound waves do.

But how the quanta come in? We compare with the discrete series of harmonics in a tube or on a string. A quantum field - like the harmonic waves in a musical instrument - carries its energy in discrete steps. The observed particles are the expelled energy amounts caused by a change in the wave mode of the field.

**Understanding where quantization comes from**

Like a string tied at the ends, the electron matter field in an atom is ‘tied’ by the elec-
trostatic field of the nucleus. As a result the quantum field, like the waves on a bound string, can oscillate only in discrete modes. This is caused by the fact that many waves bounce back and forward at the ends. They interfere with each other and only some add constructively to a standing wave, the rest extinguishes. This is precisely where the quantization in quantum field theory comes from.

**Understanding the line spectra and superposition of states**

When energy is redrawn from the waving modes of electron fields in atoms, these amounts are absorbed (as increments) by the spreading electromagnetic field. The radiation field on his turn can give off the quanta again, absorbed earlier from the matter field. These quanta we see as photons and since the energy of the radiation field is proportional to the frequency (following the relation $E= hf$), these photons have a fixed frequency and thus color. To avoid the confusing wave-particle duality, it is crucial to stress that no electron ‘jumps’ occur, but that the electron field simply changes its wave mode.

The idea that ‘a particle like an electron can be in a superposition of states’, is also difficult to grasp, unless you work with the concept of quantum fields. A state of an electron matter field can be in a superposition of discrete wave modes (each with a certain amplitude), just like the wave of a musical tone is the result of a superposition of discrete harmonic waves. Asking in which mode a vibrating string actually is in, is a rather impertinent question, both for tones as for quantum states.


**Cultural Content Knowledge – the required enhancement for physics teachers training**

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HIPST – History and Philosophy in Science Teaching – is a developmental project in which we joined several educators from European countries who tried to suggest the way of improving the current way of teaching science disciplines. Our effort was invested to developing of physics teaching materials which would present an innovative approach to physics teaching. We followed the discipline-culture approach which intends to upgrade the currently prevailing disciplinary orientation of physics curriculum in order to present physics as a culture. We chose the genre of historical excurse for developing historical cases dealing with conceptual fundamentals of classical physics. Five
different excurses followed the history of Theories of Motion, Inertial Forces, Weight and Gravitation, and Optical Image.

Although all the contents directly support conceptual understanding of the regular school curricula of physics, most of them are not regularly addressed in physics classes. We advocate for their use mainly for in- and pre-service physics teachers. Our arguments draw on the discipline-culture structure of physics knowledge. The latter states the need to display the disciplinary discourse in which the contents that are currently taught in physics class were emerged and developed. In fact, this process upgrades regular content knowledge [CK] to the cultural content knowledge [CCK] and through this step, enhances the required for teaching pedagogical content knowledge [PCK]. We will illustrate this process by explicit examples from the developed excurses.


**Active learning workshops for teachers: what is the impact in the classroom?**

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The ICPE - IUPAP recommendations about Physics Education suggest the use of active learning based methodologies at all educational levels. Teacher in-service training should be the focus for promoting these activities, because they can generate a multiplicative impact. Nevertheless, teachers who take part in workshops that promote «active learning>>, face many difficulties using this methodology in their classrooms. When faced with the tension between a content-oriented approach with emphasis on covering a selected curriculum and a more active approach with inquiry oriented teaching based on prior students’ knowledge; they often fail to implement new teaching methods. Usually they can talk about active learning but they teach as they were taught. Why is it so difficult to change?

Our hypothesis is that physics teachers do not change their way of teaching for the same reasons that the students do not change their conception of the world in spite of many exposures to the material. Teachers do not change because they have profound convictions, often incorrect, that allow them to describe, to predict and to explain different characteristics of the educational event. For example most of the teachers can explain why their students drop out, or why they are not able to solve problems, or in general why their students do not learn. At workshops we may be very worried about offering
activities that promote physics understanding to teachers, but we forget they also need to learn how to teach physics. In other words we talk and show what they should teach. As a result they may reach a meaningful understanding of physics concepts, but only rote learning about how to teach. We engage them in the physical phenomenon but not in the educational phenomenon. They do not realize instruction as a problem to solve. In this presentation we discuss how to apply the concepts of «active learning» to improve the teaching of physics. To do otherwise is to treat teachers to the same behaviour that we say they must not have with their students.

The use of Historic Tales in Physics Popularization

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Scientists, specially physicists, are surrounded by a great deal of myths. The common citizen usually conceives those dedicated to scientific research as boring, aging and lonely geniuses. People seem to think great physicists were predestined for their bright spot in history, attaching to them special qualities totally different from the rest of humans. This reinforces the way scientists are seen, by taking away important aspects of their lives such as background, circumstances, motivations, mistakes and personalities. We only see an oversimplified version of the person, who´s only attached to the knowledge produced.

It´s important to break this pattern; build an identity between the public and the person who made the achievement in science. By doing so we can help people better understand the context in which an specific knowledge was constructed and, in the process, strengthen their cognitive bond with the scientific information provided.

Also, we have to change the idea of physics (and science) as a finished job. A lot of people think that there´s not really much to be done anymore, that past scientists have achieved everything worth doing. Through history we can establish that the process to build knowledge, and explain nature, has been going for centuries and will keep going as long as mankind exists. At the same time we can show there are plenty of important things to explain and achieve, there´s a lot to do and physics needs plenty of people to do it.

The historic perspective has been present in the Science Museum at the Universidad Autónoma de Zacatecas in Mexico since its opening, 26 years ago. The Museum was first created to show a physics cabinet brought to Zacatecas in the nineteen century and rescued by a group of teachers in the early eighties. Through the years, it has evolved into a science popularization center that works using a wide range of activities.

We have developed several ways of getting history involved in physics popularization. By taking a journey through the different stages in the development of a concept, show-
ing the different approaches used by scientists or the way an specific theory managed to prevail over the others. Also, one can focus on the life of a scientist and how he, or she, developed in society and science. Finally, it’s really useful and impressive to talk about the way some specific science developments have changed human history (and how things have also worked the other way around).

There are several useful popularization means that we use to bring physics history closer to the public: Guided visits, workshops, lectures, radio capsules, books and magazine’s articles, to name a few. In this paper we will focus on the first three, that provide direct interaction and feedback with our users.

Tale telling helps create an interested atmosphere with all kinds of public, from preschool kids to grown men and women. Anecdotes are really good to get the audience involved but it’s important to go deeper than that, provide a chance to understand the facts that led a scientist to develop a theory, an experiment or to build a device. This means that, as educators, we have to be prepared to explore different aspects of the history of the physics we’re trying to popularize (or teach), depending on the different conditions we can find in our public.

Chronicles of a Science Club: When kids take physics in their own hands.

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In Mexico kids usually make their first contact with physics late in their elementary education and most of the time it comes from an abstract perspective. Teaching relies heavily in theory. Unlike other processes -like those found in reading, writing or math- most of the time physics (and science) education doesn´t involve learning by doing. It´s rare for children or youngsters to get involved in the development of experiments that will help them build knowledge.

Over the past 50 years a change has been developing. The «Hands on» perspective has gained a lot of adepts in both teaching and science popularization. The «Mind on» and «Heart on» have come to enrich and complete this attempt to get students actively involved in their education process. Museums and schools alike have benefited greatly from this approach.

But it´s not easy to fit it properly in the classroom. Teachers have trouble finding time to
incorporate experiments in class, given all the contents they have to review. Hence we need a proper space to fill this void, provide children with a program to learn physics through experiments.

Science clubs provide a useful option for this, they can work as an extracurricular space in school or as permanent programs in popularization centers. They can support the concepts studied in class, and also get kids closer to science from a young age (5 and up).

The main focus is to provide fun activities that get participants engaged in experiments, which allow them to try to explain and understand the way the Universe works. The key is to always use an active approach, keep the kids’ hands working in physics.

In 1990 the Science Museum at the Universidad Autónoma de Zacatecas, started working with an experiment based program directed to kids. After three years of work it was established as the Children Science Club, working every saturday for two hours.

Each year the Club has a different theme, and program, with a different set of experiments. Our pedagogical approach is based upon active and significative learning and constructivism, also we put a strong emphasis on team work. Each year the Club starts with simple activities that hold strong relation with participants previous knowledge and experiences, and as it advances the subjects reviewed get more complex.

Noticing the high return rate in participants, and trying to make the best out of the kids who kept participating, the Club started following their performance and opinions so it could better adjust to their necessities and help them grow closer to physics. Also a different focus has been applied to each age group: at the early stages the emphasis is put on the recreational perspective and as participants grow they get to view physics on a more formal perspective: going from concepts to making measurements.

This way the concept of Science Youth Squad was born, with the intend of getting children involved in other science activities as they participate in the Club and even when they leave it behind. The goal is to develop citizens with a strong scientific culture, no matter what they decide to do with their lives. Also, on a deeper level, the Club tries to find and help build the future’s physicists (and scientists in general) from a young age.

**ITEMS: Improving Teacher Education in Mathematics and Science**

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In Europe only 22% of students aged 20 to 24 study Maths, Science and Technology subjects (MST). In order to increase girls’ interest in MST studies, special attention needs to be paid to the crucial age of 15-18, when secondary-school girls are making decisions about subject specialization in upper secondary, and selecting university courses for further studies.
A recent study made by CISCO has shown that most girls drop out of ICT studies after secondary education. This can be attributed to, among other factors, a lack of support from role models and persistent stereotyped views that the sector is better suited to men. But a key finding of the study is that girls generally do enjoy ICT studies and are competent users of computers and computer operating systems, however less and not exactly in the same way as boys. A study on women following online courses showed they found this medium allows them to better express themselves and perceived a greater help and control on their studies as well as less repression.

The ITEMS project partnership, which includes public institutions from five different countries: two teacher training institutions, CEFIRE from Spain and Junior Science Service Support from Ireland, two high schools, Gimnazija Poljane from Slovenia and Gymnasium Isernhagen from Germany and European Schoolnet from Belgium, representing 31 Ministries of Education, is developing a framework aimed at improving the competencies of science and mathematics teachers and, consequently, increasing the students attainment and interest in these areas. That aim is mainly achieved through the design and development of online modules (Integrated Teaching Elearning Modules, ITEMs) for secondary school students in Science and Mathematics using Moodle as the VLE.

So far, a total of 6 ITEMs have been developed for secondary school students in Science and Mathematics. Teacher training courses (TTC’s) aimed at familiarising teachers in the management of the ITEMs in a classroom environment using an online/blended approach, have already been organised (there will be 20 of them by the end of the project’s lifetime, as 400 teachers will be reached). By the end of 2010 around a 100 teachers from the project partner countries will have been monitored in their use of the ITEMs in class, targeting 2000 pupils at secondary level.

The goal is to enhance students’ achievement and, as a corollary, their interest and engagement with science by improving teachers’ competencies and setting up the conditions for a change in teacher practice towards a more inquiry based model, thanks to the use of ICT.

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The SAT (Science At Theatre) Laboratory of the Physics Department of the University of Milan has been researching for six years on the opportunities given by theatrical techniques to improve the public perception of Physics. In these six years four shows have been written and performed by three of the authors with the help of different theatre directors. They are addressed to different aged students so as to cover all the spectrum of school students: from Primary School to University.

«Tracks» is addressed to the last years of Secondary School till University. Three physicists are travelling to a conference where they would present the results of their researches. Each of them brings a baggage of experiments, books and personal experiences while the journey becomes a symbol of the research.

The aim of this performance is to create fascination and increase the motivation for the study of Physics. For these purposes the main guidelines we follow in the construction of our shows are: 1) no popularization (so no simplified explanations) and 2) large use of the emotion power in making the story, in order to transmit a strong reference imaginary for Physics. One of the most striking features of this (as well as of all our shows) is the realization of real physics experiments on stage.

In this paper we will report on the results of an analysis on the perception of Physics in Secondary School Students before and after the vision of the show «Tracks» related to five performances staged in a theatre in the neighbourhood of Milan. It is based on the answers to an anonymous questionnaire that has been given to nearly thousand students before and after the vision of the show, and on those given to another one that has been distributed to their teachers.
Explaining infrared radiation and infrared sensors with multimedia
-aspects of multimodal and pictorial information processing.

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Infrared sensors (e. g. infrared thermometers or passive infrared motion detectors) conquer the everyday environment of students. Physics lessons cannot exclude up-to-date measuring devices and methods, especially as they are becoming more and more used in everyday life. With the technical development we also have to find ways to explain to our students how modern devices work. As infrared radiation is not visible and the physical explanations about emergence and characteristics are complex, methodical considerations are necessary. Using multimedia for explanations might be helpful.

The theory of multimedia learning from Mayer (2001) is based on empirical studies with more or less simple subject topics. Therefore usability and conditions for applications on more complex topics has to be proved. A multimedia lesson taking 30 minutes in the short version and applying multimodal and multcodal explanations was designed, bringing together disciplinary considerations from physics and Mayer’s multimedia principles.

The presentation shows how we tried to connect considerations about teaching Physics and knowledge about multimedia learning to design a learning environment. The underlying theory is explained. Furthermore results from empirical studies referring to knowledge tests, questionnaires on information processing as well as studies with an eye tracker are presented.

http://www.phydid.de

Physical properties of prism foil and its pedagogical applications

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Transparent prism foil is part of the backlight system in modern LCD monitors that are widely used today. Its main function is to optimize the angular distribution of the light incident on the back side of the LCD panel. The foil can be obtained by dismounting
any used LCD monitor. In our contribution the basic theoretical model of the foil will be presented as well as several simple experiments that demonstrate or exploit optical properties of the foil. We will show that beside its primary function prism foil can be very useful in several pedagogical applications. These applications may involve optical phenomena such as refraction, diffraction, dispersion and image formation. One of the special features of the foil is that it allows for the experiments in which a combination of refraction and diffraction are present in the same experimental outcome. Such feature enables the foil to be used, for example, as a test for students’ ability on how to apply acquired knowledge in new situations. It will be also shown that the foil can be used as an essential part of a simple experiment that gives reasonably accurate measurements of index of refraction for liquids. In addition to questions from optics, the foil gives possibilities for other challenging questions suitable for high school or undergraduate level. For instance, an open ended task how to determine distance between adjacent prism ridges can challenge students’ research creativity.

Finally, as a part of a high-tech based, easy available device, the prism foil can be seen as a motivation resource that encourages students’ positive attitude towards science and technology.

**Development of an Achievement Test on Force and Motion**

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The purpose of the present study was to develop an achievement test on force and motion concepts. Force and Motion Achievement Test (FMAT) was designed to measure students’ achievement level at 14 content specific objectives and seven skills related to problem solving as well as informatics and communication skills.

The core of the mechanics is the force concept which causes motion and changes in motion (Hestenes, Wells, & Swackhamer, 1992). The first course at physics is mainly about these concepts and mostly it is required for the rest of the other physics courses (Halloun & Hestenes, 1985). So, in this study force and motion concepts were chosen. There are many studies about force and motion in the literature. Most of the instruments developed in these studies are related with diagnosing misconceptions and concepts (Beichner, 1994; Hestenes, Wells, & Swackhamer, 1992; Hestenes & Wells, 1992; Thornton & Sokoloff, 1998; Trowbridge & McDermott, 1980).

FMAT differs from other achievement tests with its skill-testing aspect. Each of the skill related objectives has a corresponding content related objective and the items testing these skills were represented within a context including these contents.
The first version of the FMAT had 39 items and it was given to three experts in order to evaluate face and content validity. Also, face to face discussions were carried out with two ninth grade students to assess completion time and clearness of test items. After this process the test was revised. Improved version of the test was contained 32 items. This version of FMAT was administered to 29 ninth grade students at a public high school in Turkey. The Cronbach alpha reliability was calculated from the data and found to be acceptable (0.79). Test difficulty indices ranged from 0.03 to 0.89 with an average of 0.42. The point biserial correlations of the items ranged from 0.15 to 0.75. This item analysis revealed the items that are not working as expected. Some of the items were deleted and some others were modified. Final version of FMAT had 30 items: two true-false, 16 multiple choice, and 12 open ended type. As a result, validity and reliability of the test was confirmed at the test construction and implementation stages.


**Master and disciple in the past and nowadays**

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In my presentation I discuss, the teacher-disciple relation on all levels of education. Looking at the examples from the past, I discuss conditions which are necessary for creating such a successful relation. An example of such a relation was that of Hoefler and Smoluchowski. One generation later, a similar relation was established between professor Antoni Hoborski, distinguished mathematician, and his high school disciple Stanislaw Gołąb. Gołąb became later master of many younger mathematicians.

The master role was played not only by teachers and professors but also by parents and relatives of pupils (e.g. Galileo’s father, Kepler’s mother, Sklodowska-Curie’s father, Curie-Joliot’s mother, Feynman’s father, Ehrenfest’s brother). I argue that known and
successful high schools depend on charismatic teachers. Not all of scientists possessed charisma. Only some distinguished scientists created scientific centres, schools of physics (e.g. Bohr, Rutherford).

I also discuss what is possible to retain from this kind of specific interaction between student and teacher and what could be applied in our contemporary times, which are so different from the past, when, unlike today, there was no internet and only a fraction of society received proper education.

The master-disciple relation depends on personalities of both parties. At any rate, it not only requires a lot of time, but also emotional engagement. Although teachers with extraordinary virtues are needed, a modest and efficient relation between master and disciple can be established by every teacher. This aspect of teaching should be emphasized during the teachers training.

Learning by inquiry and liking it

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Education system should provide every citizen with basic science literacy, which is needed to meet the demands of living in the modern society, such as daily use of advanced technology products and responsible citizenship. However, research conducted by OECD has shown that in 14 out of 20 participating countries, at least 15% of all adults have only the most rudimentary literacy skills, making it difficult for them to cope with the rising demands of the information age. Poor results are not limited to marginalized groups or underdeveloped countries, and even in the best performing countries, 8% of the population is impaired in every day life and work by literacy deficits.

Interest for science studies among young people and public image of science are alarmingly low throughout the Western world. What makes things worse; even primary teachers dislike and avoid teaching science content, especially physics part.

There is no hope of improvement in the future, unless some effective measures are taken in the early education, because attitude towards science is formed before the age of 11. EU recognized the graveness of the problem and financed several initiatives, promoting active methods of teaching and learning science, as educational experts mostly agree that they are stimulating and cultivating the interest for science among pupils. Pollen Project (FP 6, Science in Society) was one of the projects, financed from EU, promoting hands-on and inquiry based science education.
Following the lessons learnt from the Inspire project (http://inspire.eun.org) regarding the use of resources in Maths, Science and Technology classes and the insight into travel well projects, in December 2009 European Schoolnet (EUN, Belgium), Dum zahraničních služeb MSMT (DZS, Czech Republic) and Direcção Geral de Inovação e Desenho (DGIDC, Portugal) launched SPICE, a 2-year project funded under the European Commission’s Lifelong Learning Programme (DG Education and Culture), with the aim to establish a Science Pedagogy Innovation Centre for Europe.

During this presentation at GIREP 2010, participants will get an overview of the project’s basic strategy and expected outputs. The primary objective of SPICE is to collect, analyze, validate and disseminate innovative pedagogical practice, especially those based on inquiry-based learning whilst enhancing pupil motivation for science studies (at primary/secondary level). SPICE will support this objective by singling out good practice pedagogies and practices in Maths, Science and Technology, which nowadays are mostly ICT-based, and disseminating them across all Europe. The good practice criteria will allow new projects to have guidelines to ensure their innovation and quality.

A teacher panel, along with a science expert panel, from 16 European countries, will help the SPICE partners in defining good practice projects that will then be tested in schools in countries different to the one where the projects come from. In the summer of 2011 results of those trials will be shared on the occasion of a Summer school organized by DZS in the Czech Republic and will be disseminated to both teachers and policy makers. Communities of practice will arise from this experience to further expand/implement the results.

A Toy for Students of all Ages: driven Spinning Top

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All over the world, the spinning top is known as one of the oldest and best-beloved items of toy history /1/. It is known under different names in 109 languages /2/.

The Earth is a huge spinning top. Other astronomical bodies are too. Some have a magnetic moment. Protons (in water molecule and organic molecules) have a nuclear spin
(angular momentum) and magnetic moment. As a toy, the spinning top fascinates how it can keep the vertical position when it is spinning. Unfortunately it can not be controlled: once started, its position could not be changed, it is uncontrollable. Bellow we present the new spinning top: the driven spinning top. It has been changed by using two permanent magnets.

So we placed a small magnet on the axis, at its upper end, of the spinning top and a 2nd permanent magnet moved by hand above the spinning top will determine its horizontal movement/3,4/. The explanation is that the force of interaction between the two permanent magnets introduces no torque so that the rotational motion is preserved.

With such a spinning top we realized 3 games. Other games can be proposed. Practical demonstrations will be shown during the presentation.

This driving is new and can be a promising technical solution. It is expected that such a technical solution to have a positive contribution to the technical culture of children. The new spinning top does not need batteries (a terrible source of pollution). So it can be used indoors or outdoors under the open sky. It is a 3D activity not like the 2D landscape of the screen of a computer or TV. It could attenuate a little bit the dangerous Internet Addiction. It encourages a little physical effort by putting it in rotation. This improves the practical skills. The new toy/didactic device received green light to be used in schools from the Romanian Ministry of Education. It is recommended as toy for classes 1-8, some physics for high school and physics and technics for technical high schools. By playing, children learn with pleasure and without effort about rotational motion, frequency, interaction, stability and precession. Pupils can play without supervision and so they enjoy more and learn more.

Concerning precession: if the spinning top is perfect symmetrical then it stays vertical and we even can not see its rotation. If we stick a coin or a paper clip on the lateral side then the precession can be observed. If we keep the wooden stick with the 2nd magnet oblique above the top then the precession can be observed. During university studies they will enjoy better and understand easier the full theoretical treatment of the rigid body rotation and Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging(MRI) and functional MRI (fMRI).

By playing students improve their hand-eye coordination, patience, self-confidence, attention and socialization. Also it could be a therapeutic toy. Being a new toy/didactic device it is worthy to be explored deeply. It could be used for experimental tasks in Olympiads of physics. Also it could be used in international children meetings for a quick socialization by organizing friendly competitions. Pupils do not need many introductory explanations; they just begin to play when they see it/5/.

3. http://www.supermagnete.de/project72
The concept of electromotive force in the context of direct-current circuits: Students’ difficulties and guidelines for teaching

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Our work deals with the difficulties which arise at university level in the analysis of the operation of simple direct current circuits which includes the concepts of energy and electrical current. Mulhall et al. (2001) conclude that teachers have problems describing energy transformations in a circuit within a coherent framework and admit that they do not have a qualitative idea of the concept of potential difference and tend to avoid it in their explanations. The final aim of this study is to analyse the students’ alternative conceptions when they interpret the balance of energy in cc circuits. The knowledge of students’ reasoning will provide a set of guidelines for designing teaching sequences to serve as guidance in teaching the interpretation of energy and proof of the movement of charges between two points on a circuit (concept of potential difference) and throughout a circuit (concept of electromotive force).

In order to investigate students’ difficulties in understanding, a questionnaire based on an analysis of the theoretical and epistemological framework of physics was used. It was put to first year of engineering students from Spain, Colombia and Belgium. The students’ answers were examined independently by two members of the research group who sought similarities and differences and chose significant statements, comparing them in order to obtain cases of agreement or variations, and then grouping these statements into categories (Watts et al. 1997).

In the oral presentation we are going to present the questions of the questionnaire and the analysis of the results. As an example, we present here one of the questions:

Q4. – If the same battery is connected to different circuits, which magnitude remains constant: the potential difference between its terminals or the battery’s electromotive force?

About a half the answers wrongly stated that what does not vary is the potential difference between the battery terminals. A small number of answers (16%) correctly reasoned that the electromotive force of a battery is a characteristic size thereof and that therefore it is kept constant. A quarter of the answers gave explanations unconnected with the theoretical framework or incoherent explanations.

The results of the study show that students’ difficulties seem strongly linked to the absence of an analysis of the work carried out on the circuit and its energetic balance. In this regard, students still do not clearly understand the usefulness of concepts of potential difference and fem. The difficulties found and the contents of the analysis of the
physics show the necessity to provide students with opportunities for them to reflect on the role played by the concepts of potential difference and electromotive force in the energetic model which explains the movement of the current in a simple electrical circuit. It will be necessary to design tasks and problems which lead to it being understood that the difference between the concepts of electromotive force and potential difference is given to measure different kinds of actions produced by radically different causes; the former due to non-conservative causes and the latter to conservative forces.


The Effect of Web Based Interactive Instruction Based on Conceptual Change Approach for Overcoming Misconceptions about Heat and Temperature

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In this study we investigated the effect of web based interactive instruction, which was based on conceptual change approach, for overcoming misconceptions about heat and temperature. Pre-test post-test design was used for measurement of instruction’s effect. We used experiments’ video clips in instruction. These clips consist of two parts: introduction part and result part. Introduction part includes experimental equipments and design of experiment. Result part includes result of the experiment.

Instruction contains several steps for overcoming each misconception. Number of these steps depends on whether students have misconceptions or not. If students have no misconception, instruction’s length and number of steps will be minimal. If students have all listed misconceptions, instruction’s length and number of steps will be maximal. Sequence of these steps is as follows: At Step 1; students watch instruction part of digital video clip without watching the result part. In this step, students also predict the result of the experiment by answering a multiple-choice question. At Step 2; students answer second multiple-choice question about the reason of their prediction at the first step. After this step interactive part of instruction begins. At Step 3a (True Prediction and Reason); students watch the whole video clip of experiment and congratulation message appears on screen. At Step 3b (False Prediction and Reason); students watch the whole video clip of experiment. In this way students accept that their predictions aren’t true. After this step to change their misconceptions some textual explanations will appear on
An Analysis on the Role of Imagination in Physics Teaching

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This paper reflects on the following question: Would it be possible to develop learning situations in which students are encouraged to use their imagination in a way that this process of creation has the characteristics to help in the understanding and development of scientific ideas? To answer this question, we first present a summary of a theoretical discussion on the process of creation in science, based on Albert Einstein’s description of his thought.

Stage 1 – Intuitive Perception of Reality: In which the thinking process begins from the individual’s many-sided interaction with the reality to be understood. However, this interaction depends more on a subjective perception.

Stage 2 – Creative Leap that connects Perceptions to General Knowledge: In which thought links the perceived diversity to a body of general knowledge that can be laws, principles or a simple regularity.

Stage 3 – Conclusions and Verifications: In which thought, from the knowledge built, verifies how it can deduce consequences to confront them with the facts already known and those still to learn.

Then, we proceed to analyze a teaching activity called “Discovery of the Atomic Nucleus”. The procedure proposed to the students is an analogy with Rutherford’s experi-
ment. Under a sheet of wood, there is an object that is a few centimeters thick, so that the students cannot see it. They will discover the shape of the object by throwing small balls on it and observing the course as they hit the object.

The activity was video and audio recorded. The students’ initial reaction is very favorable and they express terms such as “imagine that this square ... imagine that the sheet is like this”.

The students throw the balls incessantly in order to check the possible trajectories. This process only allows for indirect inferences of the object they seek to represent. In their discussions the words show that they perform a process that seeks to interpret something unknown (stage 1). These perceptions are linked to known geometric forms, in other words, the theoretical knowledge that supports their interpretations are flat geometric forms that students know well (stage 2). This is clearly shown by words like “it seems to have an edge, it’s a triangle” or “it bounces like a ball (circle)”, and etc.

The final stage is based on verifications. This is a very clear step observed in the procedure performed by the students. Having arrived at a conclusion, students continuously begin to show how their “creativity” represents what is hidden. They express this in words such as “look, if it is a square it will bounce like this (the student shows by throwing the ball). The lesson ends with a general discussion with students organized by the teacher.

This brief analysis based in speech and actions sought to demonstrate that the three previously defined stages can be characterized in the students’ resolution process. With this, we can consider that, to some extent, the students were able to develop creative thinking that at the same time met the requirements of forming ideas that seek to understand the reality through processes that are part of scientific knowledge.

**From Mental Models to Scientific Models: Similarities in Structures and its Importance in Scientific Knowledge Construction.**

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“Model” and “modelling” seem to be the most repeated key words in most of the papers nowadays, written in Science Education Journals. They are related to learning, teaching curricula design, conceptual development, research in Science Education, teachers training, and others relevant topics. In this paper will try to address the issue from another point of view: namely, the relationship between Mental Models as spontaneous construction of everyday knowledge about the world, and Scientific Models as constructed by scientists to develop scientific explanation of the world.
We will base our claim within the Cognitive Sciences framework. It is within this field that the concept of Mental Model arises (Johnson-Laird 1983, Gentner and Steven 1983). It is also from here that an historical approach facilitates the thesis of a continuity or development from Mental Models to Scientific Models. Cognitive historical analysis (Nersessian 1992, 1999) shows how the cycles of refinement of Mental Models guide science researchers until the model they produce fits within a scientific explanation of phenomena in the world.

We could at present say that the main line of research being carried out on the design of teaching/learning sequences in the science curricula is indeed model-based. This methodology is thought to be the best, and it could well be appropriate. But in our view, this is position based mainly upon empirical data. In this paper however, we will try to show how the similarities in structure of Mental Models and Scientific Models, as defined by de Kleer and Brown (1983) and most of the authors who ascribe to a Semantic View of Scientific Theories (Bunge 1974-1989, Lesh and Harel 2003, Hestenes 2009), respectively, could offer a theoretical framework for this field, which is based both in psychology and in the epistemology of Science.


**Content and Language Integrated Learning in Physics teaching: Benefits, Risks, Requirements and Empirical Studies**

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Content and Language Integrated Learning – in short CLIL - describes all types of instruction in which a foreign language is used to teach certain subjects of the curriculum
except language lessons themselves. This concept of instruction through a second language is very flexible, since CLIL can be implemented for only one or for several subjects and contrary to bilingual programmes also for shorter phases which are alternated with conventional instruction in the first language. During the last decade Content and Language Integrated Learning (CLIL) has become quite popular in German speaking countries. An increasing number of schools are offering programmes which are based on this bilingual approach in content subjects. However, this trend is not equally true for science subjects, especially not for Physics. Science teachers seem to be quite concerned how their students’ subject achievement and motivation are influenced by the use of a foreign language as a medium of instruction.

CLIL does not only trigger changes on the communicative level of teaching but it also effects teaching methods applied. Methodological requirements closely related to Content and Language Integrated Learning are discussed. Here a special focus is put on the contribution of didactical knowledge deriving from the fields of foreign language teaching and content subjects.

In addition, studies are presented which are supposed to highlight the output of CLIL in Physics teaching on different levels. The influence of CLIL on students’ subject achievement was investigated in a field study with 223 participants in Austrian Grammar Schools. Based on a control-group design, grade 11 students were instructed in magnetism either in their first language (control-group) or in English as working language (test-group). Students’ subject knowledge in the field of magnetism was tested in both groups before and after the instruction with an assessment tool developed for this study. According to the results of this field study no significant differences between both groups’ subject achievement could be observed. Communicative behaviour and the development of individual motivation and interest during CLIL phases in Physics lessons were evaluated in a case study.

How to teach about transition processes in so-called simple electric circuits

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Ohm’s law and Kirchhoff’s rules are part of every physics curriculum in practically all schools where physics is taught. But equally far spread is the method to talk only about the steady states, which are controlled by these laws without mentioning or even explaining the transition processes which are necessary to reach any of these steady states. These transition processes are rather short, therefore difficult to measure and not so
easy to explain. This may be a technical excuse for leaving them aside. But if precise observation and exact thinking is one of the ultimate goals of physics education, such a tradition is questionable. Students learn, that when dealing with electric circuits there are only steady states. The question, how a battery „gets to know“ that somewhere far away a resistor has changed is not answered. The same holds for the question how fast a current with rise to „infinity“ if a battery is shorted by a long conductor. Do our students learn that very fast processes are not important? Do they learn that action at a distance is an acceptable method to answer such questions? Do they see at least that transition processes are as important and necessary as steady states to establish a complete causal description and explanation of the electric circuit?

We will demonstrate with two newly developed computer simulation, one based on a rather simple algorithm, the other on the 1-dimensional solution of Maxwell’s equations, how such transition processes can be demonstrated and integrated into the traditional curriculum.

Different senses of entropy – implication for education

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Entropy is a central concept in physics and chemistry that is used to describe the spontaneity of natural processes involving systems and their environments. However, it is a difficult concept for students to grasp, and it is generally perceived as abstract and obscure. An additional challenge, the focus of this study, is that the word entropy has several different, but related, senses. The research questions were:

• What are the distinct senses of the word entropy and how are these senses of entropy related logically and historically?

• What are the educational implications of the answer to the question above regarding teaching and learning the scientific senses of entropy?

The empirical data were text excerpts relating to entropy from different sources. Dictionary information was used as a starting point to identify the different meanings of entropy in science and non-science language. In the cases where new senses of entropy have been introduced in science and elsewhere, original sources were consulted. Science text books and historical accounts of thermodynamics were used to locate representative examples of how the subject is presented in educational settings. Text corpora were used to identify non-science language use.
As a method for discernment of the senses of entropy, the Principled Polysemy approach (Evans, 2005) from the field of cognitive linguistics was adopted. As a result, five distinct senses of the word ‘entropy’ and their relationships were identified, as shown in the semantic network in Figure 1. The sanctioning Statistical Sense is Boltzmann’s interpretation within statistical mechanics. The Thermodynamic Sense is the original sense in thermodynamics as coined by Clausius. The Disorder Sense is the metaphoric use of entropy as disorder, in teaching or non-formal settings. The Information Sense is Shannon’s adoption of the formalism from statistical mechanics in the field of information theory. The Homogeneity Sense is the non-formal interpretation of entropy as a quality of lack of structure, which may have developed as an image schema transformation (Lakoff, 1987) from the dynamic view of the Disorder Sense to an endpoint focus.

![Proposed semantic network for entropy.](image)

In this study, educational challenges such as the existence of several formal senses of entropy and the intermediary position of entropy as disorder along the formal/non-formal scale were analysed using a two-Dimensional Semiotic/semantic Analysing Schema (2-D SAS) (Strömdahl, submitted). Baierlein (1994) has recognised that there is an educational challenge associated with the introduction of fundamental thermodynamics concepts such as entropy during teaching in terms of adopting a microscopic or a macroscopic approach. Eventually, an aim of teaching ought to be to merge these perspectives into an integrated view on the physical quantities involved. The main obstacle to this integration is that the Thermodynamic Sense refers to an aspect of heat engines, while the Statistical Sense refers to an aspect of a particle model, resulting in fundamentally different conceptions.


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**Iterative development of a teaching/learning sequence on Acoustic Properties of Materials**

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In the last decades, different researchers have focused their attention on producing a sound theoretical framework about the design and validation of teaching/learning sequences (TLS) (Lijnse 1995, Leach & Scott 2002, Méheut & Psillos 2004, Duit et al. 2005, Tiberghien et al. 2009). Agreeing with the view of the design-based research framework (Design-Based Research Collective 2003), after having designed an innovation it is considered necessary to carry out a research study on its effectiveness. The effectiveness of an innovation is understood as the great extent that the experiences and outcomes obtained with the intervention are consistent with the intended objectives (or learning targets).

Although it is true that an important body of theory and approaches have been generated within this paradigm of research, it is not so common to find empirical studies which focus on the process of evaluation and refinement of a TLS from its original design, reporting the difficulties arisen when implementing the innovation in classroom and the required modifications suggested. It is even less usual to do so within a partnership between secondary school teachers and researchers. We agree with some authors who consider that the process of developing innovative materials should be iterative in order to enhance students’ learning achievements in each cycle. For sure, this process involves different stages, such as design, implementation, evaluation, and refinement, enlightened by research data.

This paper presents a longitudinal research study focused on the process of design and refinement of a TLS, which deals with the acoustic properties of materials concerning the phenomenon of sound attenuation. This research is intended to obtain information about:

(a) The difficulties arisen when implementing the innovative TLS in a real classroom context with secondary school students (15-16 years old).

(b) The types of changes considered necessary to overcome the students’ difficulties previously identified.
(c) The effects that certain didactical changes introduced in the original design of the innovation have on students’ learning achievements.

The pedagogical approach, the intended learning targets and the content structure of the sequence will be briefly presented. The rationale that is on the basis of the design of the sequence will be also discussed. Results of students’ needs and difficulties evidenced during the classroom implementation of the sequence and the changes proposed to overcome them will be further explained.


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**Container Design for Vortex Rings Generation**

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A vortex ring consists of two vortices of equal strength but opposite sign that are placed close to one another and travel along together, with uniform speed. A vortex ring is a fundamental element in the turbulence. They are of great interest in different areas as meteorology, aerodynamics and superfluid physics. They are used for underwater drilling, in fighting oil well fires and are used for modeling the downburst, a hazard to aircraft. They have been observed in the oceans and in the atmosphere. Their dynamics are practically bidimensional due to the presence of stratified fluids, to the rotation of the system, or to the combination of both factors. In order to understand the origin and
What the Michelson-Morley experiment tells us about the existence of a luminiferous aether

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The aether hypothesis is among the most discussed scientific subjects in the historical evolution of physics. Most of the great physicists of the 19th and the beginning of the 20th century have been working and commenting on the subject. Einstein for instance in some statements denies the existence of an aether straightly, whereas in others he vehemently defends the aether hypothesis.

When teaching the history of physics we have to simplify and to compress. Regarding the aether concept a teaching tradition has established, that in its minimal version reduces the historical course of events to three steps:

(a) By the experiment of Young it was demonstrated that light is a wave phenomenon. Every wave needs a carrier medium. This medium was identified with the aether, a concept that existed previously.

(b) Michelson and Morley had tried to measure the relative movement between the aether and the Earth. No such movement could be detected. This was the proof that an aether does not exist.

(c) The problem was solved with Einstein’s Theory of Relativity in the year 1905. In his seminal paper On the Electrodynamics of Moving Bodies we read: “The introduction of a ‘luminiferous’ ether will prove to be superfluous in as much as the view here to be developed will not require an ‘absolutely stationary space’ provided with special dynamics of the vortices it is necessary to understand the processes that take place in the systems in which they appear. These flows are described in general by very complex nonlinear equations, but if one is interested in its global properties can be used the equations of conservation for mass and linear moment. In this work we present a prototype that will allow the student to understand the generation of the vortex rings under different volumetric flows, emphasizing the type of the nozzle. The effect of the temperature, the saline concentration under the axial and radial speeds of the vortex evolution is also verified. Through visualization techniques, three stages were observed during the evolution of the rings: an exponential stage associated with the injection of the tracer, a parabolic stage and finally a dissipative stage. The Reynolds number was determined for three different volumetric flows, with an error of 3.5 % as compared to theoretical values; the values obtained, between 27 and 48, correspond to a laminar flow. This prototype also will be useful for the accomplishment of experiments in where transport processes take place, so the students could obtain the diffusion coefficient as well as another dimensionless numbers as Archimedes, Nusselt and Lewis numbers of great interest in transport phenomena.
properties, nor assign a velocity-vector to a point of the empty space in which electromagnetic processes take place."

The method of arguing is based on the fact, that an experiment that supports a scientific hypothesis does not prove that the hypothesis is true, but an experiment that is in disagreement with the hypothesis proves that the hypothesis is untrue: a hypothesis cannot be verified but it can be falsified.

Since the rejection of the aether hypothesis is based only on the Michelson-Morley experiment, it is worthwhile to reconsider the experiment. Indeed, we shall argue, that the Michelson-Morley experiment does not make any statement about the existence or non-existence of a luminiferous aether. For that purpose, we shall make use of a method that often helps to disentangle an intricate historical situation. We shall tell a fictitious story about the Michelson-Morley experiment. Although some parts of our tale are totally unrealistic, it should be acceptable insofar as no physical principles are violated.

It will be seen that the Michelson-Morley experiment does not make any statement about the existence or non-existence of a luminiferous aether at all. This observation has far-reaching consequences for the teaching of the field concept and of the idea of the so-called empty space.

**Homework on the Moment of Inertia of a Human Arm**

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The author has been in charge of dynamic classes for first year students in a university. The author thinks that the concept of the moment of inertia is a key issue for students to understand the dynamics of rigid body. Based on this idea the author has introduced some demonstration experiments related to the moment of inertia in the class in order to attract students concerns about it and assist them to think problems actively. However, the author thinks further method is necessary for them to acquire enough understandings on the moment of inertia, and introduced a homework related to it. This homework has been set for three years in a series in order to make students to have real feelings on the moment of inertia and promote the students’ understandings on it. This homework consists of two parts. The first part is such that each student measures the sizes of several parts of his or her own arm and calculates the moment of inertia with respect to the axis through the shoulder. In the second part each student calculates the period of swinging motion of arm by assuming this motion is a rigid body pendulum and compare this value with the measured one when swinging naturally without walking. The calculated results by all students were checked whether the calculations were conducted correctly or not, and the distributions of mass, length and the moment of inertia of the arm of all students are obtained based on the correctly calculated data. Some statistical
relationships between the length of the arms and the moment of inertia and so on were also obtained. These summarized data were fed back to the students in order to promote students’ concerns to their measured values. It was confirmed according to the questionnaire survey after the class that this homework was effective for students to obtain the real feelings about the concept of the moment of inertia and to promote their concern about it. The detail will be reported in the presentation.

Influence of content structure on students’ understanding of Newtonian mechanics – results from an empirical study

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Repeatedly it was shown that students’ understanding of mechanics – even after instruction - is fragmentary. Many reasons are responsible: The complexity of the topic itself, students’ misconceptions and the quality of instruction. There is good evidence that increasing students’ activities fosters their understanding. Insufficient evidence exists on the influence of the content structure itself on students’ understanding, although this could also be a major issue.

In the study presented, two different approaches towards teaching Newtonian mechanics in grade 7 were compared. The two treatments did not differ as far as teaching methods are concerned. The major distinctive feature were alterations in the content structure of the introductory course: The first course, was based on an instructional design starting with the introduction of speed and acceleration in one dimension and continued with the discussion of forces and Newton’s laws. The alternative course on the contrary started right away discussing two-dimensional motions and consequently focused on velocity as a two-dimensional (vector) quantity. Newton’s second law was introduced using the impulse equation.

The effects of these two courses on students’ understanding, their interest in physics and their self concept were compared in a quasi-experimental field study with 27 classes and more than 500 students. In addition interviews were conducted with all participating teachers and selected students. We found significant differences of students’ understanding in these two populations. In this presentation, selected findings based on the qualitative and quantitative data from this study are presented.
Teacher change in exploring representational approaches to learning science

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The researcher worked closely with two biology-trained teachers to plan three teaching sequences in the topics of forces, substances and astronomy that were subsequently taught to Year 7 students. The sequences sought to develop a model of classroom practice that foregrounds students’ negotiation of conceptual representations.

The difficulties encountered by individuals in learning science point to the need for a very strong emphasis of the role of representations in learning. There is a need for learners to use their own representational, cultural and cognitive resources to engage with the subject-specific representational practices of science. Researchers who have undertaken classroom studies whereby students have constructed and used their own representations have pointed to several principles in the planning, execution and assessment of student learning (diSessa, 2004; Greeno & Hall, 1997). A key principle is that teachers need to identify big ideas, key concepts, of the topic at the planning stage in order to guide refinement of representational work. These researchers also point out the need for students to engage with multiple representations in different modes that are both teacher and student generated. A representation can only partially explain a particular phenomenon or process and has both positive and negative attributes to the target that it represents. The issue of the partial nature of representations needs to be a component of classroom practice (Greeno & Hall, 1997) in terms of students critiquing representations for their limitations and affordances and explicitly linking multiple representations to construct a fuller understanding of the phenomenon or process under study. The classroom practice should also provide opportunities for students to manipulate representations as reasoning tools (Cox, 1999) in constructing the scientifically acceptable ideas and communicating them.

Research question: What impact was there on the participating teacher’s practice through the adoption of a representational focus to teaching science?

Data collection included video sequences of classroom practice and student responses, student work, field notes, tape records of meetings and discussions, and student and teacher interviews based in some cases on video stimulated recall. Video analysis software was used to capture the variety of representations used, and sequences of representational negotiation.

The teachers in this study reported substantial shifts in their classroom practices, and in the quality of classroom discussions, arising from adopting a representational focus. The shifts were reported by them as a three-fold challenge. First, there was an epistemological challenge as they came to terms with the culturally produced nature of representations in the topics of force, substance and astronomy and their flexibility and power
as tools for analysis and communication, as opposed to their previous assumption that
this was given knowledge to be learnt as an end point. The second challenge was peda-
gogical, in that this approach was acknowledged to place much greater agency in the
hands of students, and this brought a need to learn to run longer and more structured
discussions around conceptual problems. The third challenge related to content cover-
age. The teachers sacrificed coverage for the greater depth offered by this approach, and
were unanimous in their judgment that this had been a change that had paid dividends
in terms of student learning.

Cox, R. (1999). Representation construction, externalized cognition and individual differences,
*Learning and Instruction*, 9, 343–363

and Instruction* 22 (3), 293-331.


**Opportunity for student to inquiry everyday life
from different view--- using open source video analysis
and modeling tool to analyze clip
from high speed camera**

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The theme for this year GIREP conference is “Teaching and Learning Physics Today:
Challenges? Benefits?”. We all know from Newton’s law: *Every body persists in its
state of being at rest or of moving uniformly straight forward, except insofar as it is
compelled to change its state by force impressed --- quoted from Wikipedia. We, as hu-
man being, are always looking for better future. That is why we always try to find new
challenges --as external force for us to conquer and move forward. Challenge means op-
portunity. A knife could be a murder weapon, but it could also be used to create a beau-
tiful art. It is how the tool being used that determine the result. The internet and new
technology has change the way of our living dramatically. High speed video recording
was very expansive in the past. Thanks to modern technology, 300fps with 512x384
pixels resolution was in the affordable price market during the last few years. We will
show video clips from everyday life and demonstrate how it can be used in physics
classroom. Students are not only look at the same world from a different view but also
inquiry the wonder of physics with the help of open source physics tools. Tracker is a
free java video analysis and modeling tool from open source physics project. Students
can compare video of the real world to animations of theoretical models. Students can
build their own model and compare model data with experimental data with analysis
tool. . Simulations created with easy java simulations are also designed to help students
to dig deeper into the physics world. There are hundreds of physics related simulations
available for free download at NTNUJAVA web site. You are welcomed to visit our web site http://www.phy.ntnu.edu.tw/ntnujava/ and join the collaborative community.

**Related web sites:**
1. Tracker: http://www.cabrillo.edu/~dbrown/tracker/
2. Open source physics project: http://www.compadre.org/osp/
4. NTNUJAVA: http://www.phy.ntnu.edu.tw/ntnujava

**Biomedical physics: challenges and problem education**

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Characteristic feature of a modern society development is the accelerated growth of manufacture and introduction of technics for different problems of medicine, agriculture and biotechnologies. Biomedical and electronics physicist should be able to use knowledge in three areas: physics, medicine and computer engineering. It demands training of the experts, capable to connect modern achievements of physics, radio physics, chemistry, biology and medicine and to use full possibilities of computer technics. In consideration of absence of the common vital processes’ course, it becomes impossible to predict or describe them by instrumentality of classical or quantum physics, but the combination of these theories could be a basis of definition of a living matter. This understanding is an indicator of qualitative student’s education.

The problem education is always focused on independent activity of students in groups which pupils carry out during a certain interval of time. This work is an example of such educational method by means of bio-technical system’s modeling. The main feature of such system is an existence of subsystems in it. There are concrete practical examples of our department in the project.

The base of the synthesis of such systems is bionic law, i.e. maximal using the laws of physics and technical disciplines for description of the biological parts. It allows to achieve next results:

1. extending knowledge of physics, mathematics, system analysis, biology, chemistry, medicine etc.;
2. obtaining skills to work at the “border” between physical and medical specialties;
3. working in small groups;
4. maximal computer technologies using for solving the technical and medical problems;
This method stimulates the creative activity of students and their cognitive interest, makes it possible to find the original answers and decisions. Current technology allows to assume totality research, search and problem methods.

At the end of the project, students present their achievements and studies like presentation or posters, which include the progress of work, their own conclusions, prospects for further research before an audience of key professors and scientists of the department.

**Preliminary Investigation of Student Understanding of Spectra**

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At present, physics education research has tended to focus on student understanding of basic topics in introductory physics courses. There has been less emphasis on topics in modern physics such as line spectra. The structure and formation of spectra are a part of the university and secondary school curricula in Croatia. The Physics Education Group from Zagreb has noticed that the concept of line spectrum formation seems to be very difficult, even for students who have completed an upper-level university course on quantum mechanics. During the last year, a systematic investigation of student understanding of line spectra was begun. A series of semi-structured demonstration interviews have been conducted with nine senior physics majors to probe their understanding of line spectra. The results guided the design of a written questionnaire that has been administered to 96 students at the University of Zagreb. The questionnaire consists of 5 open-ended questions and 8 multiple-choice questions, for which explanation of reasoning are required. Some of these questions have also been administered in the introductory physics course at the University of Washington, both during and after instruction. The aim is to examine the extent to which physics students develop a functional understanding of spectra. Findings from the interviews and the written questions will be presented and serious conceptual and reasoning difficulties will be discussed. The results have implications for instruction.

**Exploiting language in teaching about entropy**

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**Introduction**

Entropy is often considered as an abstract concept and difficult to grasp for novices and there are many ideas about how and in what way the scientific concept of entropy
should be introduced to novices. A popular way to introduce abstract scientific concepts is the use of metaphors and analogies. It has been proposed to view it as disorder, freedom, information, heat and spreading, respectively. While physics is often regarded as an exact discipline, where terms have precise definitions, the mentioned words have many different senses within and outside science. The purpose of the present study is to analyse and evaluate a set of four common metaphors and one way of exploiting the everyday language use of heat that are used in teaching the scientific concept of entropy. Their semantic implications and usefulness for instruction are discussed.

**Metaphors and analogies**

Metaphor was regarded as one of the main tools of rhetoric in ancient Greece, characterised by the following form: A is B, e.g. ‘Achilles is a lion’. Black (1962) argues that metaphor goes beyond poetic ornamentation and is a useful tool in everyday language and for modelling in science. Typically, a new or abstract target domain is compared with a more familiar, concrete base or source domain. While metaphors are typically implicit and focusing on language, analogies are more explicit, pointing out similarities between two domains contribution to conceptual transfer.

**Method**

We analyse four metaphors for entropy that have been or proposed to be used in science education as deliberate instructive tools for learning. These are entropy is disorder, information, freedom and spreading, respectively. In connection to each metaphor, we suggest the relevant senses of the proposed source domain words from the online dictionary www.dictionary.com, and discuss possible interpretations. By using the different senses of these words listed in dictionaries, we present how students may interpret metaphors such as ‘entropy is disorder’

Falk, Herrmann & Schmid (1983) have developed an alternative approach to teaching physics. In this framework, entropy is seen as the everyday conception of heat. The dictionary www.dictionary.com list 25 senses for the word ‘heat’, out of which we suggested seven senses as the most relevant for our analysis.

**Conclusion**

Williams has shown that many words in science have many senses, as shown in dictionaries (Williams, 1999). By following the approach of analyzing senses in dictionaries, we argue that also words that have been proposed as sources in metaphors for entropy have many senses. This semantic ambiguity adds further to the challenge of learning the concept of entropy. The use of several metaphors, such as combining ‘entropy is freedom’ and ‘entropy is information’ as proposed by Brissaud (2005), is one way to come to terms with the limitations of the use of just one metaphor. In slight contrast, though, to Williams (1999), we do not believe that educators can or should strictly limit their spoken language to precise definitions; carefully designed analogies should allow some degree of variation in language use.

The challenge of using ATLAS experimental data in schools

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In December 2009 the ATLAS physics experiment, one of the largest and most complex scientific experiments for the investigation of the fundamental processes in nature, started observing high energy particle collisions at the Large Hadron Collider at CERN. For more than 12 years the ATLAS experiment has had an ambitious education and outreach activity culminating in making high energy particle collisions available to students and teachers in a pedagogical environment on the Web. The Learning with ATLAS education portal is now available, and some of the education scenarios are based on real data from the first data taking at the Large Hadron Collider at CERN in 2009. The use of scientific data poses challenges both to the scientists and to the teachers and students. The pedagogical approach is demanding but also very rewarding, as it makes today’s frontline physics available and understandable at schools. The approach is compatible with most school curricula, but includes components that go beyond what is normally taught at school.

The tools to inspect and explore the particle collisions are to a large extent identical to those used by the physicists. The ATLAS event display is used to inspect particle collisions and determine the mass of the sometimes invisible particles. For the neutral strange particles - composed of a strange quark and a light quark - the decay of the unseen neutral particle to two charged particles is visible on the display. The exploration of particle collisions is combined with pedagogical material including written background material, films and animations to demonstrate how the ATLAS experiment works, and how the information from the particle collisions can teach us about particles that play an important role in microcosm. In addition to describing how to explore particle collisions, particle animations and film clips will show how an international frontline physics experiment with 3000 physicists from all over the world is run.

**Technical details:** The film sequences have sufficient resolution to be shown on a large screen. For a proper impact a good sound system is needed.
We can only teach if the student is motivated. In the Europe of knowledge and specialized skills, learning is a continuous process. If young people, up to 17 or 18 years want to be interactive, innovative and knowledgeable citizens, they need to learn a variety of subjects, including Physics and Chemistry.

Thrilling subjects and activities that keep the interest in the subject should be introduced into the classroom (motivation excited states). Plain motivation cannot be the learning fundamental state. Often subjects to be learned are boring and uninteresting for young people. The learning process will be eased if student are already motivated. The teacher’s task is to motivate students. Such a difficult task will be a pleasant one if done in teams of teachers, in collaboration with research institutes and universities.

The “Environmental Radiation Project” (www.lip.pt/radao) was born with this motivation perspective and every day similar projects are conceived throughout Europe, as can be noted in www.scienceinschool.org.

The Project has been now operating for 3 years, involving 51 schools spread out through Portugal, reaching 500 students and 80 teachers. Within the project the thrust of motivation has been improved and sometimes changed over the last three years. The project is under continuous observation in order to assess the student’s achievements and motivation. Some preliminary results have already been shown in the Girep 2009 conference [1]. This year we added a continuous evaluation of the student’s knowledge acquisition progress, introducing online tests using the Moodle platform [2]. Schools compete with each other trying to get the best scores. Two test levels were introduced. A basic level, for students up to the 9th year and an advanced one for students up to the 12th year. Our perception is that competition has increased the students’ motivation to participate in the project.

The project offers a wide range of available experiments using inexpensive materials allowing demonstrations / verifications / measurements [3]. An experiment that has enjoyed much success, is the biological effect of ionizing radiation and its use in the
sterilization of substances such as canary seeds or a simple slice of bread. The pictures below illustrate these two situations.

An overall assessment of the students’ knowledge on the subject has been made throughout the three years project’s life. It has been noticed that some of the least known topics were the existence of radon gas in nature, its decay chain and the consequences to human health.

Teachers update on radiation topics was noticed as a very important one, since many did not have specific training on this subject when attending their university courses.

Fig. 1 Average height attained by canary seeds irradiated with X-rays

Fig. 2 Germination of canary seeds irradiated with X-rays

Fig. 3a) Bread irradiated with 50 Gy of X-rays after some days.

Fig. 3b) Non-irradiated bred after a few days. Mold is clearly visible on it.

Identifying Pre-service Physics Teachers’ Misconceptions with Three-tier Tests

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In order to measure individuals’ conceptions, different diagnostic tools have been developed and used such as; interviews, multiple choice tests, concept maps, and multiple-tier tests (two tier tests and three tier tests). Among these tools, interviews have advantages as flexibility and obtaining in-depth information. However; interviews can be conducted on limited number of individuals. Multiple choice tests can be administered to a large number of individuals; but cannot investigate the students’ responses deeply. In order to compensate the limitations of interviews and the ordinary multiple choice tests, researchers extended multiple choice tests into two or three-tier tests. With the application of three-tier tests to determine misconceptions, researchers can obtain rich information about the individuals’ misconceptions eliminated from lack of knowledge and errors.

Some previous research studies draw attention to the teachers as a possible source of student misconceptions. For this reason, identifying teachers’ and teacher candidates’ misconceptions become crucial to better understand the ones of students’. In the present study, three different three-tier concept tests on geometric optics, simple electric circuits and force and motion were administered to 30 senior pre-service physics teachers at Middle East Technical University (METU) in Turkey to analyze their misconceptions. For each of the three topics, common misconceptions measured by each of the tests are listed. Pre-service physics teachers’ misconceptions in all three topics will be analyzed and presented for one, two and three tiers separately in terms of percentages of each misconception. Also development, analysis, and importance of the usage of three-tier tests will be discussed.
Recently, teaching of astronomy has come to play an important role in the science/physics education. Because astronomy is not only the oldest of all sciences, but it can also be called the mother of all sciences. However, studies show that students and science/physics teachers don’t have a sufficient scientific literacy about astronomy.

In light of these facts, the main purpose of this study is to determine and compare the misconceptions of physics and science teacher candidates about basic astronomy concepts. For this purpose, the Astronomy Concept and Achievement Test (ACAT), including 28 multiple choice questions, developed by Trumper (2006), was revised as three-tier and used as data collection instrument. The study was conducted with 250 science and physics teacher candidates attending one of the universities in Turkey.

The first tier in ACAT, concept or the problem is asked as multiple choice questions. In the second tier the reason or justification of the answer given to the first tier is asked. In order to discriminate misconception from lack of knowledge, in the third tier, they are asked to what extent they are sure about their answers in the first and second tiers as choice namely “I am sure- I am not sure”.

To assess science and physics teacher candidates’ conceptual understanding as achievement test, it was given a true score to the candidates who chose the correct alternative in the first tier and the corresponding correct reason in the second tier and they had been sure about their answers. Likewise, to assess candidates’ misconceptions, it was given a score to the participants who chose the misconception alternative in the first tier and the corresponding reason in the second tier and they had been still sure about their answers.

As a result of the research; in terms of achievement, science and physics candidates’ test scores are very low. Also, teacher candidates hold a series of misconceptions about day-night cycle, moon’s phases and rotation-same side visible, moon’s phase in solar eclipse, reason for seasons.
Innovation of Active-Learning on Physic Education by Visualizing ICT Tools with Milliseconds Resolution for Promotion of Conceptual Understanding

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We are developing various active learning modules on physics education to overcome students’ misconceptions by use of ICT tools with milliseconds resolution, such as, video analysis of high-speed digital movies, motion detectors, force sensors, current and voltage probes, temperature sensors etc. Recently, it becomes very convenient to use cheap high-speed-cameras as Casio EX-F1 (1200fps) or EX-FC100/FC150 (1000fps), which open exciting opportunities to explore clearly visualizing by ultra-slow motion movie of too quickly moving phenomena that are difficult to see by usual video movie camera of 30 fps.

Here we present our special effort to developing ICT-based active learning modules on collisions in center of mass system (CMS) by visualizing with milliseconds resolution, where it is noted that we can always easily realize CMS collisions of two pendulums-balls separated by putting a straw between the two balls, where separated two balls are just stabilized in CMS positions of these two balls’ system. Therefore we can clearly show the momentum conservation rules by use of various types of collision in CMS such as in two pendulums or even in many pendulums systems. That is, we can determine the mass ratio from the “Huygens’s principle of leverage”, i.e., each ball’s displaced distance in CMS is always inversely proportional to each ball’s mass ratio. Now, we can measure the relative mass ratio between various two different materials by such 2-body pendulum collisions.

We also investigate “Newton’s Cradle” cases, i.e. various continuously collisions in CMS for two groups of balls-pendulums as 1 balls-2 balls, n ball-m balls, etc. It is noted that we always get a countable mass ratio and we also get the same magnitude of momentum but opposite sign. Thus, we can easily find out the momentum conservation rules in terms of countable ratio of distance or velocity for two colliding objects in CMS.

We introduce an analysis of a kinetic model for molecular motion of gas by visualizing high-speed-movie-camera with milliseconds resolution. Various new examples are given for good illustrations towards innovative practice of active learning on milliseconds world, such as microscopic visualization of vibratory motion of straw-whistle by ultra-slow motion movies and also another visualization methods of various oscillating wave phenomena, electric currents phenomena etc. by ICT devices having milliseconds resolution.
Furthermore, we describe newly developed active learning modules on mass measurement of air in a big-balloon pendulum by collisions with a lacrosse ball pendulum or with a water balloon pendulum each having a given suitable masses.


Enhancement of Student Conceptual Understanding of Quantum Mechanics through the Development of Animated Visualisations

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There has been substantial research done in recent years concerning student difficulties and misconceptions in quantum mechanics [1-6]. Understanding quantum mechanics suffers from the abstract nature of the material, false analogies with classical systems, overgeneralization and confusion between related concepts. Visualizations and animations can play an important role in helping students to construct mental models of quantum-mechanical concepts. As a UK Higher Education Academy Development Project, we have built on existing prior pedagogic research, including work done at the University of St Andrews, to create ~30 visualizations and animations to specifically target student misconceptions and areas of difficulty in introductory and intermediate-level quantum mechanics. The visualizations were created using Mathematica and Flash, and file sizes are quite small (~50 kB for onedimensional, and ~1.5 MB for three-dimensional visualizations). Examples of topics covered include the finite well, the potential step, quantum tunneling, the asymmetric infinite well, propagation of wave packets, degeneracy of states, comparison of the classical and the quantum simple harmonic oscillator, perturbation theory and two-particle boson and fermion wave functions. Each visualization includes an animated step-by-step exploration which explains details of the visualization. We have used the visualizations and animations in three quantum mechanics courses in the 2009/10 academic year. We have aimed to evaluate their educational effectiveness through student questionnaires and a diagnostic survey. The questionnaires focussed on the usefulness of the animations compared with other parts of the course, average time spent working with an animation, clarity and usefulness of the explanations as well as giving students the opportunity for additional free-text comments. The diagnostic survey focused on conceptual and visualization understanding of concepts.
covered in the visualizations, such as wave function collapse, the slanted infinite well, superposition of states, the finite square well, degeneracy of states, and quantum tunneling, and was administered to level 2 and level 3 students. The visualizations as well as instructor resources, such as links to pedagogic research and worksheets, will be made available as open educational resources in summer 2010.


The importance of the constitution of professional learning communities in the implementation of curriculum innovation in high school

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This study shows the importance of the constitution of professional learning communities to ensure a greater possibility of implementing innovative content in the physics curriculum in high school. A qualitative research was done, based on semi-structured
interviews with the 12 teachers who took part in the project of curricular innovation. Recent investigations in the field of Science teaching indicate that teachers’ participation in professional learning communities (Couso, 2009) intensifies their development, as the exchange of practical knowledge and the discussion of concepts and classroom behaviors increase their confidence about the work they do. Thus, in a context of curriculum innovation, the structure of these professional development communities contributes significantly to the updating of the physics curriculum in high school, promoting the inclusion of concepts of modern and contemporary physics (MCP). Participation in these communities allows teachers to make deep reflections about innovations both in terms of specific knowledge and methodologies, leading them to accept the risks of innovation, since this new content still lacks the stability that comes with time (Chevallard, 1992). Thus, from 2003 on, a project has been developed which establishes proposals for the elaboration and implementation of teaching sequences involving MCP. This project resulted in the creation of a study group that gathered teacher-researchers, postgraduate students, and six high school teachers and which had traits similar to those of the professional learning communities. As a result of the reflections coming from their use in the classroom, the teaching sequences were restructured until 2007, when the group was modified with the replacement of the high school teachers. This was done to validate the structure of the altered teaching sequences. A preliminary analysis of these interviews shows that the participation of teachers in communities ensures a greater possibility of implementing innovative content, and encourage their professional development, because in these meetings teachers expose their real difficulties in the classroom, what the problems found during application of the proposed activities are, what went right and what went wrong, and perform a work of intense collaboration among them, resulting in the conception of new alternatives to the proposed activities. One teacher’s account illustrates this: “(...) it looks like that did not work, maybe if you follow this route it will work better, maybe if we tailor the discussion in this way it will facilitate the understanding of students”. In addition to that, this social interaction that occurs during weekly group meetings, ensures greater confidence for teachers in their actions, to the extent that their difficulties may be discussed with their peers. All of this falls in line with the study of Couso and Pintó (2009), which asserts that the possibility of taking part in social interactions produces professional knowledge.


COUSO, D., PINTÓ, R., Análisis del contenido del discurso cooperativo de los profesores de ciencias em contextos de innovación didática, Enseñansa de las Ciencias. 27(1), 5 -18, 2009.

Intuitive approach to defects in LCs

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Liquid crystals (LCs) can serve as an excellent instruction aid for various topics in physics, in the first place to help visualizing microscopic configurations of the constituent elements (rod-like or disc-like molecules), or for a clear understanding of several optical phenomena, like birefringence. They provide a natural way to understand symmetries and ordering (positional and orientational) underlying different states of matter, and the corresponding introduction of order parameters suitable to quantify the degree of order.

In particular, pictures of layers of liquid crystals put between crossed polarizers in a polarization microscope reveal a variety of textures. This conveys information about the inner structure of the LC phases as described by the director \( n \). From polarization microscope pictures, the director field can be visualized and the arrangement of the molecules may be inferred. In nematic liquid crystals pictures show typical patterns from which director singularities can be deduced in a clear way.

In LCs, defects are of fundamental importance both in understanding the microscopic structure of LCs as well as because of their technological significance. For this reason, they might deserve to get some mention in school. In this contribution, we present the classroom introductory work on defects in nematic liquid crystals (for the fourth year students of the Faculty of Education having combined majors in science): understanding polarizing microscope pictures, tracing local optical axes, deciphering molecular arrangements and visualizing the director field, and identification of director singularities. Also, students are invited to try to construct the director field for some types of restricted geometries which induce formation of defects (like a wedge disclination in a cylinder). Characteristic features (leading to the concept of strength) of the most common topological defects that occur in nematic LCs are described and energy considerations included.
Self-reflection, comparative reflection and analogical reflection in the framework of metacognitive modelling activities using the ModellingSpace technological environment

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The modern educational technological environments do not focus on the transmission of knowledge, but on the triggering of metacognitive functions (Cimolino et al., 2003). Reflection acts as a booster for metacognition. In this work, we present, initially, a review of the research on reflection in technological environments. Through the review and in combination with the benefits of the analogical reasoning (Harrison, 2002; Meyer, 2002), we propose an alternative kind of reflection, the analogical reflection, instead of self-reflection and comparative reflection. Self-reflection is considered as someone’s reflection on his/her own actions (Schön, 1991). As comparative reflection, we consider the reflection on others’ actions (Elbers, 2003). By the analogical reflection, we mean the reflection on analogies.

Based on the analogical reflection, we outline our pilot research. It is a case study on three groups consisted of two students each. The students work collaboratively in the ModellingSpace technological environment (Dimitracopoulou et al., 1999). Every group works in the same modelling activities on kinematics, but they reflect in a different way (self, comparative, analogical). The activities are divided in two sets. In the first set, the students reflect only at the end of the activities, while in the second set the students reflect both during and at the end of the activities.

In our research we consider the analogies as metacognitive tools. This means that the students use analogies to reach the metacognition level. Our basic hypothesis is the following: In self-reflection, it is very possible that someone cannot recognise his/her own mistakes. In comparative reflection, this possibility is potentially reduced, because perhaps the others do not make the same mistakes. We estimate that this possibility is minimised when the analogical reflection is activated, because it is easier to recognise a strange behaviour in a familiar cognitive field, where the normal behaviour is well known.

Finally, we present briefly an instructional framework, in which the students are asked to reason analogically and reflect on modelling activities, in order to exploit and improve their metacognitive skills.

The activities are related to the Principle of Conservation of Mechanical Energy and Work-Energy Theorem, while the scenarios are based on a linear motion considering an inclined smooth/rough plane. The data mining rises from the students’ worksheets,
models and history files, recorded by the ModellingSpace. By analysing the data, we plan to design a mapping tool for assisting students while reflecting analogically.


**How Small an Anchor Can Be? Physics Learning with Authentic Learning Tasks**

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In the last few years science education has been analysed very intensively and comprehensively by well-known international school-performance-comparison studies (TIMSS, PISA). The most important results of these studies – concerning the education of German students – are the low performance of students in Germany in transferring their learned knowledge on different problems, such as specialized scientific and non-scientific – often daily – tasks (‘inert knowledge’; Whitehead, 1929). Furthermore their deficits in dealing intelligently and expertly with text-tasks and the emphasized meaning of intelligent practice was uncovered as well as the development of a task oriented learning (‘task-culture’; BLK, 1997; Kuhn & Müller, 2004; Müller & Müller, 2002).

The work presented here is set in the strained field of these analyses and presents related approaches for science learning in authentic contexts as tasks and problems based on newspaper articles (Kuhn, 2010) and advertisements (Vogt, 2010). The main focus is on improving both motivation and knowledge transfer by working on these authentic ‘learning anchors’. In the framework of a ‘task-culture’ this ‘anchor-media’ should combine the preferences of affectivity and authenticity of one of the leading approach

In this contribution the background theory with two main roots in current science education research (task oriented learning, Anchored Instruction) is explained, hypotheses are derived, and the methods of investigation (quasi-experimental design, instrument choice, validity control, analysis of covariance, hierarchical linear model, path analysis) are presented. The results for several essential concepts of physics (velocity, temperature and heat, energy) are discussed, focuses on the following main aspects: Comparing experimental classes (with authentic learning anchors) with control classes (without authentic learning anchors, but otherwise the same lesson plan, and the same teacher) there is a significant improvement of motivation (p < 0.05 in all cases, down to p = 0.001), representing a strong effect (effect size: Cohen d up to 1.66), and a rather sustainable one (similar results still after almost two months). The same holds for performance only by working on Newspaper Story Problems, including transfer (p < 0.05 in all cases, d = 0.9 and larger, similar results after almost three months). In contrast the working on problems based on advertisements could not support these effects on performance. Finally, perspectives and open questions are addressed.

The \textbf{P&I} program is an elective, out-of-school, accredited program for high school physics majors, who meet on a bi-weekly basis for 15 months. The program currently into its 6th cycle, with over 150 graduates, implements a \textbf{Project-based learning} (PBL) instructional approach. Student pairs, coached by industrial engineers, design and construct a working model providing a solution to an authentic, open-ended technological problem, employing principles of electro-optics.

The P&I program requires a high degree of active participation and long term commitment, with which the participants are sometimes unable to comply. The instructional design enhances the following 4 learning dimensions as a way of supporting and scaffolding students’ efforts and guarding against the undermining effects of conflicting demands and natural attrition during the long term, ambitious program.

\textbf{1. Learning to apply knowledge}

The students’ initial physics knowledge is fragmented, and its application range is limited to standard text-book problems. Activities extending the basic knowledge include explaining observed phenomena, designing a specified system and determining physical features (e.g. remote calculation of distance).

\textbf{2. Learning to use tools}

Initially the participating students have very limited skills for using common and more advanced technological and problem-solving tools. Likewise, there are deficiencies in their knowledge organization and integration skills.

\textbf{Technological tools:} Opportunities and modelling are provided for using basic technical tools, common physics’ measurement instruments, and computer-based measurement (e.g. data-loggers and audio analysis software).

\textbf{Cognitive tools:} Software tools facilitating visualization of systems and phenomena are employed: simulations, spreadsheets, word processors and graphic software.

\textbf{Systematic Inventive Thinking} provides a set of strategies and thinking tools, for designing multiple, constraint-free solutions to technological problems.

\textbf{3. Learning to communicate}

Students’ verbal, oral and graphic communication skills are reinforced by photographically documenting events and systems, preparing and submitting experiment reports and homework assignments, composing a project report including text, graphic visuals,
Magical Elves and Formulas as a key to technological inventiveness: The case of non-contact distance measurement

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Some of the predominant weaknesses of prevalent student views, are related to the «Reality Link» - beliefs about the connection between physics and reality, and the «Math Link» - beliefs about the role of mathematics in learning physics. We will describe an instructional sequence implemented within a «Project Based Learning» framework for high school physics majors, that uses the quest for non-contact distance measurement as a motivating context, to promote technological inventiveness by applying thinking strategies and physics and mathematics formal knowledge to real world problems.
The Physics and Industry program is an extra-curricular, accredited program for 11th & 12th grade physics majors. The students meet on a bi-weekly basis, extend their physics and problem solving knowledge and construct a working model solving an authentic technological problem in the field of electro-optics.

An introduction to the concepts and strategies of Systematic Inventive Thinking is used to enable the students to generate creative technological thinking while still in their novice status. One of the strategies involves «Magical Elves» – imaginary creatures, which are called upon to perform required functions. The important issue at the initial stage is inventing a large variety of solution models by applying thinking tactics (e.g. «adding a dimension»). At later stages the elves’ required attributes lead the student to identify concrete components and materials that can be used to implement the solution model.

Distance measurement is required in many of the projects: Surveillance of premises, assisting blind persons, preventing vehicle collisions etc. The students are required to produce a variety of Magical Elves models for finding the distance between two objects (stationary or in motion). Following are some visual examples of elf solution models:

An elf whose foot size is given, progresses from A to B. Counting the number of footprints will provide the distance.

An Elf sitting on A, starts running towards B and then returns. The elf measures the time taken and calculates the distance, using his known constant speed. Elves continue running between A and B to find out whether the distance has changed.

Our analysis revealed an almost exclusive focus on one dimensional solutions, many of which relied on the $s=vt$ formula. The idea of helping students break out of this limited perspective emerged when we presented the triangulation method of non-contact distance measurement. We saw that students were able to utilize trigonometric formulas to calculate the unknown distance.
11th grade physics majors possess a large collection of mathematics and physics formulas. In fact, students regard formulas as primary problem solving tools - inserting “input” values on the right hand side and calculating the “output” value. We concluded that **purposeful scanning of formulas could generate inventive ideas of building systems for distance measurement**. For example, the formula of the linear magnification of a lens could trigger the idea that a lens might be useful in measuring the distance to an object of known size, using the image size and distance. Students listed a large collection of relations from trigonometry, kinematics and dynamics in response to the request to scan the formulas for a length or distance variable, to reformulate the equation and to explain how it may be used as a basis for designing methods for measuring distance.

Following is one example of the implementation of optical principles for non-contact distance measurement. A laser light source is directed at a slanted mirror at a given distance. The reflected light, hits a distant target and is reflected diffusely. A directional detector placed at right angles to the laser, responds when the object is at a distance \( L = d \times \tan(\alpha) \).

We will provide additional examples indicating how distance measurement offered a relevant and challenging domain for students, to improve the Reality and Math links of their physics thinking.

**A Nanoscience Course for Upper Secondary Students**

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The Organization for Economic Co-Operation and Development (OECD) suggests [1] that the number of jobs involving Nanoscience will increase by 2 million by the year 2015. The same report estimates the market value of Nanoscience products at over 1000 billion dollars by 2015. At the same time, roughly 40% of Nanoscience-related entrepreneurs struggle with the availability of workforce familiar with Nanoscience and –technology [2]. The employers’ complaints center on the applicants lacking either specific expertise, familiarity with technical applications, or broad knowledge. In view of these problems and opportunities, we offered a meaningful authentic task to physics teacher students to design a Nanoscience- and technology-oriented course for upper
secondary students. The course is supposed to give the students a background in Nano-
science as well as inspire them to pursue further education in the field.

The course is constructed from Nanoscience expert lectures and in-school learning units. The expert lecturers are asked to give insight into the specific problems they work on. These problems represent the fields of biology, chemistry and physics in Nanoscience. The in-school learning units consist of theoretical and experimental approaches to one big idea of Nanoscience [3] at a time. Both science concepts as well as commercial products are examined throughout the course. The major topics of the course are Forces and Interactions (via surface tension and surfactants), Tools and Instrumentation (via DNA electrophoresis and Atomic Force Microscopy) and Size-Dependent Properties (via thin films).

A co-operation between the scientists in the Nanoscience Center in Jyväskylä and the physics teacher trainees was a starting point for this course. The teacher trainees have designed the learning units from ideas and discussions on Nanoscale topics, using educational reconstruction [4] to define meaningful and precise learning goals for each unit. In doing this, they received assistance from the scientists. This design procedure was developed for our pilot course in 2007 and is now implemented for the second time. The new course takes place in May 2010 in the Training School in Jyväskylä. We present an overview of the course and one of the learning units as a case in educational reconstruction in physics teacher training as well as a school inquiry.


Do external forces act on electrical toy car, if it moves uniformly and rectilinearly on a horizontal surface?

Elementary physics deals with very simplified and idealized models; therefore sometimes it seems that it is incapable of explaining and describing the processes and phenomena that take place in the environment. A careful observation and analysis of the functioning of the surrounding objects, such as, for example, simple kids’ toys, shows discrepancy between the observations and the theoretical knowledge, which is studied in physics lessons.

In the present work we address paradox properties of electrical toy cars, and demonstrate how these can be applied on laboratory lessons for studying mechanics and electrodynamics.

The main goals of our work were:

1) Searching ways to apply Socrates’ methods on teaching physics by asking paradoxical questions and then analyze the questions raised in the classroom;

2) Expanding possibilities of the elementary physics in order to teach not only solving routine problems, but also understanding physical phenomena around us.

We focus in particular on the apparent contradiction with the Conservation Momentum Principle. The experiment shows that the velocity of a moving little electrical car doesn’t change when a same-mass car is put on it. This is in contradiction to our expectations of the velocity to decrease half its value, according to the Momentum Conservation Principle.

In the present work we also discuss the question of the reasons for a car motion: the work of motor or the presence of the road. It is known that a car moves if its motor works. If it moves with a constant velocity, then external forces, according to the First Newton’s Law, don’t influence its motion and the air resistance can be considered neg-
ligible. But why is it that if the motor switches off, the car quickly stops? If we hold a rope, connected to the back part of the working car, the car does not move, but its wheels spin and slide. The car begins to move if we release the rope. A mystery force seems to influence its motion. In order to measure this force, we need to connect the back part of the car to an end of a calibrated elastic spring. As analysis shows, the «mystery» force is actually the sliding friction force between the wheels and the road. If we measure this force, we can determine the friction coefficient. This idea was used for the laboratory work, in which the sliding friction force is measured by a calibrated spring.

The measurement of a car velocity shows that it doesn’t change during the period of the car’s motion. The car velocity permanency should be due to the electromagnetic properties of its motor. According to the Faraday’s Induction Law and the Lentz’s Rule, the magnetic friction influences the armature rotation in an electrical motor. Just the magnetic friction which depends on thy car velocity represents the main reason for the car stable motion. The acceleration time is so short that it’s necessary to use very sensitive devices in order to detect one. However, it is possible to estimate the acceleration time indirectly, by investigation the car velocity dependence on external loading.

Our students implement these experiments with great enthusiasm. Queries proved efficiency of this lab and high motivation of the students.
Applying the first law of thermodynamics in a multi-phased process in university – What is the problem?

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This research focuses on analyzing the problems that university students faced when trying to solve a qualitative problem related to a multi-phased process of an ideal gas after an instruction had taken place. The data was collected during the introductory courses of thermal physics in the University of Eastern Finland in 2008, 2009, and 2010. The courses were designed to get performed during first or second year studies. Overall the sample consisted of one hundred students. The students participated in a test when required processes, laws, and models had been covered in lectures and exercises.

To probe students’ conceptual understanding we used the diagnostic test designed by David Meltzer. For success in the test one should understand the first law of thermodynamics, to recognize and understand isothermal, isobaric, and isochoric processes, and to understand microscopic explanations and interdependences for certain quantities. The context was an ideal gas in a piston-cylinder system.

Our results show that the students faced several kinds of problems related to concepts of heat and work. Especially determining the signs of these quantities in a cyclic process seemed to be difficult for the students, when only a few students were able to perform this adequately though the required processes with interpreting pV diagrams had been introduced during lectures and practiced in exercises. Some students also had problems to differentiate these concepts, and sometimes “heating” was referred as doing work. It was also observed that some students did not understand the role of work in changing the internal energy of the system. The students had a number of other difficulties as well. Some students did not understand how internal energy is related to the kinetic energy of particles or to temperature. Other finding was students’ tendency to give erroneous dependencies between quantities. Few students also confused adiabatic and isothermal processes.

These results are in an agreement with earlier findings reported in research articles. Especially the problems with the concepts of heat and work have been reported earlier, and this research indicates that same problems are global, if not universal, in nature. Almost total lack of the use of graphical presentations, like pV diagrams, was a minor surprise considering that the use and interpretation of those was emphasized strongly in teaching. In addition, students’ incapability to interpret the magnitudes of work and heat in a cyclic process was somewhat unexpected considering the emphasis and number of examples that it was given in the teaching.

Besides the concern and surprises, the results gave us some ideas what we should do differently to improve students’ learning outcomes in the future. We present that the use of graphical representations should be varied more, and students should produce more
graphs instead of just interpreting them, so that they would develop better understanding of the usefulness of different representations. This should help students to produce graphs spontaneously. Specially designed problems that challenge students to interpret phenomena with and without graphical presentations would also be helpful. Tasks and examples making an unambiguous distinction between heat and work would be useful when pursuing the deeper understanding of the first law. For a teacher the first step to improve students’ learning is to become conscious of these kinds of problems and to critically evaluate one’s own teaching practices.

School Inquiries based on Soft Elastomer Lithography

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We have used polydimethylsiloxane (PDMS) and also tested some other polymers as a material for a set of school science inquiries based on soft lithography. In soft lithography, polymers such as PDMS, polyurethane (PU), polypropylene (PP), polystyrene (PS), polyimide (PI), or the electrically conductive polyaniline (PA) are used instead of conventional rigid photo masks for lithography. These may be used as stamps, molds or masks to generate mesoscopic patterns and structures for small devices. The advantages of soft lithography over traditional photolithography make it ideal in the boundary conditions of school science. Soft lithography does not require expensive cleanroom processes or instruments; a standard school laboratory is enough. The materials to be processed can be chosen for safety and cost. Soft lithography allows for threedimensional structures on three-dimensional substrates with a large variety of materials with interesting chemical, biological and physical properties to study at school.

PDMS, as an example, is a two-component elastic and transparent mouldable polymer which is widely used for biomedical micro- and nanoapplications, as it is a biocompatible and flexible material that can adapt itself into chemically and geometrically challenging organic environments like human body [1]. The technological applications range from microcapillary channels, pumps and valves to electrophoresis, micro reactors and integrated lab-on-chips [2].

We took advantage of the mouldability and optical properties of PDMS in designing three school inquiries. First, we fabricated elastic replicas of a commercial optical grating with 1000 slits/mm. If the elastic replica is stretched parallel or perpendicular to these grooves, the spacing between them i.e. the grating constant decreases or increases respectively. The elastic gratings may be used as dynamometers, pressure gauges or strain gauges. The second inquiry we demonstrate is an elastic lens. It is a water-filled circular PDMS pocket whose curve radius and focal length can be adjusted by changing the water pressure inside the pocket. Personally adjustable eyeglasses are an application for this. The third inquiry uses PDMS as a stamp to fabricate physically, chemically and
biologically controlled active patterns on a substrate. Electrical components, etching masks and cell cultivation pads are examples of these.


Peer Learning tutorials to improve trainee primary school teachers’ conceptual understanding in physics.

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The aims of this project were to assess undergraduate trainee primary school teachers’ scientific knowledge and cognition of key concepts in science and the design, implementation and evaluation of a Conceptual Physics Course utilising Peer Learning for trainee primary school teachers with the aim of improving their conceptual understanding of physics. The Conceptual Physics Course was run for four weeks (1 tutorial a week) during the autumn semester of the academic year 2009/2010, examining four physics topics (electricity, heat, light, density) which are part of the Primary Science Syllabus in Ireland. The course was run on a voluntary basis outside of regular college hours, numbers attending the sessions on average were N ≈ 20. Peer Learning is a teaching and learning strategy that involves groups of students working together it promotes critical thinking through discussion, clarification of ideas and evaluation of others’ ideas, with the teacher as a facilitator of learning [1, 2]. Each member of a team is responsible not only for learning what is taught but also for helping team mates learn, thus creating an atmosphere of achievement [3]. Students work through the assignment until all group members successfully understand and complete it [3]. In this study the term Peer Learning is used to represent a two-way, reciprocal learning experience where the students learn from each other and the authors acted as the facilitators of their learning [4].

The Conceptual Physics Course was evaluated through an examination of the trainee teachers’ conceptual understanding and their attitude towards physics. The authors developed conceptual understanding tests. The tests were administered pre and post every
tutorial session. The trainee teachers’ were asked to answer the conceptual questions and rank on a scale from 1 to 5 how confident they were with their answer, with 1 being not confident and 5 being most confident. A questionnaire was administered pre and post to the entire group of trainee teachers (N = 132), it asked questions on how confident they were in teaching science, what their view of science was and on their attitude towards science in general. Qualitative data reports the trainee primary teachers’ attitude and confidence in teaching science to young children. Quantitative data reports the trainee teachers’ responses to conceptual tests. The findings reported are initial investigation in this area and the research is ongoing.


An innovative context- and inquiry-based teaching-learning strategy aiming at a versatile concept of energy

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Problem definition

Curriculum innovation committees for the exact sciences in the Netherlands have chosen a context-based approach to education. Several representatives of international context-based education innovation projects (e.g. Chemie im Kontext, Germany) name transfer from one context to another as a problem on which there is insufficient research data (Parchmann et al., 2006). Besides that, students’ ideas in current (non-context based) education on energy are diagnosed as inflexible in formal examination tasks (Borsboom et al., 2008). Therefore it is worthwhile to investigate how students can develop a versatile concept of energy in a context-based approach.

To model the development of a student’s concept we propose a subdivision of versatility into three levels, building on the difference between assimilation and accommodation (Duit, 2002):

I. A life-world concept of energy,
II. A concept that can assimilate very diverse situations,

III. A concept that may be exchanged for a new concept when new experiences make this profitable.

We will investigate an expected further subdivision of level II.

Research question

Our main research question addresses the changes in interaction between context and concept during the development of the various levels of versatility: How can we design the changing relationship between context and concept during the development of a versatile concept of energy in secondary school students?

Method and results

To investigate transfer we will use the model of actor-oriented transfer (Lobato, 2006) in which students’ concepts occupy a central position. For the first round of research we designed a context-based teaching plan aiming mostly at achieving stages of versatility level II. Careful considerations have been made in choosing contexts (Gilbert, 2006), creating inquiries that make use of bridging analogies (Brown, 1993; Clement, 1993) to help achieve versatility level II, and being able to observe the various stages in the learning cycle of our students from the perspective of actor-oriented transfer. This design is tested with 16-year-olds in school year 2009-2010.

In our paper we will present a discussion of our design, our classification of the various levels and sublevels of versatility, our measuring instruments, and our findings of students achieving the various stages of versatility level II.


Keywords:

energy, versatility, context, design research, teaching design, bridging analogies, actor oriented transfer
Addition table of colors: the additive and subtractive mixture in a single mathematical model

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The color phenomenon is one of the most sensitive subjects in optics teaching for young children. This is related to the fact that students possess a system of beliefs and intuitions derived from personal everyday experiences that leads to the construction of a common sense theory often incompatible with scientific laws.

According to most studies, these misconceptions result from students’ experiences with gouache, watercolor and colored pencils. For students, «adding» a light is the same as painting. Moreover, most color mixing commercially available (such as color paddles) or the traditional color wheel are not supported by the physical principles. Even in the teaching practice on this subject, classic “circular” representations of additive and subtractive mixture are rather usual, and, according to Laurence Viennot, lead to students’ confusion, as a result of using essentially identical representations of substantially different operations.

International studies tended to reach to similar conclusions: these common sense beliefs are very stable and conventional physics instruction does little to change them. Curiously, there is a consensus among experts who agree with the fact that the teaching of color requires a detailed comparative analysis and synthesis of the additive and subtractive mixture.

A mental model, based on the concept of color perception as the outcome of the responses of three types of cones, was designed to introduce students the additive and subtractive mixture as a single model. An Addition Table of Colors (ATC) is a mathematical representation which generalizes the laws related to the perception of color and allows the students grasp the difference between these two types of mixture, and overcome their misconceptions related to this subject.

Broadly speaking, the ATC is based on a single representation, by which students build equations for color combinations, by attributing the plus signal (+) when they have body lights and the minus signal (-) in the case of filters or objects, i.e., when light is absorbed. In all the terms of the equation we only use primary colors (red, blue and green) just like the human optical system.

The ATC was part of a colour module developed for two lectures and one practical class for the 8th grade children. The analysis of previous studies and the science of the color phenomenon provided the outline of the main objectives of the module: to allow students to relate the perceived color with the properties of the object, the incident light, and with our physiological system, leading to deeper understanding about the additive and subtractive mixture.
The lectures, the laboratory activities and the teaching materials were carefully prepared with rigorous content and skill objectives in order to develop relevant physical concepts and scientific reasoning skills. The module, based in ATC, combined this approach with teacher training and was implemented in an experimental group with, approximately, 200 schoolchildren.

In the control group (with also 200 students), the color phenomenon was taught as usual, with the goals set by the teachers, without any intervention of the project. The two groups of students were compared in terms of content knowledge acquired in the learning of this subject through comparison and analysis of their pre- and post-tests.

5http://amasci.com/miscon/opphys.html

From linear text to hypertext in Physics educational documents

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Internet and e-learning have a great potential in Science education. We wonder to which extent and under which conditions the web environments learning can be optimized in order to get higher educational value. That’s why we carried out the AFINET’s project (Aprendizaje de la Física a través de Internet) intended, analyzing the hypertext characteristics (i. e., organisation based on nodes and links), to explore how Physics can be learned by means of Internet. Moreover, this project deals with the processes involved in the transformation of traditional educational texts into educational hypertext.

We assume that there are some qualitative differences between linear texts and hypertexts, such as the non-linear reading sequences, the multimodal languages and the active role of the learner. Besides, we assume that there are a set of favourable arguments to study these qualitative differences to improve hypertext designs as educational tools. Then, it’s necessary to bear in mind all these arguments when designing web environments, especially when deciding how contents have to be organized and presented, and how the language modes have to be used and combined.

We began a study about Hypertextual documents from a socioconstructivist perspective and we tried to gather different orientations about their design. Later, we made an analysis of how several educational webs of Physics are designed, choosing web pages elaborated in different countries and for different educational levels. From these tasks,
we obtained some results to be applied in the elaboration of “good practices” about online teaching and learning specific contents in Physics. An itinerary for converting a linear text to hypertext and some rules for the design of web pages for Physics courses will be presented in the conference. An example of itinerary to transform a linear course about energy for secondary school students into hypertext material will also be shown.


Redesigning a hypertextual course about Acoustics

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When one decides to design on-line educational materials, he have to bear in mind multiple dimensions, such as the non-linearity of the hypertext, the use of embedded multimedia languages and the interactivity between learners and educational tools. The Internet and the Information and Communication Technologies provide a challenge to develop all these dimensions in order to enhance web-based learning. The AFINET project (Learning of Physics through the Internet) is intended to know which transformations of a classic linear text on Physics education need to be done to develop hypertextual materials.

This type of transformations have been applied to some educational material about Acoustics, taking into account the synergy and coordination between a Physics Education research group and another one expert at designing web-pages.

- Firstly, these transformations are based on the nature of the selected topic. That’s why we began analyzing the interrelations between ideas and concepts on Acoustics, in order to propose a hierarchical organisation of concepts. This organisation is represented by a conceptual map and it is intended to substitute the classical way to show the contents by means of a content table. Some of the associated problems will be presented.
- On the other hand, some of the proposed transformations are related to the pedagogical approach intended for the online educational material. For instance, the linking propositions among topics were rephrased as questions in order to provide students with more meaningful links between ideas. We will show the discussion about these questions, which have been designed to allow students a deeper understanding of their navigation.

The main students’ reactions to an online course on Acoustics, which is not designed according to an index model but to a concept map model and which is not sequenced so that any student can choose a different navigation way, will be presented.


**Augmented Reality Games in high-school education.**

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The anticipated lack of science-educated people has been exposed in newspaper headlines, TV-discussion programs and more elaborated sources as a European Commission-report (EU, 2004) entitled “Europe needs more scientists”. It reports of the falling recruitment of students in science at upper secondary and higher levels. The report holds all parts of the education system responsible for young people’s lack of interest in science and thereby not choosing a career in a science-related area. The same tendencies are noted in the US (National Academy of Sciences 2006; NCEE 2007; PKAL 2007a; US NSB 2007). Result from the ROSE-project (Schreiner&Sjöberg, 2006) indicate that although both boys and girls in developed countries think that science and technology are important for society only some boys and very few of the girls can see themselves working with S&T related jobs. In *Science Education NOW* (EU, 2007) and *Science Education in Europe: Critical Reflections* (Dillon & Osborne, 2008) the authors targets the way science is taught as the main factor behind the declining interest in science studies. They criticize the pedagogy in school science and claim that it is dominated by a conduit metaphor where knowledge is transferred to the students without any discussion. Research shows that this static way of work is one reason why students, and particularly female students, choose to leave science subjects when they can.
One suggestion to turn this ongoing trend is to introduce educational games in science education (Shaffer, Squire, Halverson, & Gee, 2005; Squire, 2006; Shaffer, 2006; Foster, 2008; Barab et al, 2009). Carefully designed games have potential to engage students in “real-science” work where they can be active participants in meaningful and situated learning processes. In my research I have designed a game concerning a Socio-Scientific Issue (SSI). Sadler (2009) distinguishes between professional science and school science in describing SSI and propose a way in between where parts of the two intertwine in a real-world problem with a surplus of open-ended questions that engage and situate learners in a comprehensible context. I use a gaming platform called Augmented Reality games (AR-games) developed at the Teacher Education Program, Massachusetts Institute of Technology by Eric Klopfer et.al. (Squire & Klopfer, 2007, 2008; Rosenbaum, Klopfer, & Perry, 2007). The games are played on GPS-sensitive mobile phones and the game area is in students’ normal environment outside their school. The issue at stake is electromagnetic radiation, it’s propagation and the risks concerning public health. Students take on five different roles, journalist, project leader from the power company, municipal environmental technician, engineer from the national radiation authority and chairman of the student organization. In each role three students collaborate and move around in the game area collecting information by real and virtual interviews and virtual measurements. The information is used in a following debate where the different roles argue for their standpoint in the game. My research concerns the students’ experiences and impressions playing such a game. In a first paper I’m right now processing data collected by a questionnaire and by interviews to answer the following research questions.

- To what extent do the students inhabit their roles?
- In what way was the students challenged by the question at issue?
- How did the students perceive the impact of the outdoor-part of the game?
- Which different sources of information were used during the game?
- What kind of social activity did the game encourage within the different roles?

Preliminary results indicate active participation and engaged players in the game.

**Computer assisted kit-like modelling of physical systems**

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It has been well recognized that developing student skills in modelling – the major process of solving scientific and engineering problems – should become the major objective of physics teaching. The paper presents an approach to systematic modelling of physical system behave-our by multipole diagrams portraying energetic interactions between the system parts. The diagram topological configurations are isomorphic with
the geometric configuration of the modelled real systems. This allows for setting up the diagrams in a kit-like way based on the mere inspection of real systems without any equation manipulation. Only a very small set of elementary multipoles is sufficient to represent ‘pure’ physical phenomena like energy accumulation or dissipation. Multipole models of more complex phenomena or system parts are built from the elementary multipoles in a hierarchical way. This approach can be applied in a unified way to multidisciplinary systems in which phenomena from different physical domains take place simultaneously.

In the physics course, students are engaged in constructing models of physical systems in the form of multipole diagrams to describe, explain, and predict the system behaviour. This activity requires from them self-dependent reasoning and reflection. They start with constructing a qualitative (conceptual or mental) model in the form of a multipole diagram, which they convert into the quantitative (mathematical) model by specifying values of the multipole parameters. Students then verify the validity of their model by comparing its responses with those gained from experiments, or from computer-assisted analysis (simulation) of their model. In the latter case, they use the software system DYNAST, which is capable of not only solving equations, but also of formulating them automatically for multipole diagrams submitted in a graphical form. The model responses can be plotted in different forms, and they can be also used for animating geometric pictures of the modelled systems.

Students can thus fully concentrate on the physical aspects of system behaviour without being distracted (and restricted) by the intricacies of equation formulation and submission to the computer. This is not to say, however, that students should not learn how to formulate equations at all. Even there DYNAST can help them, as it allows them to submit their equations in the natural textual form (in the contrary to programs requiring conversion of equations into a block diagram). After solving their equations, students can compare the results with those obtained by analysing the related multipole diagram. In any case, the multipole modelling approach allows students to investigate far more realistic and interesting systems than the ‘textbook’ systems treated in traditional physics courses. The approach even allows for curriculum inversion in the sense that students investigate first behaviour of animated simple real-life systems, and then only – after being motivated – they learn theory and do modelling of the systems.

The author’s full course on multipole modelling is at http://virtual.cvut.cz/dynlab-course/. 
Using Facebook and YouTube in an Introductory Project-Based Physics for Architects Course

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Although the majority of students in the introductory physics courses are not future physicists or engineers, a significant number of physics courses are still designed having future physicists in mind. Too often the range of topics and employed pedagogy do not reflect students’ interests, aspirations as well as their preferred ways of learning. This creates an unproductive and sometimes threatening physics learning environment for the students and for the teacher. What if a large introductory physics course (140+ students) was designed having in mind smart and talented students, who are not physics majors, but future architects? Moreover, what if one of the main aims of the course was to help the students connect physics to their future profession and everyday life? The Physics for Architects Course at Ryerson University is just that. The course has four goals:

(a) to help future architects and building science students to understand basic physics principles relevant to architecture;
(b) to teach the students how to communicate these principles to scientists, engineers as well as the general public;
(c) to help the students gain confidence in their ability to understand physics concepts, and
(d) to provide the students with the opportunity to appreciate the beauty of physics and its applications to everyday life and architecture.

Course topics included elements of structural loads, vibrations and resonance, heat transfer, moisture in the air, water propagation through various media, optics and acoustics as applied to architectural design. The course culminated with a semester long group project: a physics demonstration exhibit (PARADE – Physics at Ryerson Architecture Demo Exhibit) that showcased student-designed “physics in architecture” projects. During the first two years of the course, the PARADE was presented to the entire faculty of Engineering, Architecture and Science and the general public. In addition, the photographs taken during the project were uploaded on Facebook and shared with the students, their friends and the larger community. During the third year of PARADE implementation, the students were also asked to create short (up to 10 minutes) video clips showcasing their projects and explaining the physics ideas behind them. Consequently the students uploaded their video clips on YouTube (http://blogs.ubc.ca/mmilner/students-projects/) and were able to watch each other’s projects and provide peer feedback and project evaluation. As a result, the students could take their projects outside of the classroom walls and share the projects with the larger community.
We will report on the results of a 3-year long implementation of the PARADE Project and discuss the challenges and benefits of the technology-enhanced project-based instruction in a large introductory physics course for non-physics majors.

Four Developmental Stages for Cultivating Interdisciplinary Scientists and Engineers II
– Correlation between the Analytical Abilities and Logical Presentation Skills–

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It is important to design and implement a suitable education program for cultivating quality graduates, who can evolve into interdisciplinary scientists and engineers. In the previous report at ICPE2009 [1], we described an undergraduate course named as “SAIL” in our faculty. This four-year consistent curriculum is based on four developmental stages of (1) Study, (2) Analysis, (3) Innovative design and (4) Logical presentation.

We opened introductory courses to develop analytical abilities (Study/Analysis) to deduce conclusion from objective data, and project-based learning courses to enhance design abilities (Innovative design) to identify any problem and to discover its solution from nothing. A course for poster sessions were also offered so as to experience intensive discussion with teachers and classmates (Logical presentation). Our main interest is consistency of the whole curriculum. The program was started four years ago, and it is appropriate for the occasion to evaluate the achievements of our developmental steps.

In the present study, average scores (GPA: grade point average) of the three courses on introductory physics in the first grade were compared with scores of the oral examination for graduate-school admission in the fourth grade. The average score of the introductory courses provides an indication of analytical abilities for each student, which is at the second stage in our educational steps. On the other hand, the score of the oral examination offers a direct measure of logical presentation skills at the final step of our developmental stages.

A correlation between the GPA of the introductory courses and the oral examination score was found to be good enough with a correlation coefficient of 0.56. A GPA of major courses was also strongly correlated with the GPA of the introductory courses, and the correlation coefficient was 0.66.
This results shows that the logical presentation skills are based on the analytical abilities. In our introductory courses, we make lecture demonstrations for teaching a procedure to quantify the physical principle and to deduce basic laws. The power of analysis and deduction is fundamental for communication capabilities in responding quickly to others and getting to the point of the arguments. The effectiveness of our introductory courses is verified by the strong correlation with good achievement at the graduate-school admission.

In conclusion, we validated the consistency of four developmental stages set for an undergraduate curriculum in our faculty. Our proposed educational concept, SAIL, is expected to be a model system for physics education.


Science Education TV by Internet: the use of video in teaching Physics

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In the recent years we can see a huge presence of free television programs by Internet, where we can find several interesting topics available all the time. Unfortunately, most of the material is related with entertainment and general topics. In this work we show our advancements on the development of a Science Education TV channel by Internet in order to provide a wide quantity of free educational resources for teachers and students. The website is presented in three languages: English, Portuguese and Spanish. The project is supported by six universities from Argentina, Brazil, Colombia, Cuba, Mexico and Venezuela. We start our stock with videos of Physics for Classical Mechanics Laboratory. All the materials are free of cost; even the Mexican government has given a lot of educational and scientific videos from the “Videoteca Educativa de las Americas”, and the complete series of secondary school courses. Some computational tools are incorporated in the video edition like flash animation and graphical analysis with the aim of promoting research on Science Education. We share and discuss results of this project on Science Education TV in the higher education and High School level too. The great potential of the Information and Communication Technologies applied to
free television in the web, also can be used for training Physics teachers, in this way we present a Colombian Physics training program. Finally, we established the methodology for good quality, rigor, didactic and peer evaluation process of the videos and TV programs in the context of a journal television on teaching sciences.

Collecting, organizing, representing and interpreting values of measurement in elementary school

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The concept of measurement is fundamental in science education, as it is for science in general. In order to be meaningful, the value of a measurement must be given with a certain level of uncertainty. In France, official instructions for elementary school thus argue for having students do activities of measurement, followed by treatments and analysis of the data obtained during these activities. The notion of measurement «uncertainty» appears in 4th and 5th grades. A similar approach is proposed in other countries, for example in the NCTM standards in the United States.

However, excepted the work of Petrosino, Lehrer & Schaulbe, most of the researches on students’ difficulties about measurement uncertainty concerns older pupils. In this paper we try to identify and to develop the reasoning of young French pupils about measurement variability: how do pupils reason about data collection before instruction? Can we lead them to understand the advantage of repeating measurement? Are they able to elaborate and interpret frequency table and bar graph to represent the results of several measures of the same quantity? Can they acquire the notions of mode and confidence interval?

We present a teaching sequence divided into two parts: the first part included seven one-hour sessions in grade 4, the second one three sessions in grade 5, the following year, with the same students. The main sources of data were field notes, videotapes, as well as the intermediate written traces produced, and individual written tests given each year. We also administered a clinical interview designed to probe student reasoning more extensively.

We show that this sequence enabled the pupils to be aware of the necessity of repeating measurement and that each of the values of measurement provide some information. Concerning organization and interpretation of the data, we notice that at the end of the sequence most of the pupils were able to build a frequency table and a bar graph from a list of N measures of the same quantity. When they interpreted such a graph, most of the pupils took into account the measures of the whole class, either by giving the mode or by giving an interval. Moreover some of them were able to argue in terms of confidence interval, by making use of a correct qualitative statistical reasoning.
Scientists computation methods and tools are essential components for the development of knowledge in physics. However, the balance that exists in modern research between theoretical aspects, experimentation and computation is not yet generally reflected in the high school and undergraduate university physics curricula and practices. Indeed, in most introductory physics courses, the use of computational knowledge and technologies is limited to the display of text, images and simulations, or to a supporting role in data acquisition and analysis. Consequently, these curricula are outdated and do not appeal to a large number of students, which feel that what they are learning is disconnected from what they perceive to be relevant for their future real world professional activities. To change this situation, it is important to develop introductory physics curricula and supporting learning resources which include computational modelling activities and can be implemented in research inspired learning environments where theory, experimentation and computation are effectively balanced [1-6]. In this paper, we report on a set of learning activities built around exploratory and expressive computational modelling experiments with Modellus which were implemented in the introductory biophysics course taken by first year biomedical engineering students at the Faculty of Sciences and Technology of the New Lisbon University. The activities were presented...
in a new type of digital documents which used interactive text, images and embedded movies to explain fundamental concepts and problem solving processes, and contained free document space for students to register answers, comments or searches using text and images. We describe examples of computational modelling problems selected from activities about the motion of living beings, equilibrium and stability which were designed to focus the modelling cycle on the exploration of multiple representations of mathematical models and on the interaction between analytical, graphical and numerical solutions. We also discuss the effective impact of these computer based modelling activities on the learning process of key physical and mathematical concepts relevant for the biophysics course.


Mathematical theory of peer-instruction dynamics

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Recently, there have been a growing interest in constructing mathematical teaching-learning models [1,2]. In this report we show a mathematical theory of Peer Instruction (PI). In contrast to the previous theories that describe long-term learning gain [1,2], our theory describes rather a short-time period of learning due to PI. However, our main result turns out to coincide with the constructivist-view model proposed by Pritchard et al. [2].
We introduce number densities of students answering correctly before and after discussion. Naturally, the number densities depend on many variables such as the contents of posed ConcepTest [3], student parameters (such as education, rhetorical abilities, personal skills, etc.), the strength of psychological coupling with neighbors, etc. However, here we consider only variables related with posed ConcepTest. Then, we may construct a “master equation” of PI for a ConcepTest which describes the change of students’ answers before and after discussion. By denoting the normalized number of students choosing the answer $a$ for posed ConcepTest $q$ before discussion and after discussion as $\rho_1(q;a)$ and $\rho_2(q;a)$, respectively, the master equation may be given by

$$\rho_2(q;c) = \rho_1(q;c) - \sum_{d(\neq c)} T_{dc}(q) \rho_1(q;c) + \sum_{d(\neq c)} T_{cd}(q) \rho_1(q;d).$$

(1)

The second term of the r.h.s. of Eq. (1) represents the “outgoing processes” in which students who polled the correct answer before discussion change their responses to incorrect answers after discussion. The third term represents the “incoming processes” in which students who polled incorrect answers change their responses to the correct answer after discussion. $T_{ab}(q)$ represents the “transition rate” of students’ answers from $a$ to $b$. In principle, such a transition rate is a function of student parameters, student-student relationship, contents of posed ConcepTest, and many other factors. It should be noted that all parameters and functions in Eq. (1) can be determined from PI data obtained easily by using “clickers”.

After employing some approximations we have found that the number of students answering correctly after peer discussion is approximately described by a simple function of the number of students answering correctly before discussion. We have obtained overall agreements with data taken from university as well as high-school physics courses, which will be shown in detail at our presentation.


Sky Observation Like a Method of Physical Education

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Nowadays the teaching and the divulgation of Astronomy, suffer from a lack of attractiveness. Almost everybody agrees that the most effective approach to attract the general lay public or particularly, the students to the focus of Astronomy is the observation of the sky with the aid of telescopes or binoculars in order to present them objects in some special aesthetic appeal or particularity as a cluster of galaxies, a planet approaching, and more.

We apply an efficient teaching method of attractiveness, as measured continuously for more than two years, which has shown high efficacy. In this method we use legends and myths from various cultures about the constellations and their localizations in the sky. We include also the myths of the Brazilian indigenous, in an approach of Ethnoastronomy.

The objective of this study is to show the effectiveness of the method and some of their routines of teaching, preferably starting with legends involving a large number of clusters (comprising a large part of the sky observable in a given season), using the asterisk to the identification and after following to a constellation from which can be extracted the necessary information as the basis for the taught content.

This method was applied between very different cultural and social groups, especially with students ranging in age from 14 to 19 years from private primary and secondary schools, both public and private. We began to test the method in a regional scale (Brazilian Northeast) and after, we applied the program in a national scale, with those students who were selected to participate of the International Olympiad of Astronomy (OIA), by applying a didactic method directed to the spatial vision, in the case of observational astronomy applied by the Scientific Committee and Didactic (CCD) of the Brazilian Olympiad of Astronomy and Astronautics (OBA). The effectiveness of the method was demonstrated in two aspects that show the expansion of the way to increase interest in science: First, we could observe the ease of dissemination of general astronomical culture, by amateur astronomers to the lay public and heterogeneous (variants, such as social class, age and educational level, were taken into account). Second, the possibility that, after the use of this method is possible to introduce concepts from other areas of astronomy, such as Cosmology, Position Astronomy, Astrophysics, extragalactic astronomy, History of Astronomy (with emphasis on Archaeoastronomy), depending on the purpose to be achieved by the teacher or the amateur astronomer, to teach a class with this method.
Although the study of physics is related to various situations of our life and its growth has brought fundamental changes, leading to a transformation of society, most secondary school teachers of Brazilian schools have to face the challenges of teach a subject for which most students show lack of interest and great difficulty in learning. In their everyday classroom, the teachers often find some students, sometimes the majority, who are unable to understand the meaning of what is transmitted to them. In order to reach these students, the motivated teacher, tries different approaches, trying to make their lessons more interesting, but unfortunately, often not succeed in achieving minimally awaken the interest of their students. A great problem that teachers had to face in a recent past, was the lack of good textbooks of Physics. Many of the books adopted, especially in public schools were not of good quality. In general, the books were unattractive, with few illustrations, with content compressed into single volumes, most of them. Thus, the classes were essentially an eternal copy of the notes of the teacher,
among those few students interested in class.

The new collection of physics presented in this work introduces significant changes to teaching physics in high school. This book presents a clear break in the traditional way of teaching, while introducing major innovations, with the insertion of new multimedia technologies. In addition to developing the basic content of physics established for the school by the National Curriculum Parameters (PCN), this new collection seeks to relate the laws and physical phenomena in the everyday life and development of technological processes. Following the technological evolution of our society, in each chapter are presented a great deal of sites in the network, where students can obtain information on the various subjects, animations and simulations of the phenomena studied. One of the great innovations is the creation of the Modern Plus Portal, where the student can find texts on the history of Physics, as well as some commenting on important personalities of the same period, but related with different themes, such as Biology, Chemistry, and so on. Another activity on the Modern Plus Portal is the section Physics in Our World, that are special readings whose purpose is to show the close relationship of physics with the life and the daily life of the human being. In addition, the Portal Modern Plus presents to the students a lot of experiments, demonstrations of simple experiments that are designed to encourage the student to develop his own experiments, establishing a deeper relationship with physics.

This collection is being applied in some of large high schools of the city of Fortaleza, in the Northeast of Brazil. We are developing our project examining everything that concerns to the application of this new way of teaching. We visit schools, we have contact with the teachers and the students, in order to know fully the results of the students, their grades in the ratings and interest in the new technologies introduced in the teaching of physics in comparison with the traditional method of teaching. We hope to strengthen the students’ interest for Science in general and for Physics in particular.

ICT-based student conceptual understanding with real-time analysis tools

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We introduce ICT-based applications, offering students to shape their scientific concepts. Visualization of phenomena may be one of the solutions to overcome students’ naïve concepts. We have developed ICT-based various modules, such as video analysis with graphic software, usage of IT sensors, high resolution digital camera to visualize phenomena¹-³. Some modules are useful and effective enough to change students’ concept dramatically.

We present several new modules on Newton Mechanics, Electromagnetism, Waves and other topics to establish deeper understanding of students, e.g. conservation law of
momentum, charge and discharge of a dynamo-electric generator, an inducted electromotive force, a standing wave and so on. We also develop the equipment to lead conceptual understanding for velocity and acceleration as vectors in two dimension with the scattered 1 mm diameter glass beads on the acrylic board\textsuperscript{1,4}. According to Physics Education Research, even university students have difficulties to treat them as vectors\textsuperscript{5}. In our approach, we record moving objects on the frictionless glass beads and acrylic board by the high resolution digital camera, and analyze these videos afterward. Video analysis allows us to study two dimensional motion by marked the location of the moving objects sequentially. The software shows the locations, velocities and accelerations as data and graphs with a synchronized video. Once students have data, they are able to study beyond a classroom.

We will discuss some effective results of trial for students who will be science or physics teachers. Finally, we will discuss on some typical results of pre-test and post-test in our instructional approaches based on ICT, i.e. some evidence on improvements of physics education.


\textbf{How Pre-service Physics Teachers Interpret Static and Kinetic Friction: A Laboratory Experiment}

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The aim of this study is to explore pre-service physics teachers’ conceptual understanding and their reasoning underlying a physics topic. Friction was chosen as a concept since it is one of the key terms of physics. This concept is discussed broadly starting from elementary to university physics curricula, for this reason the full understanding of this concept is important. This study was conducted in a laboratory environment by setting up an inquiry experiment. Data were collected in an elective laboratory course
designed for pre-service physics teachers at Middle East Technical University (METU) in Turkey. Ten pre-service physics teachers enrolled to the laboratory course were included in this study as participants. At the beginning of the laboratory course, a brief pre-test was given to the pre-service physics teachers. The purpose of the pre-tests was to search their preconceptions about the friction forces (static and kinetic), net force and applied force, acceleration and Newton’s second law of motion. The inquiry process, in which probing questions were asked, was used in order to enhance pre-service physics teachers’ conceptual understanding and to involve them into the discussion in the laboratory. With these questions, the purpose was to encourage them to be more open in discussing their opinions during the laboratory session. Also, they were used for getting information more deeply and completely related to this concept. For this experiment, a worksheet was prepared by modifying the related topic from Physics by Inquiry (McDermott, 1996). Worksheet included two parts. In part one, we asked pre-service physics teachers to examine static and kinetic friction force for different types of sliding surfaces, different masses and different sides of the same object. They analyzed the factors which affect the friction force and distinguish static and kinetic friction forces. In the second part, they performed a basic Newton’s second law of motion experiment in which they observed the motion, took data, plotted graphs and interpreted them considering the friction forces. During the laboratory work, the pre-service physics teachers were required to evaluate the whole experimental process and interpret their findings. The laboratory session lasted for four hours with twenty-minutes of individual interviews with participants at the end of the course. The researchers’ role was a guide and data collector during the process. The entire process was video recorded for data analysis. In addition, pre-service physics teachers’ written works on the experiment were used for analyzing their conceptions on the topic. At the end of the work, feedback questionnaire was given to investigate pre-service physics teachers’ attitudes towards the experiments as well as its implementation. Qualitative analysis of data showed that pre-service physics teachers, even though they are capable of using equations related to static and kinetic friction, are lack of conceptual understanding on the topic. The results of the study also showed that, the participants of the study do not have difficulty in interpreting the factors effecting static and kinetic friction, but most of them have some problems in interpreting the graphs of applied force versus acceleration and net force versus acceleration. Pre-service physics teachers’ replies to the feedback questionnaire showed that they had positive attitude toward the instructional process. According to the results of the questionnaire, pre-service physics teachers found the topic in the instructional material interesting and at an appropriate level for their future high school students and for themselves. They also claimed that the experiments in the worksheet challenged them to re-think critically about their previous knowledge regarding the friction and these experiments helped them to come up with ideas that they had never thought before.

The purpose of this study was to compare the effect of experimenting with Physical Manipulatives (PM), Virtual Manipulatives (VM), and a blended combination of PM and VM, on undergraduate students’ understanding of scientific concepts in the domain of Light and Color. In the case of the blended combination the use of VM or PM was selected based on whether it provides an advantage/affordance that the other mode of experimentation cannot provide. These affordances of either VM or PM were identified through a literature review of the domain and a framework was developed upon which the blending of PM and VM was based. The study involved 70 undergraduate students enrolled in an introductory physics course that was based upon the Physics by Inquiry curriculum (McDermott and The Physics Education Group, 1996). A pre post comparison study design was used, in which the participants were assigned to one control group (CG=23 students) and two experimental groups (EG1=23 students, EG2=24 students). None of the participants had taken college physics prior to the study. The duration of the study was 13 weeks during which students met once a week for 1 hour and 30 minutes. The CG used PM to conduct the study’s experiments, whereas the EG1 used VM. The EG2 used a blended combination of PM and VM to conduct the same experiments. Conceptual tests were administered to assess students’ understanding before and after instruction. The data collected through the tests were analyzed both qualitatively and quantitatively. The quantitative data analysis involved (a) paired samples t-test for the comparison of the pre-test scores to the post-test scores of each test of each group, and (b) ANCOVA for the comparison of the post-test scores of each test across the study’s groups. The qualitative analysis focused on identifying and classifying students’ scientific and non scientific conceptions concerning the properties of light, shadows, pigments, and colored light. The analysis followed the procedures of open coding. Findings revealed that the use of the blended combination of VM and PM enhanced students’
understanding of concepts of light and color more than the use of PM or VM alone, which appear to support our argument about using a framework that blends PM and VM according to their affordances.

Teaching energy: Analysis of a research-based teaching sequence

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This research is focusing on the teaching and learning of the concept of energy. The aims of the study are to: (a) review the international literature on teaching and learning about the concept of energy, (b) identify the key teaching and learning challenges associated with the energy concept, (c) develop a research-based instructional sequence to address these teaching and learning challenges and, (d) implement and evaluate the instructional sequence.

The participants of the research are forty students in two intact classes of an urban high school of Limassol in Cyprus of age 15-16 year old. One class is designated an experimental group, the other a comparison group.

The instructional material for the experimental group is a reconstructed version of the Cyprus National Curriculum for Physics for Class A Lyceum. In particular, this is designed and developed according to research evidence-informed designing of science instruction interventions (Scott, Leach, Hind and Lewis, 2006). Furthermore, the reconstructed version includes: (a) The explicit instruction of energy as an abstract mathemat-
ical idea which can be stored, transferred, conserved and degraded, (b) The use of: (i) visual representations (SPT11-14, 2006, Lawrence, 2007), (ii) computer simulations, (iii) interactive teaching approaches based on the communicative approach (Mortimer and Scott, 2003).

Within the theoretical framework on which the development of this instructional sequence has been based, energy is related to four key aspects: it can be stored in energy stores, transferred along transfer pathways, conserved and, degraded. Furthermore, changes which are observed in a system, as a physical process takes place, can be described in terms of energy changes, involving the emptying of an energy store with the simultaneous filling of other stores, with energy being transferred along specific pathways. As energy is transferred from one store to others, its total amount remains the same (SPT11-14, 2006, Lawrence, 2007).

The transfer of energy within a system can be represented diagrammatically both qualitatively and quantitatively with a Sankey diagram. In the case of more complex systems, the course of energy can be represented with a Full Sequence Energy Diagram.

In analyzing the physical changes observed in a system, a sequence of four different kinds of descriptions can be used: the ‘problem statement’, the ‘physical description’, the ‘energy description’ and, the ‘mathematical description. Physical description refers to both a verbal and visual representation of the changes observed as these take place in a system in the natural world whereas energy description refers to a representation of these changes in terms of energy.

The use of both the physical and energy descriptions is well suited to overcoming the difficulties related to the teaching and conceptual understanding of the ideas of conservation and degradation. In particular, the same physical process has been simulated to take place under ideal and real conditions respectively. In the case of degradation, energy is illustrated to be transferred also along a heating pathway in energy stores found in the environment.

Data to evaluate the designed instructional sequence are collected through two research instruments: (a) questionnaires administered to the students prior to, during (short-length diagnostic probes only to students of experimental group) and after the experimental intervention; (b) interviews which are conducted with students and the teacher of experimental group. To avoid a possible influence of pretesting on the posttest scores (Cohen, Manion and Morrison, 2007, Slavin, 1984), the posttest includes an additional part with questions which refer to two unknown systems. Furthermore, data are collected through video recordings of the interventions.

Some preliminary findings revealed by the data analysis will be presented at the conference, focusing on the posttest results for the experimental and comparison group.
Empirical results from the evaluation of the effectiveness of an activity sequence about energy for the upper elementary grades

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Teaching and learning about energy has attracted much attention in the science education research literature, especially in the case of the elementary and middle school grades (e.g., Doménech et al., 2007; Driver & Millar, 1986; Kesidou & Duit, 1993; Nordine et al., 2006; Solomon, 1992). This seems to be directly related to the wide recognition of energy as an important objective of science teaching starting from the elementary school (AAAS, 1993), on the one hand, and the corresponding need for teaching simplifications that compromise the abstract nature of this construct and students’ need for a satisfactory qualitative definition, on the other. Traditional teaching approaches have failed to respond to this need in a productive manner. In an attempt to maintain consistency with how energy is understood in physics they tend to either provide abstract definitions or bypass the question “what is energy?”, which is vitally important to students. We suggest that shifting the discussion to an epistemological context provides a means to overcome the difficulties inherent in introducing energy as a physical quantity. We propose a teaching approach for the upper elementary and lower secondary grades, which introduces energy in the context of a theoretical framework that has been invented in order to facilitate the unified analysis of changes in physical systems, regardless of the domain they are drawn from. This framework is elaborated in a progressive manner through the introduction of the various properties of energy (i.e. transfer, form conversion, conservation and degradation). Each property is introduced in a manner that highlights its contribution to the explanatory power of the theoretical framework. The paper outlines the rationale underlying this teaching approach, provides an overview of the activity sequence and reports findings from its implementation in three intact sixth-grade classes. The results that have emerged from this implementation suggest that students’ interaction with the activity sequence helped them (a) develop improved ideas about the invented nature of energy, (b) appreciate the value of the theoretical framework of energy with respect to the unified analysis of changes in physical systems regardless of the domain they are drawn from and (c) develop the ability to apply the theoretical framework of energy to derive qualitative accounts for changes occurring in physical systems they had not analyzed before. In addition to this, the results indicated aspects of the activity sequence that could be usefully revised, so as to further increase its effectiveness. The paper concludes with a discussion of the implications for validating activity sequences and for teaching and learning about energy.

This paper pertains to a participatory process of design, development, and iterative refinement of a teaching module on the Electromagnetic Properties of Materials (EPM). The development of the EPM module combined principles from the inquiry-oriented teaching and learning framework, and learning through technological design in a way that sustained student interest for the extended time that was necessary to attain conceptual understanding of magnetic interactions and electromagnetic phenomena. Another anticipated learning outcome was the development of learners’ epistemological awareness regarding the interconnection and distinction between science and technology.

Following the tradition of design-based research, as our major goal was to improve the initial design by testing and revising conjectures as informed by ongoing analysis of both students’ reasoning and the learning environment, we aimed at (i) investigating the effectiveness of the design and implementation of the EPM module on promoting important learning objectives that relate to inquiry and EPM understanding, (ii) identifying possible flaws of the design and the way the module was implemented in practice, (iii) improving the initial design by replacing the parts of the design that are causing the flaws based on the findings and the lessons learned from the implementation, and (iv) enacting the revised version of the EPM module and investigating its impact on students’ learning.

Trial implementations of the module were carried out with two upper secondary classes in a school setting, two groups of 15-17 year old students who participated in summer science camps and two cohorts of pre-service teachers. From each of these groups
we collected data in the form of three types of student artifacts (constructed magnetic trains, posters and written reports) as well as pre- and post-test data from students’ written assessment tasks. After each cycle of implementation, we used the collected data and the feedback from the teachers in an iterative process for the refinement of the module. We analysed the data collected through phenomenography and artifact analysis. The analysis of the data collected revealed four types of the flaws that hampered students’ learning. The first type of flaw concerns difficulties related to the development of students’ conceptual understanding of several magnetism and electromagnetism concepts (e.g., a significant percentage of students expressed the idea that when a ferromagnetic object is placed into a magnetic field, it acquires magnetic properties, but no poles appear on its ends); the second type of flaw pertains to the difficulties on the transferability of concepts within the design and construction of the electromagnetic train model (e.g., students’ failure in understanding how different types of materials affect the magnetic field around a magnet had a negative impact on the construction of the electromagnetic train, since students failed to think of an efficient propulsion mechanism with the use of electromagnetic interactions); the third type of flaw relates to students’ understanding of the design process (e.g., students’ posters encompassed either surface descriptions or misunderstandings of the steps that are followed within the design process); and the fourth type of flaw encompasses difficulties concerning students’ epistemological awareness in relation to the distinction and interconnection of science and technology (e.g., students tended to differentiate between science and technology depending on whether they refer on natural or artificial entities).

In our presentation, we will elaborate in detail on each type of flaw, describe the types of modifications we made in addressing these flaws during redesigning our module and, present representative results to illustrate the impact of the modified module in helping students overcome the identified difficulties.

**Energy conversions in roller coasters**

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The interplay between potential and kinetic energy is characteristic of roller coasters and a common basis of textbook examples. In traditional roller coasters the initial energy is supplied by the chain pulling the train up the lift hill, while some recent “launched” roller coasters instead provide sufficient initial kinetic energy to take the train to the top of the first hill. The train then uses its initial energy to make its way around the hills and valleys, screws, loops and other elements of the track, until it enters the final brakes, which absorb the remaining energy. Although textbook roller coaster problems usually assume energy conservation, textbooks also reflect the real-life insight that energy losses do occur, and that the hills get lower and lower during the ride.
Energy considerations can be used to also for more detailed analyses, e.g. of the effect of the train length and differences in forces on the rider depending on the place in the train, as it moves over a hill or through a valley /1-3/. Students can compare theoretical analyses with real-life data, e.g. from accelerometers and frame-by-frame video analysis. Students can use their mobile phone stop watches to time the passage of the roller coaster train at selected parts of the track. In this way they can study energy losses during the ride and examine to what extent it is valid to neglect energy losses in the analysis of forces on the rider. Both the launch systems and the magnetic induction brakes of modern roller coasters offer many opportunities for physics investigations. Examples of student assignments, reports, difficulties and discussions concerning energy conversions will be presented.


Teaching the Postulates of Quantum Mechanics in High School: A Conceptual Approach Based on the Use of a Virtual Mach-Zehnder Interferometer

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This paper presents an instructional approach for the teaching of quantum mechanics in high school level. This approach is based on the canonical formulation of quantum theory in which six postulates play a central role. We shall propose a ‘translation’ from quantum formalism to an accessible language for high school students in which the postulates are presented on a conceptual-phenomenological basis. The quantum postulates are described in terms of concepts such state, superposition, observables, eigenvalues,
probability, collapse and time evolution. Mathematical formalism is avoided by using simulation software assistance. The strategy is focused on the use of a Virtual Mach-Zehnder Interferometer (Pereira et al 2009). The Mach-Zehnder Interferometer is assumed to be a powerful tool in the context of quantum physics teaching (Adams 1998, Scarani and Suarez 1998).

In quantum mechanics the ‘state’ represents a set of complete information about the physical system. The ‘observable’ (eg. momentum or energy), represents the measurable physical quantities of the system. All possible results of a measurement are defined as ‘eigenvalues’ of the observable being measured. The physical states associated with these eigenvalues are the ‘eigenstates’. They correspond to mutually exclusive alternatives. Incompatible observables such as position and momentum do not have a complete set of simultaneous eigenstate. A conceptual version of quantum postulates is formulated as the following.

**Rule 1**

*Before a measurement, a system is assumed to be in a superposition of state (a linear combination of its eigenstates).*

**Rule 2**

*A measurement usually changes the state of the observable being measured, unless the state is already in one of its eigenstates.*

**Rule 3**

*The result of a measurement yields one of the eigenstate of the observable being measured. The measurement process selects one of its eigenstate and rejects all the others.*

**Rule 4**

*The laws of quantum mechanics do not predict the result of a measurement but only the probability of the system for jumping in one of its eigenstate.*

**Rule 5**

*Repeated measurements of the same observable in succession yield the same result.*

**Rule 6**

*The state of a physical system changes with time.*

Many important statements of these postulates can be conceptually shown on the VMZI. In the fig. 1, single photons are shot into the interferometer, one at time. Two detectors are placed in each path in order to perform a measurement. After hitting the beam splitter, each photon can be thought as a combination of reflected and transmitted eigenstates. The detection forces the photons to collapse in one of its eigenstates (path 1 or path 2). Before the measurement we are unable to determinate which path the photon will take. We only can determinate the probability of finding the photon in one particular path.
A study of knowledge-based inferences in comprehension of physics problems.

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Problem solving is the main activity used to teach and evaluate in physics courses.  
Physics problem solving has been the subject of research for many years, but most of  
the results of those investigations have yet to reach the classroom. This work is part  
of a project that aims to construct a cognitive model of how students solve physics  
problems, in order to give directions in the design of teaching strategies to be applied in  
physics courses of different levels of the educational system.
Problem solving depends on the construction and manipulation of mental models (internal representations) in the mind. These mental representations of the problem can have different levels of abstraction, from the situation model, to the physical model (articulated in the form of laws and principles of physics), to the mathematical representation necessary to find the solution of the problem. The construction of such a cognitive model as the one mentioned before must take into account the complexity of these processes that occur during the resolution of a physics problem, which begins with the comprehension of the statement of the problem.

To understand the statement of a physics problem students activate their knowledge of the world and of the specific discipline and construct a situation model of what the text is about. To that end they generate knowledge-based inferences to complement the explicit information given in the text and construct a meaningful representation that is coherent and explains actions, events, and states mentioned in the text. Without this construction the text cannot be comprehended and the problem cannot be correctly solved. A strategy to improve comprehension in physics problem solving is to identify and justify those inferences.

The construction of mental representations also involves the generation of knowledge-based inferences. An inference is generated when information that is not explicitly present in the discourse (oral or written) is activated. It is also plausible to assume that inferences play an important part in the process of elaborating a model of the problem, due to the need to go from a natural language (in which the statement is written) to a more formal, abstract and specific language, such as the mathematical equations that express the physics laws and principles.

In this work, we briefly review the main perspectives concerning the generation of knowledge-based inferences during comprehension of a discourse and in reasoning. We also attempt the implementation of a preliminary instrument to study the construction of inferences in the context of solving a physics problem. To that end, we analyze the interviews made to a group of university physics professors, during which they solved a physics problem. The goal of this experiment was to identify and characterize the knowledge-based inferences made by the subjects in the process of solving the problem. These preliminary results are presented and discussed.

Curricula Innovations in Physics Education and the Didactic Contract

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Contemporary society increasingly lives side by side with the advances of science and technology, either through the consumption of scientific or technological products or
through the medium of communication. Paradoxically, schools do not seem to follow such developments and often offer outdated science education to their students. This in turn makes these students not view schools as a place capable of preparing them for today’s world; hence, compromising the adherence to the teaching project.

Many actions have been taken attempting to change that. In the 1960s several teaching projects aimed at restructuring the science curricula and also attempting to attract young people into the scientific and technical areas. However, some obstacles curtailed implementing such proposals. A major problem, especially in developing countries, was the training of teachers able to implement curricular innovations in the classroom. Davis (2003) points out that innovative programs and methodologies involve managing a variety of problems and taking risks. Research suggests that teachers are the most sensitive part of any curricular innovation, and need to adhere to such changes (Pintó, 2005). Thus, they must have the skills required to put them into practice. How to train teachers that are prepared for updates and curricular innovations, both in content and methodology?

This study presents a survey conducted with future Physics teachers studying at the University of São Paulo. We offered a range of innovative theoretical and methodological resources that could assist them in their teaching/learning activities. One of these features was the presentation of the Didactic Contract concept. Proposed by Brousseau (1986) in the mathematics teaching context, this concept allows understanding and analyzing the pedagogical practice with respect to the teacher - student - knowledge to teach mediation. These three elements maintain didactic relationship alive and cannot be viewed separately.

The activities with the future teachers were conducted in 2008 and 2009 and involved implementing the didactic sequences on the contents of Modern Physics under a supervised curricular internship. Reports were produced from the activities carried out which should contain reflections of a didactic methodology. The reports were analyzed by one of the researchers, extracting from them passages that could reveal reflections of the teaching mediation process. The results showed that many statements of the students indicated the need for changes in the school work routines. Some students reported detailed and well located changes, while others seemed to surmise deeper changes, such as defining new didactic contracts.

The conclusion of the results seems to indicate that one of the teacher’s didactical knowledge on innovative contexts is how to manage a set of reciprocal rules and obligations between teachers and students given the knowledge to be taught. Such rules and obligations make up the new didactic contract to be established, proving to be a teacher’s key skill in order to implement curricular innovations in the classroom.


Many of the objects that are part of today’s everyday life cannot be accessed directly by the senses. The bank statements viewed on ATM screens show the money in the bank. Friends may be under assumed names in social networking sites. Books, photos and music files are stored in hard drives. The virtual world is part of modern society as we know it, particularly young people. In particular, the entities defined by the theories and models of physics are also far from the senses. And these conceptual entities have a dual character: they establish a relationship with the empirical world and are a part of a hypothetical-deductive sophisticated network. (BUNGE, 1977). One of the objectives in teaching physics is to provide the means to conceive and deal with these entities found within the theories and models (OGBORN et al, 1996 and OGBORN. J.; MARTINS, L, 1996). Treating them as the same objects in day to day activities, or considering them as mere abstractions, could distort the physical information and may lead to learning problems when using such details outside the classroom (PIETROCOLA et al, 2001).

Thus, part of physics teaching requires changing the ontological attitude (FINE, 1986), in terms of conceiving objects and criteria that could justify its existence in the theory/model.

This paper presents an exploratory research that investigated the criteria used by physics undergraduate students to describe the realism of entities present in physical theories. The investigation used the data from a questionnaire answered by 33 last-year students in the Physics program from the University of São Paulo, Brazil. In this questionnaire, among other things, students indicated in a Likert scale the degree of reality they attributed to a list of entities, followed by a short explanation of their choices. The list of conceptual entities derives from the scientific domain and from others outside science. Categories of analysis were extracted from the justifications. 11 categories were defined from the results. They are related to the perception of the object, a subjective understanding or some characteristic assigned to it. These categories offer a way to understand some attributes used by students to define the reality of objects. The results of this
work will support a new phase of research that will cover a larger number of students.


Measurement in physics education research with the Rasch model

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As any other empirical scientific discipline physics education research needs to base its conclusions on the results of measurement. Researchers often attempt to measure student knowledge, understanding of concepts or student attitudes, entering in this way inevitably the realm of psychometrics, which is often regarded by physicists as an area in which it is difficult to achieve reliable measurements. Are there ways to bring measurement in physics education research closer to the standards of measurement in physics? The use of the stochastic Rasch model could be a step in that direction.

As a means of test analysis, Rasch measurement parallels physical measurement processes by being largely concerned with the construction of linear measures along specific, unidimensional constructs. It allows users to create an interval scale of scores for both the item and person measures. The first requirement is that the variable to be measured with a test is specified and described by a set of well chosen test items. The model assumes that the test is unidimensional, meaning that each item probes only the measured variable. The location of a person along the measured variable is described by a measure called person ability, which gives the information about the intensity of the measured variable that the person possesses. Items are described by another measure called item difficulty. Item difficulties and person abilities are calculated from raw test scores for items (from the number of correct answers to an item) and persons (from the number of correct answers given by a person) and expressed on logit scale. The construction of measures is usually performed by some Rasch model software such as Winsteps. Each item and person measure comes with its Rasch standard error which in-
Didactic Footnotes on $E = m \cdot c^2$

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Usually, when introducing the Special Relativity one begins by discussing the failure of the Michelson-Morley experiment. Einstein’s explanation was: The velocity of light in empty space is the same in all reference frames and is independent of the motion of the emitting body. This axiom turns Newtonian Mechanics into Einstein’s Special Relativity. Using this axiom, Einstein could prove the important theorem: The mass of a body and the energy of a body are just different words for the same physical quantity. The well-known formula for this theorem is:

$$E = m \cdot c^2$$

What happens when axiom and theorem change places? The sentence - mass and energy are the same physical quantity - is now the axiom which changes Newtonian Mechanics into Einstein’s Special Relativity and the sentence – the velocity of light in empty space is the same in all reference frames and is independent of the motion of the emitting body - becomes a theorem. For mathematicians such an exchange is not unusual. Doing so will open up new ways to teach modern physics.

As a teacher at a German High school the author has tried out this new way of teaching
several times and it has been shown that no difficult kinematic considerations are necessary to find fundamental conclusions of the Special Relativity Theory. In addition it has been shown that the Special Relativity could be introduced in a way that a schoolgirl or schoolboy at the age of 14 years could understand. After only a few lessons the pupils know

- why the mass is increasing while its velocity is increasing.
- why 1 mm³ of a magnetic field of a so-called magnetar is e few kilograms.
- what it means when we say, we gain energy in nuclear reactions.

**Difference of goals when implementing technical design in secondary science education**

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In secondary education, in order to get students well qualified for further education and training, increased emphasis is on teaching relevant technological and scientific skills (Abell & Lederman, 2007). A particular domain of skills that needs much more attention to be implemented in secondary education is technological design. In higher education, either in vocational or university education, designing in various technological domains is becoming an important skill as well. Moreover, teaching design within science and technology in secondary education might increasingly motivate students to become more involved in science and technology in higher education.

In the Netherlands, the last decades, some initiatives have been worked out to implement technological design in secondary school. These initiatives include implementation within the regular school subjects (De Beurs, 2000), as well as initiatives to start up new subjects like NLT or Research and Design (Appelhof, Bulte and Seller, 2008).

From a first evaluation of the implementation of the subject Research and Design (Appelhof et al, 2008), it seems that many people who are involved in the implementation of technical design have different goals when developing and / or implementing technical design in secondary school. This diversity in goals can negatively influence the success of such an implementation, and thus needs to be challenged (Penual et al, 2008).

**Research question**

This paper discusses the goals and ideas about usefulness of technical design as given by students, teachers, staff and educational designers, and their possible coherence (Penuel et al, 2008).

The discussed research questions will be:

1. What are essential characteristics of technical design skills?
2. What are the goals of students, teachers, staff and educational designers when implementing technical design?

3. What is the coherence among the goals of students, teachers, staff and educational designers and can they be related to goals as found in higher education and professional life?

4. Can goals as found above be found back in the results of technical design education?

Methodology
Starting point will be an analysis of technical design skills as found in higher vocational and academic education, as well as professional life. A comparison will be made with the learning goals as mentioned by different Dutch initiatives to implement technical design. Students, teachers, staff and educational designers will be tested and interviewed in order to get an insight in their goals. Products as well as process reports will be used to get an insight in the achieved goals in the technical design education. Design experts are needed for this evaluation of design processes and products.

Results and discussion
The paper will give an insight in the expected goals and skills learned by different initiatives to implement technical design. Practice shows a bad coherence between goals of different initiatives in the Netherlands, as well as between the different participants of the particular initiatives.


The Serious Games in the teaching-learning process in physics: What are they? What has been done? Where do they go?

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One of the most popular technologies today, and it is common for many people is video games, so we dare say that anyone living in an urban environment, at least once in their life played one, either for fun or to pass the time. This has led many developers and researchers in education are turned toward the media, for use in the teaching-learning process of science.

This paper aims to show primarily a discussion of the concepts of play, video games and serious games, given by different authors and developers, which results in the generation of three new definitions, the product of this analysis and intends to contribute to the study of the role for games in the process of teaching and learning of science and physics in particular ways.

It presents a chronological classification of serious games focused on teaching and learning of physics that have been developed from 2000 to 2009, as well as articles related to them. So that this review can contribute to different research groups wishing to initiate an agenda related to the subject, in addition, a series of tools that can serve to teach, learn or socialize physics through the use of video games. Also presents a classification of each according to his pedagogical foundation.

In the end, presents a discussion and conclusion of the above, which seeks to establish a research agenda of the Serious Games oriented teaching and learning physics, in addition to describing the various technological tools that can be used to develop a serious game.

Computational Physics and ICT: Computer Modelling and Simulations in Science Education

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Research argue that one of the most meaningful and engaging forms of learning is modelling, that is using computational environments to build representational models of the phenomena that are being studied.

According to (Hestenes, 1999) model construction is composed by a model which describes four types of structure, namely:
(a) the systemic structure which specifies the composition (internal parts of the system) and the environment (external agents linked to the system)

(b) the geometric structure which specifies the position with respect to a reference frame and the configuration (geometric relations among the parts)

(c) the temporal structure which specifies the change in state variables governed by interaction laws

and (d) the interaction structure expressing relations among causal links, usually as function of state variables

One of the crucial components of Physics education is the correct abstraction of a physical phenomenon to a conceptual model and its translation into a computational model. This leads us to the notion of a computational experiment where the model takes the place of the ‘classical’ experimental set-up, and where simulation replaces the experiment. According to (Landau et al, 2008; Tobochnik & Gould, 2008) computational physics (CP) provides a broader, more balanced, and more flexible education than a traditional physics major. In this work we use the computational experiment as an integration of the (CP) with the discovery learning method. We use the methodology of (CP) in order to create a computational experiment suitable for the creation of expressive models by the students, incorporating the four fundamental components (Modelling indicators) suggested by (Hestenes, 1999). The experiment was used by Grade 12 students using a simulation environment created in Java for the domain of “motion under central forces”.

The following research questions were formulated for our research:

a. How the computational experiment is related to students’ learning performance?

b. Is approach to learning, Modelling indicators of Hestenes (1999) and learning performance correlated?

Students wrote the pseudocode and the Instructor wrote the corresponding source code in Java. The decision of the model (interaction laws, geometrical, temporal structure) was made by the students, while the method of simulation was the method of discrete time using the already known Verlet algorithm.

Initially students participated in two questionnaires in order to determine their approach to learning (conceptual approach, mathematical and information-based approach) and their conception about the modelling indicators.

We classified approach to learning as: 1 stands for the conceptual approach, 2 for the “mathematical” approach, and 3 for the information-based approach. For the modelling indicators (systemic structure, geometric structure, temporal structure and interaction structure): 1 stands for the fully favourable part, 2 for the partially favourable part and 3 for the unfavourable part. The fully favourable part corresponds to recognition by the student of all modelling Indicators of Hestenes (systemic structure, geometric structure, temporal structure and interaction structure.) The partially favourable part corresponds to recognition of some of the indicators and the unfavourable part to failure to recognize even one of the Indicators.
Results of the experiment showed a remarkable towards the favourable part of the modelling indicators and that modelling indicators are strongly correlated to the approach to learning (the conceptual approach) and the learning performance.


**A Simple Convection Current Demonstration**

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Alternative concepts of earthquake causes, found after the finishing of the conventional instruction in Thai high schools, were such as the belief that earthquake occurrence depended on the topography, particularly; earthquakes often happened near the islands. Moreover some Thai students believed that earthquakes happened in rainy areas more than those in dry areas, because wet soils slid easier than dry soils. It generated earthquakes easier as well. [1]. In contrast, some previous studies reported that students though earthquakes occurred only in hot countries, because the heat cracked the Earth’s surface into pieces, coupled with the shaking [2-3]. Overall these alternative concepts revealed the less regarding of the convection current in the Mantle of the Earth that was the main cause of the natural earthquake in the World.

To correct and enhance students understanding of such concept, we suggest a convection current demonstration set. This simple demonstration aims to illustrate both the particle motion in the Mantle and the plate movement. It consists of very basic materials such as a beaker, vegetable oil, glittering flakes, plastic sheets and an alcohol burner set. Additionally, we apply the demonstration set in the 5-E model of the inquiry-based teaching approach for earthquake cause classes. In our preliminary work, it revealed the positive findings of both student conceptual understanding and the satisfaction.

**Keywords**: Convection Current, Earthquake Causes, Inquiry, Demonstration

Shadows are one example of phenomena that we experience in every day life. Indoors, lamps and other sources of artificial light create shadows when objects are placed in the path of the light rays.

Students of primary and secondary schools may not recognize by themselves the intimate connection between physics and mathematics. For them it may be quite a motivating experience when they become aware of connections between different school subjects. Physics teachers should therefore show real-life examples, where skills and concepts obtained at abstract courses of mathematics can be effectively used. On the other hand, mathematics teachers can occasionally illustrate mathematical concepts by looking at appropriate physical objects. Shadows offer a variety of examples where geometry can be used and studied.

First we look at a photograph of the shadow of the mountain Špik. The shadow has a triangular shape and from it we can find the position of the Sun, and the time when the photograph was made.

We can create more examples in the classroom. We only need a stick, a light source, a dark room and a wall. Varying the position of the stick (or the light source), we find a mathematical relation between the stick’s position and the length of the shadow on the wall.

Students must first make a plan of how to carry out an experiment. They have to decide what are the independent and dependent variables, and which quantities should be kept unchanged, i.e., constant. Measurements should be tabulated and represented graphically. Students should try to understand what the results represent and how reliable they are. They should draw picture of the experiment in order to find geometric relationship between the stick and its shadow, and see how the values obtained through this relationship correspond to the measured values. Here they could include computer and use programs for dynamic geometry. If students worked in groups each group could demonstrate their work to other groups in the classroom. Many steps are possible and teachers could assess each of them separately. We used this approach in schools and found that some of students are more confident with the experimental part while others are more comfortable with the graphic presentation of the data and the resulting mathematical

relations. If students work in groups then they can learn from each other and the teacher only needs to supervise their work and help them if they cannot successfully perform the experiment.

Through such examples it may be possible for the student to better understand connections between physical phenomena and their corresponding mathematical descriptions. We show some examples that are used in teaching seminars and how they are subsequently used in schools.

**Teaching Astrobiology from a socio-scientific Perspective using a digital Learning Environment**

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We report from the European project CoReflect (www.coreflect.org) where groups in Cyprus, England, Germany, Greece, Israel, Sweden and the Netherlands are developing, implementing and evaluating teaching sequences using the internet platform *Stochasmos* (Kyza & Constantinou, 2007). Within this design-based project (Barab & Squire, 2004) teachers and researchers work together on the design of digital learning environments (LE:s). The approach seeks to bridge the worlds of academia and the world of educational practice. All LE:s build on different socio-scientific issues (Sadler, 2004), and *Stochasmos* are used to help teachers scaffold students in collaborative learning.

The local working groups of researchers and teachers design one LE each. The design goes through different phases: implementation, review and refinement. The aim of this article is to describe these phases, for the Swedish LE. The Swedish group chose socio-scientific issues in the content area of Astrobiology. Astrobiology captures questions that have been found to be of interest to students (Sjöberg & Schreiner, 2006). The socio-scientific driving questions are:

*Should we look for, and try to contact, extraterrestrial life?*

*Should we transform Mars into a planet where humans can live in the future?*

Students are expected to: a) demonstrate a basic understanding of essential concepts of astrobiology, b) discuss the nature of science, c) link hands-on lab-work to astrobiology research, d) provide evidence-based answers to the driving questions, using scientific, social, economical and ethical perspectives.

Based on the evaluation of the pilot enactment several changes were made in Stochasmos and to the teachers’ guide. Even though *Stochasmos* gives the work structure, through tabs and templates the need for a scaffolding teacher was obvious. The teacher needs to be familiar and knowledgeable about the content in order to be able to produce challenging questions. A stricter planning for the teacher, with explicit instruction about student activities was introduced to promote science oriented discussions. The students liked working with the computer – it is a familiar environment. The teacher experienced
an increase in student anticipation and focus. The analysis of the second enactment is ongoing, and will be presented at the conference.


**Innovative way of studying physics**

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Plenty of famous people (e.g. actors, politicians, …) usually say, when they are talking about their education, physics wasn’t their favourite subject in school. They say there are only definitions, laws or principles and a lot of formulas in physics. Nobody understands them. In my opinion physics is very beautiful natural science with plenty of applications. For example: everybody uses mobile phone and computers, drives cars, prepares food in microwave, watches TV or films in cinemas, … And every of these applications are based on physics laws. Physicist discovered the law of resonance in
circuit with alternating current, the law of electromagnetic field and electromagnetic wave and then the mobile phone was discovered. The basic principles of mobile phone were discovered by physics, other improvement of mobile phone (small and powerful batteries, elegant appearance, …) is advanced technology.

I want to show to my students, that physics is beautiful and useful science for whole life. I prepare for them:

- innovative kinds of tasks which are based on life (the outstanding performance of Usain Bolt in August 2009, the accident of train in the Czech Republic, …), some interesting parts of movies (qualitative and quantitative tasks of some nonsense in movies, …);
- innovative way for motivation of studying kinematic: finding task in Czech songs, working with maps and timetables (I know students have mobile phones with the Internet access but they can lost signal outdoors and they have to be at home or at camp in time. They have to find some information in timetable or in classical “paper” maps), …;
- innovative way for motivation of studying physics (team homework, home prepared physical experiment for others, …);
- physical show: “Physical Circus”, 24hours with physics (it was in 2005: The World Year of Physics);
- educational excursion to interesting places connected with physics or science in general (e. g. CERN, science-centrums, car factory, …).

My experience is that students like it and they want to understand how things work. Simple experiments make clear basic principle of working things. When students study physics at university, they will know these basic principles.

When students demonstrate their homework, they have to answer to other students’ questions, they have to explain their opinion and they have to admit their mistakes, if they do it. This is very good for their next study and life: they are able to make out their case and find their mistakes.

Streamlining a sensor technology course in cadets’ physics education by pre-evaluation

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At the National Defence University, in the cadets’ curriculum a specific surveillance and target acquisition course is lectured in the 5th semester. This course deals with tasks of sensor technology. According to the university pedagogy principles, mathematical skills and physics knowledge have been rehearsed during previous semesters. This study investigates how cadets’ knowledge on physical phenomena can be improved in the application oriented course by a pre-evaluative diagnostic intervention and other
active approaches. Qualified education according to the Bologna principles means, that customer and process quality challenges must be considered also in the Finnish cadet education. The mission of evaluation is to produce such feedback, that it could direct and guide educational development processes. Typically evaluation is divided into diagnostic evaluation, formative evaluation, and summative evaluation and correspondingly the evaluation concentrates then on the starting level, on teaching and learning processes, or on the outcome evaluation. A diagnostic or a discovering evaluation is planning oriented and discovering by its nature. It clarifies the starting point in a learning process: student’s ability and attitudes and the status of the current knowledge level. If the given education starts from a too abstract or from a too simplistic starting point, then the learning results tend to be less successful. The sensor technology course at the NDU is common for the whole cadet course consisting of the majors in technology studies (24 cadets) and also those, who have selected another discipline for their major subject (non-majors in technology studies, 72 cadets). The conducted study investigates physics knowledge level among cadets. The study was made during the first lecturing week of the surveillance and target acquisition course. Two major physics concepts on the survey were: properties of the electromagnetic wave and thermal radiation. Also some practical skills were asked e.g. experience on utilization of night vision devices (NVG or thermal image camera) and utilization of some applied software. The study showed that no remarkable differences in the knowledge level exist between the two cadet groups. However, this pre-evaluative test gave much information for the course developers, how to streamline the course structure and contents to such a direction, that it will more properly fit to the student profile. The study revealed for the course developers the parameters, which should be empowered with more focused attainments.

Electromagnetism - seeing and calculating

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Teaching electromagnetism is not an easy task. In Polish basic-level Physics curriculum for instance, this section is practically neglected. While present in the extended course, it is often excessively formalized and not sufficiently illustrated with simple examples. Left-hand rule of induction and Oersted experiment dominates over the concept of energy conservation (i.e. Faraday- von Neumann- Lenz principle) or the continuity of magnetic lines (i.e. the inexistence of magnetic monopoles, or in other words difficulties in defining magnetic field lines in the same way as the electric lines). Some textbooks reduce magnetism to the relativistic explanation by Einstein, not giving a single bit of information on permanent magnets, coils, wires and so on. On the other hand, precise calculations of two interacting permanent magnets is not trivial, either [1].
In our previous collaborations at the EU level [2] we have developed some experiments illustrating Lenz law, magnetic interactions qualitatively and quantitatively, diamagnetism, Earth’s magnetic field [3] and electrostatics [4]. The experimental kits (40 experiments) are under didactical testing in upper secondary schools all over EU.

In present work we suggest some of experiments in electrostatics and magnetism, both with real objects as well in interactive ways [5], but now tightly connected with problems selected by our Czech collaborators from Prague University [6,7].

The well known problem of two electrically charged balls [4] is illustrated in our Christmas glass balls experiment [5]. Interaction of a magnetic-dipole coil with the static magnetic field [6] forms the basis of another simple experiment [8]. Altogether, these materials form an important step towards understanding electromagnetism both experimentally as conceptually.

Given the urgency of revamping our energy system due to climate change, increasing global energy use, and fossil fuel depletion, it is increasingly important that everyone have some basic understanding of energy use in their lives and society. The «Energy for Everyone» model is being developed and refined as part of materials that are useful in both formal and informal settings.

«Energy for Everyone» is synthesized primarily from three existing curricula -- the Karlsruhe Physics Course from Germany [1], Energy and Change from the UK [2], and CASTLE from the US [3]. In this model, learners color pictures of concrete situations using a hierarchy of colors to represent intensive differences (in temperature, pressure, etc.). Learners use language («differences drive change, and differences tend to disappear») and metaphors («energy, entropy, and other extensive quantities can be thought of as fluid-like») to construct runnable, imagistic simulations [4]. Their semi-quantitative dynamic images are then related to quantitative real-world situations, such as the energy use of the US [5]. Examples and experiments provide further support.

This flow-based model is common in engineering, less so in science. Given the difficulty learners have with energy in science, the hypothesis is that this more intuitive, macroscopic understanding of how systems behave will help learners achieve «functional science literacy» [6], based more on usefulness than on the contemporary science view. Since a fluid-like model for energy is probably «unavoidable» anyway [7, 8], one goal is for this approach to be established as a viable complementary alternative model [9] -- perhaps even by calling it an engineering model -- that educators can feel confident teaching. The social aspects of energy make this more than just an intellectual exercise.

[5] Lawrence Livermore National Laboratory. «Energy Flow Charts.»
A school project: a horizontal sundial

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It is not always easy to recognize the connection between basically not so complicated motion of Earth around the Sun and its non-trivial consequences upon observable circumstances. These are, for example, the changing length of the day, the changing positions of the sunrise and sunset on the horizon, the changing direction of the shadow, thrown by a tree, etc. The fact, which makes everything more difficult to comprehend, is the tilt of the Earth’s rotational axis with respect to the plane of ecliptics, bound to the spherical shape of the Earth. The connection, i.e. the cause for certain observation can be visualized if the teacher uses a model of the Sun and the Earth in three dimensions. Continuing from there he can introduce and explain some simple consequences first and then proceeds to more intricate.

I shall present an example, how rather complicated parameters of motion of the shadows on horizontal grounds can be elucidated step by step, if one starts with a simple model of an equatorial sundial. I shall also describe how a horizontal sundial can be calibrated in a classroom without using the nontrivial equations of projective geometry. During the procedure of making their own equatorial and later also horizontal (or even vertical) sundial a clear conception of geometrical connections between the light source and the shadow, observed in arbitrary plane, is formed in minds of pupils.

Teaching physical concepts using the history of physics

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Physics graduates are valued for the generic or soft skills they have accumulated during their course and their ability to see the links between disparate areas of science. Indeed, employers frequently rate these attributes more highly than their specialist knowledge. But how do students see the ‘big picture’ or answer the question, “how did we get to here from there” when they are being taught increasingly specialised material as their degree courses progress through the years?

An approach adopted in the University of Strathclyde is described in this paper, and it is the basis of a level 4 class, “Physical Concepts”. In Scotland academic levels are in a range of 1 → 5, where 1 → 3 is equivalent to the Bologna Bachelor, 1 → 4 is the Scottish honours Bachelor and 1 → 5 is the Scottish integrated Master. The class was originally designed for students of the BSc in Physics with Teaching in which the Postgraduate Certificate in Education is awarded along with the degree and qualifies the graduate as a secondary school teacher. It has also proved to be a popular option for mainstream physics students.

The aim of the class is to track the development of the key concepts in physics and review how this shapes the current understanding of the subject. In summary: (i) the history of physics is examined including the use of timelines and the danger of making predictions concerning its future directions, (ii) the contributions of significant individuals are set in context both from a historical and scientific perspective, (iii) the major conflicts in the history of physics are identified together with the protagonists, their arguments and their eventual resolution, (iv) concepts from the secondary school curriculum in physics which students find difficult are selected and appropriate teaching strategies found, and (v) questions to test conceptual understanding are drafted.

At the end of the class, the intention is that students have a better appreciation of physics as an evolving subject rooted in practical usefulness but with a coherent and self-contained structure of concept and theory. Due to the nature of the subject, the weekly meetings of the class focus on discussion and brainstorming, while assessment is based on assignments and presentations including the use of peer assessment.
Two simple ways of verification of the $1/r^2$ dependence in Coulomb’s law at both high school and university level

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Coulomb’s law is usually the first formula learned by students in the area of electrostatics at both high school and university level. But quite often this formula is just stated, perhaps referring briefly to historical measurements using torsion balance, without any quantitative demonstration or lab. The natural question can be raised by students whether the exponent is really 2 and not, say, 1.99 or 2.01.

The experiment determining the exponent using charged spheres was described in the literature several times. We will present the variant of such experiment enabling rather simple and fast measurement we developed for our new Interactive Physics Laboratory for high school students. (The project of this Lab was described in a short talk at GIREP 2009.)

Yet, student measurements using charged spheres cannot aspire to high precision and should be considered rather as rough estimates of the exponent in Coulomb’s law. The most precise experiments performed in the 20th century utilize the equivalence of $1/r^2$ dependence and the fact that the electric field inside a charged conductive sphere is zero. We will present low-cost variant of such experiment using simple home-made detector of electric field with FET transistor. The quantitative analysis of such measurement fits to introductory university course (e.g. for future physics teachers), the simplified reasoning can be presented also at high school level. We will mention also related experiments with Faraday’s cage we are preparing for the Interactive Physics Laboratory mentioned above.

Sound or Music?
Music students in the physics lab.

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Music is an important component in an adolescents’ life. Students are used to listen, sing and play music with different musical instruments. Some of them start studying music and playing an instrument very early in their life, and in the secondary school they can already be young musicians with some music international prizes. It’s not unusual then that, upon meeting physics, they want to apply and give some answers to their questions about sound and music. Besides learning in general about sound waves
and their phenomena, music students wish to know how the music instruments they play work or function. They can also ask about all the tools they use, for example the electronic tuning fork or the role of the substance for covering the strings of the bow of a violin. Music offers to physics a good occasion to support and explain some objective concepts as harmonics and also subjective concepts as pitch, timbre.

For physics teachers to introduce lab activities based on specific music instruments could be a challenge and also an enrichment of physics lab experiments. The teacher can propose to motivate students to construct a monochord for studying Pythagoras’s music scale or investigate and explain the different parts of an accordion. The didactical approach with such students should respect their competencies and their music knowledge or techniques. The interaction between music and physics should be interdisciplinary; music concepts should be completed or integrated.

A collection of activities developed with three music students in the physics lab during a school year starting from the stationary wave to monochord to singing glasses, Chladny’s plats and diatonic accordion will be presented and evaluated.

The Efficacy of Multimedia Learning Modules in Learning Introductory Physics Courses

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Developed by Physics Education Research Group at University of Illinois, Multimedia Learning Modules (MLM) are combinations of various media within a single computer program streamed online. These ~15-minute modules are research-based presentations and learning activities designed to introduce the key course concepts through flash animations with synchronous narration. (See the screenshot of the Ampere’s Law MLM in Figure 1; full modules can be viewed at: https://onlines.physics.uiuc.edu/courses/phys212/gtm/No_Login/page.html.) Each module has two to three questions that are embedded into the content itself. Students must answer the questions in order to proceed. Automatic feedback and related prompts guide students in determining the correct answers to these questions.

During the past decade, the field of multimedia learning has emerged as a coherent discipline with an accumulated research base. MLM design, guided by physics education research, is based on principles of multimedia learning in which students use both auditory and visual channels to assimilate information. By maximizing the students’ short-term memory, the research suggests that the use of the dual learning channels improves student learning. While focusing on how people learn from words and pictures in computer-based environments, the MLMs coordinate the animations with narration to enhance learning outcomes.
We are using this material at California State Polytechnic University in Pomona and are evaluating their effectiveness in student learning of introductory calculus-based physics courses. The research described in this presentation began during the Spring 2009. Students in one section of PHY 133 (Electricity and Magnetism) served as control group (traditional) while a second section was offered via a hybrid/online format. Both classes Figure 1- Screenshot of the online multimedia prelecture on Ampere’s Law in electromagnetism. met twice a week. The traditional class met 75 minutes each period while the hybrid class met for 50 minutes with the remaining 25 minutes (one-third of the class time) was offered to students in an online format through the use of prelectures via Multimedia Learning Modules. Students were required to view the MLM before each face-to-face class meeting. A similar study was conducted during the Winter 2010 in PHY 131 (Mechanics) only the class meeting time was the same for both sections and both classes met three times a week for 50 minutes. We will show the impact the multimedia prelectures had on student performance both before class, in the classroom, and on nationally researched tests.

Rag Puppets: a show behind science.

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The explanation of a physical theory usually goes through a conceptual path, making reference to the ideas implied or the specifics of an experiment as a demonstration. In this kind of theory rich approach it’s common for the public to lose attention from the activity’s main topic. That is why we have explored a different route in order to popularize and teach physical concepts with children: theater representations based on rag puppets.
Puppet’s plays are directed to children from 6 to 12 years old. First of all they try to create a space that will make it easier for kids to get closer to physics. Also they have been created with the intention to help children gain knowledge about a scientist’s context; the situations that led him/her to work on a specific line of research and how his/her work influenced science and society. This way, children can know a bit more about the life of scientists: how was their character, where they worked and which were their motivations to do specific research and experiments.

The first plays that were presented included discussions between two proposals, where two scientists tried to convince the public of the truth of their idea. For example, there was a debate between Aristotle and Johannes Kepler about the geocentric and heliocentric theories.

Other way the plays have been performed is with sketches. This approach works on telling story without specific scientists taking part in it but showing the explanation of certain concept with other characters.

Finally there’s a more extended kind of presentation, that involves more time and resources, which tries to show a bigger picture of a scientist: both his life and work. This is a good line of work to show the human side of science, and break a lot of the myths that surround it. In this case we have performed a play about the life of Edwin Hubble.

When reading a fantastic story or tale, people often like to see common people making extraordinary things; scientist are common people and make extraordinary achievements as well. Talk about scientists usually gives the idea that they are beyond human, smarter than everybody else, only dedicated to science and nothing else, old and boring. With these plays, we try to show the human side on scientists, motivating children to think of the life as a scientist.

**Intelligent Tutoring Systems for teaching the Newton’s Laws**

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The Information and Communication Technologies (ICT) applications have an important impact in every-day aspects of our life. In the educational field, the on-line systems or more specifically the Learning Management Systems like Moodle platform can be apply for distance education with a wide number of participants. A problem derived of this, is that the relationship between teachers and students are not the same, the system can support hundreds of students but there are just a few teachers that can interact with them. This work presents an alternative solution for that problem; we show the use of
an Intelligent Tutoring Systems (ITS) in order to instruct a big number of students. The Intelligent Tutoring System identifies the learning style of the students and adapts the course content according to particular characteristics of them. With this strategy, the Intelligent Tutoring System will focus in the learning process, showing content, evaluating skills and feedback results. If one student has a problem of learning some particular subject; then the Intelligent Tutoring System alerts to a teacher who takes the control of the situation, and works with the student in order to solve the learning problem. The advantage of this system, is that the teacher only focus on a very specific problems that cannot be solve by the ITS system, and by this way we can achieve a better student support improving their learning. It is shown a prototype that we apply to college students, we choose the Newton’s Laws, because is the first topic covered in the college curricula in Mexico.

Proposal of Didactic in Sciences of Elementary Education in Brazil: focus on Scientific Literacy and Sustainability

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Traditionally, science courses in the early years of elementary education in Brazil are focused on the introduction of health and personal hygiene topics and the presentation and classification of some living organisms. There is little deviation from these standard topics in the classroom and other scientific topics that students encounter outside of the classroom are usually not discussed.

Key topics that are bypassed by Brazilian lesson plans include, for example, the socioeconomic impact of technological advances. Such subjects are only included and discussed by independent initiative of the teacher. The result of this lack of formal and standardized education on natural phenomena is an omission of important contemporary issues and dilemmas involving sustainability and the environment in the classroom dialogue depriving the child of the necessary vocabulary and knowledge to fully understand the world around him or her.

Other countries have already revised their lesson protocol to include topic on the changing environment. Fourez (2003) suggests that students benefit from early «Scientific Literacy» and real-world application of scientific topics even without further specialization on the concepts. Scientific Literacy would then be necessary and sufficient for the inclusion of a natural science perspective in a young person’s worldview. Hurd (1998) and Yord et al. (2003) assert that a basic understanding of science and technology is a prerequisite for good citizenship.

Like these and other authors, we support a science curriculum that will satiate the students immediate need to learn about and discuss problems that involve natural phenomena as a way to introduce them to the universe of science and technology and form more conscientious citizens.
In our view, the process of scientific literacy is spurred by direct contact with scientific knowledge and process. We will then mark the learning by cornerstones or indicators of this process of literacy.

The first years of elementary education the focus should be on the collection, organization and classification of scientific data. Besides, it is also important to develop the habit of creating and testing hypothesis as a necessary step to answer a scientific question. We then look for the ability to use inference and logical extrapolation to argument and justify broader conclusions about the natural world and its relationship with society and the environment. Finally, students should eventually show the ability and desire to predict broad changes in the natural world, society, and environment based on the observations during the scientific method.

Our work is concerned with the inclusion of themes of STSE (Science, Technology, Society and Environment) in grade school with the goal of initiating the Scientific Literacy process and increase the awareness and interest of students in regards to the consequences of advancements in science and technology as they relate to changes in society and the environment.

With investigative problems and reflection questions, we hope the students will create their own hypothesis and plans that will aid in the search for a solution. We also expect them to be able to discuss alternate ideas presented by their colleagues and even dive into controversial topics that may arise in discussion.


High-Speed Video Analysis of Two-Dimensional Movement of Objects onto Fine Beads

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Two-dimensional kinematics demonstrations are difficult to apply in practice by friction. In case of horizontal motion, many teaching materials are developed and some of them, such as the dried ice pack, the ball bearings and the air table, have come into general use in lecture rooms or laboratories. Sawamoto et al. have developed the method of demonstrations using fine spherical plastic beads (NaRiKa; D20-1406-01, industrial materials of styrene form) onto a level glass plate [1]. Fine spherical beads are useful for
frictionless demonstrations of two-dimensional dynamics and kinematics. The apparatus that uses the beads is simple and quieter than ordinary apparatuses. This apparatus consists of the fine spherical plastic beads onto a level glass plate or fine spherical glass beads (industrial materials for road paint) onto a level plastic plate. Even in any case, fine spherical beads onto a level plate play an important part in the friction-less tabletop. These beads function as ball bearings to reduce friction between moving objects, glass Petri dishes or metal disks, and the tabletop. The beads that are charged adhere onto the level plate by static electricity, in these cases plastic is negatively electrified and glass is positively electrified, arrange themselves in the triangular-lattice-like pattern. The motion of the glass Petri dish on the fine beads clinging onto the level plate was analyzed by the video analysis using high-speed camera (CASIO, EX-F1). The beads under the Petri dish were visible through the bottom of the glass Petri dish. The high-speed video showed that only a small number of beads under the base of the Petri dish supported the Petri dish. It was confirmed that the distribution of the diameter of the fine beads is essentially part in the low friction motion.


**Approaching the concept of force due to atmospheric pressure:**

*a teaching experiment based on Torricelli’s barometer*

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Torricelli’s barometer experiment consists of a glass tube filled with mercury, stood upside-down in a container also filled with mercury. This experiment is a common application of the hydrostatic equation ΔP = ρgΔh. However, several of its more complex characteristics are masked by the mathematical simplicity and the ease of application of the hydrostatic equation.

The deeper interpretation of this experiment was as troubling to scientists in the 17th century as it is to students today. As Hosson and Caillarec [1] have demonstrated, students attempting to understand the principles of the experiment are likely to prefer partial or local reasoning to a wider conception including the crucial factor of atmospheric pressure.

Approaches centered on the space above the mercury tend to be expressed in terms such as ‘something is pushing up/ attracting/ holding up the mercury in the tube.’ Those which take first into account the column of mercury itself are often based on the analogy of the thermometer, where a constant quantity of mercury undergoes changes in volume according to variations in temperature. A final approach is based on theorizing a border
between the mercury in the tube and that in the container, two distinct bodies of liquid which then interact.

Taking into account historical controversy on this subject on one hand, and current research on student reasoning on the other, a teaching interview was designed which aimed to facilitate students’ understanding of Torricelli’s experiment. This interview focused chiefly on introducing the importance of the force exerted by air pressure, a concept foreign to the 17th century scientists and frequently overlooked by students.

The interview took the form of a series of experiments, each one of which was designed to highlight the insufficiency of one of these partial analyses. The series was organized so as to lead the student step by step away from the errors caused by local analysis, and to require an evolution of his/her thought processes towards a more comprehensive approach.

The interview was conducted with three third-year students in teacher training. The results of this experiment confirm those of previous research, suggesting a marked tendency towards localized reasoning. The interviews suggest that one of these local approaches, the theorizing of a limit between the mercury in the tube and that in the container underneath, leads to the interpretation that the test-tube mercury floats on that of the container. The results also indicate that students rarely manage to apply, or even understand, the strictly analogous demonstration of suction provided by the more familiar syringe.

The interview also contributes significantly to the development of the students’ concept of the vacuum, which evolves from a dichotomous to a relative interpretation. The sequence of experiments succeeds in contributing to their understanding of the significance of the role played by the air surrounding the tube.

The first Czech - Slovak e-laboratory, as a contribution to a remote laboratories cluster within EU, with real remote interactive experiments and the data transfer is presented. The cluster was established as a common undertaking of three universities - Charles University in Prague, Tomas Bata University in Zlin, and Trnava University in Trnava and is oriented on the Natural science experiments. At the present stage of development e-laboratory includes the experiments from physics, chemistry and environment monitoring with 12 free access experiments, running round the clock.

The laboratory uses the unified approach, as the hardware is the ISES (Internet School Experimental System) and its modules(see www.ises.info), and the software for the server-client connection is based on internet services with browser and Java applets [1]. The unique quality of the system is its simplicity both in the use (uses only common browser and Java installed and active) and in the compiling (using the paste and copy approach of the pre built building blocks), enabling the easy using of experiments by any interested and easy building of new experiments by using ISES hardware and ISES CONTROL KIT software. The experiments may be found both on http://www.ises.info (Water level control, Meteorological station in Prague, Electromagnetic induction, Natural and driven oscillations(see Fig. 1), Diffraction on microobjects, Solar energy conversion and Heisenberg uncertainty principle) and http://kf.truni.sk/remotelab (Environmental monitoring in Trnava, Electrochemical cell (see Fig. 2), Energy transfer in oscillator, Free fall and Mathematical pendulum). The laboratory has been extensively used for teaching purposes using Integrated e-Learning (INTe-L)- a new strategy of education based on e-experimentation [3].
Figure 1. The web page of the remote experiment “Natural and driven oscillations”

Figure 2. The schematical diagram of the remote interactive experiment “Electrochemical cell”


Increase of Representational Coherence with Cognitive Activating Tasks for Physics Experiments

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Research clearly shows that for a proper understanding of scientific experiments, phenomena and concepts, various mental representations and their interplay are vitally important (Gilbert, Treagust, 2009). Additionally, students’ learning progress by observing (Crouch, Fagen, Callan, Mazur, 2004) or doing own lecture experiments (Harlen, 1999) is rather small. There is an increasing body of evidence, however, that learning about and from experiments can be enhanced by proper cognitive activation as the predict-observe-explain sequence (Kearney Treagust, Yeo, Zadnik, 2001; Crouch et al. 2004).
Within this line of research, this study aims at development and investigation of cognitively activating tasks focussing on the essential role of representations in the context of experiments (Experiment Related Representations, ERR). The research questions are as follows:

(i) In general, to which extend representational competence in the context of experiments can be induced by cognitively activating tasks related to them?

(ii) In particular, what degree of coherence between representations learners can achieve by tasks engaging them in correction, completion and adaptation of experiment related representations?

(iii) Is the representational competence of learners related to their general level of physics understanding within a specific domain?

In this contribution, we report on the results from our continuing studies on representational competence in the above sense in a whole range of students’ expertise from secondary level to university level.

It was found that physics teacher students were more skilled in working with descriptive representations even on a formal level (e.g. mathematical equations) than depictive representations (e.g. graphs). Most students had difficulties fitting their knowledge into an integrated representation (e.g. graph of the time course of voltage in a self induction experiment), even when they showed proper understanding of the necessary elements ($U_{\text{ind}} = L \frac{dI}{dt}$) and correct application (e.g. to switching spark). Generally, even students’ degree of coherence is low and has to be improved.

The same applies even more to secondary school students. In a quantitative, quasi-experimental study (4 classes, $N > 100$, domain: ray optics) with one-factorial design (with/without explicit representational exercises: completing, correcting, adapting, mapping) representational competence and physics achievement are measured as dependent variables. Control variables containing physics motivation and pertinent sub scales of intelligence (verbal, visual, memory, processing) are measured with field-tested and validated instruments (Kuhn, Müller, 2010; Wechsler, 2003). Students’ representational competence is assessed with a self-developed instrument. Details of intervention, validation of instruments and first findings related to the above research questions will be reported at conference.


The course which I intend to present here is the Cultural History of Physics. At our university this is an optional course for the students of electrical engineering, following the compulsory, two-semester Physics course.

Studying the history of physics can contribute to deepening the students’ understanding of physics, which has fundamental importance in the course of their studies. The name of the course suggests that it is easier to understand the history of physics if it is integrated into the history of global culture. It gives insight into the art of the given period of history, and also highlights the cultural aspects related to the physicist concerned. On the other hand the course provides a means of motivating the students to look for further insight into the history of physics and physics itself as well as into art thus inspiring them to explore connections between these areas of culture.

This talk intends to introduce this subject in a short way. To characterize the course I would like to highlight the role of the chronological tables extended to some famous contemporaries from the other areas of culture. Some special details from the chapter of the geniuses of the 16th and 17th centuries will also be presented as examples in order to illustrate the character of the course. The examples emphasize the wider cultural aspects mentioned in connection with Galileo, Pascal and Newton, among others, and a student’s “multimedia like” presentation will also be reviewed.

In the second part of the short talk, examples of testing the students’ knowledge will be presented. I will be highlighted how distance learners can be inspired to use the coursebook, or the Internet (or books) at home. This will put problem based learning, or at least a possible approach to it, in the foreground. A further example dealt with is the crossword puzzle as a possible means of self-assessment for the students.
A Conceptual Progression of Students’ Mental Models of Magnetism Across Scale

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We describe the learning trajectories of secondary students from the United States and Finland for a “case” physical science topic (i.e., magnetism) along several dimensions: (a) the increasingly sophisticated ways in which students construct mental models about magnetism, (b) conceptual coherence in students’ models of magnetism and (c) students’ ability to construct and apply models of magnetic phenomena across scale. Magnetism across scale is a topic well suited to exploring how secondary science students can develop conceptually coherent and integrated mental models of key ideas in physical science. Magnetism is also important for understanding contemporary technological advances (e.g., recording and data storage devices, ferromagnetic drug delivery systems and biosensors) based on the fabrication and manipulation of nanoscale magnetic materials.

Researchers have catalogued a range of non-normative ideas about magnetism such as (a) models of magnetism \cite{borges1998models, constantinou2001young}; (b) confusion between magnetism and charge \cite{borges1998models, constantinou2001young}; (c) action at a distance \cite{constantinou2001young}; and (d) the concept of field \cite{constantinou2001young, constantinou2001young}. Yet, there has been no systematic study using a model-based framework to explore the content, structure, and coherence of secondary students’ developing ideas and mental models of inter-related concepts of magnetism or magnetism across scale. This research uses a progression of lessons and assessment tasks to elicit students’ construction and revision of models of multiple magnetic phenomena and magnetism across scale. Iterative cycles of investigation, reflection and revision provide students the opportunity to revise their mental models for coherence and explanatory power. This research will advance our understanding of science learning and teaching at the secondary level in two socio-cultural educational settings. Additionally, it will contribute to the development of cutting-edge physical science curricula for secondary students that foster the development of coherent understanding across size and scale.


Students Understanding of Statistical Mechanics at the Beginning of Solid State Physics Instructions:
Development of Concept Inventory

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Key words: statistical mechanics concept inventory, misconceptions, reliability, validity

Physics Education Researchers have designed and developed a number of concept inventories covering different physics domains starting with Force Concept Inventory [1]. These inventories have acted as an effective tool for the teachers to discover the misconceptions held by their students about a particular concept and to develop new strategies to remove such misconceptions. Solid State Physics is the largest branch of Condensed Matter Physics which looks at the behavior of a large collection of atoms placed in close proximity to one another. For an in depth appreciation of physical behavior of such a large collection of particles requires the conceptual understanding of Statistical Mechanics, which provides a scaffolding as well as a foundation for solid state physics. It tells us that how the overall behavior of a system of many particles is related to the properties of the particles themselves. Naturally, it finds an extensive use in Solid State Physics and therefore a firm conceptual understanding of statistical mechanics is very essential for the learners, before they start learning the Solid State Physics course. In this paper we look into an undergraduate Solid State Physics course, we have tried to identify the fundamental Statistical Mechanics concepts, which should be known to the students before they start studying the solid state physics course. Based upon this identification after discussion with a group of teachers teaching this course and a group of students, who have passed this course, a concept inventory has been
designed in multiple choice format in which, more than one questions focusing on a single concept are included to assess and to gain deeper insight of students’ conceptual preparation to undertake the study of the Solid State Physics Course. The preliminary results of a test based on this concept inventory administered to a group of post graduate students to check the validity and reliability of the questions and concepts being targeted is reported.


Why are there no white mice on the North Pole?¹
Or,
how simple considerations lead towards surprising conclusions

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Using dimensional analysis considerations enables addressing various scientific problems, which are otherwise hardly interpretable. A simple mathematical toolbox reveals wide possibilities for a profound scientific insight

Imagine we are suddenly squeezed by an order of magnitude. It is known as isomeric dimension change without shape deformation. Things like that happen in fairy tales or at children movies. As a matter of fact, what does it mean? How will it influence our life, our behavior and our abilities?

Let’s start with the most simple and trivial things - hearing and our vocal abilities. If we had been reduced by a factor of ten, our vocal cords and ear drums would become smaller. It occurs to be that the major part of our speech would be undistinguishable for a human ear and it would sound as high and unclear as mice chirping. If we would be enlarged in comparison to our environment the situation is getting even worse. Our voice would sound very low and our ears would not respond to the most of the sounds around us. Well, we would already find ourselves in a deep communication problem! One can understand now the reason dogs hear high voices, which for us, human beings, are beyond the range of hearing.

Let’s talk about scaling the size of the environment, where the events happen. Assume a human body dimension is a unit of measure. The sizes of animals surrounding us span over four orders of magnitude. It is quite incredible, considering the variety of the living organisms. More ancient animals span over twelve orders of magnitude.

The mass varies as the third power of the length dimension L: \( M = \rho \cdot V = \rho L^3 \rightarrow M \sim L^3 \). It is proportional to the amount of food the beast eats. The total skin area S is proportional
to square of the lengths dimension, i.e., $S \sim L^2$. Now we have a relative scaling, enabling compare energy input (food) to energy output (heat transferring into the air and sweating). The ratio between energy input and its’ output is known as $R (=1/L$ in our case), the metabolic rate. It points out the living limits of certain species of organisms.

To summarize, dimensional analysis applications spread over a wide range of considerations, beginning from the qualities of animals, via experimental procedures and finally reaching energy calculation considerations of the A-bomb. Dimensional scaling considerations clarify complicated issues. Evoking that simple, thought, powerful means of physical realm, gives a deeper insight in the origins of physics.

1 White mice on the North Pole problem will be addressed in course of the lecture

„Firefly” – a new contest in science for primary school: what we learn from the answers

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Three years ago we proposed a new national contest in science called Firefly (Swietlik). It is based on simple hands-on experiments and the science knowledge gathered from many different sources. The competition is addressed to children from primary school (grade 2 to 6, 8-13 years old). The first three runs of Firefly, indicated a growing interest in such competition among pupils, teachers and parents from the entire country. The number of 4664 pupils from 245 schools participated in the first run of Firefly (2008) and 8340 pupils from 377 schools - in the second run (2009) in Poland. This year the number of participates has increased to 13270 and 566 schools.

The contest has a form of a multiple choice test, taking place at the same time in the end of March in all participating schools. A separate test is prepared for each school level. The number of problems and the duration of contest are adjusted to the pupils’ age. Questions are equally composed on three categories: (1) biology, chemistry and medicine, (2) ecology, geography and climate, (3) engineering, physics and astronomy. Before the test the pupils are encouraged to perform a set of simple hands-on experiments selected for the competition each year. Children do them at school during classes or individually at home at any convenient time before the test.

Children are awarded individually according to the sum of points they earn during the test. Additionally, every year we award several schools with the highest participation in percentage terms.

This contribution is devoted to the elaboration of the results concerning question content analysis in comparison with the statistics of answers given by pupils. The science curricula background or its lack is also taken into account. We will show the examples
of tests for all grades. The answers given by pupils confirm a loose correlation between science curriculum and students common knowledge in primary school. On one hand, benefitting from different sources: science books, educational films, science festivals, lectures, exhibitions, every-day life experiences but also from our pre-tests and experiments available on-line, children appear to memorize much more than is expected on the base of the national curriculum. On the other hand, science subjects learned by heart at school and not followed by experiments, shows or live examples seem to be not interesting and quickly forgotten. The key role of hands-on experiments in inclinations towards science and in science education is emphasized.

We encourage partners from other countries to participate in the organization of the competition in order to establish an International Contest in Science for Primary Schools.


Teaching physics as a second subject

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Despite the decreasing numbers of physics lessons in our school curricula, we observe also a (hidden) scarcity of physics teachers. In this situation for many teachers of other science subjects teaching also physics is a preferable option, both for their schools and for their own career position. They need, however, to develop the necessary competences, confirmed by an official certificate of competence.

Several universities, among them ours, have developed and run postgraduate 3-semester studies preparing teachers to teach a second subject. Department of Physics at our university prepares non-physicist teachers of science subjects to teach physics and astronomy in lower and upper secondary school. The curriculum of the studies amount to 380 hours, including lectures with demonstrations, tutorials, workshops and laboratory. The whole-day meetings take place once a week. Laboratory is an extensive school experiment lab and takes 80h. The workshops involve mainly physics and astronomy education. Elements of distance learning are also present (tests, homework).

The people who attend our courses have a Master degree in one of the following: mathematics, computer science, chemistry, engineering, sometimes biology or geography, and at present are active teachers. They perceive teaching physics as a veritable challenge. To us, catering to their needs is also a challenge. We have to learn how content-specific are their teaching skills; what “educational” needs they have and how they are related to their students’ needs. They have to learn how to manage the ever-changing school curriculum. They also simply have to learn some basic university physics, and some of
them also mathematics. We offer all that. Our teachers take a semester each of classical mechanics, electromagnetism, thermodynamics, quantum physics and astronomy. Each of these courses ends with a written and oral examination. There are also in-term online tests, not graded, that can be retaken up to 3 times. The tests have a diagnostic and formative role: provide fast feedback for individuals and monitor group performance, showing progress but also locating weak points for both students and lecturers to work on. Some homework problems are also given each week, to be solved before next week tutorials, during which group discussion leads to complete solution with contributions from several participants.

We also believe in the need of hands-on practical experience, hence the 80 hours lab course. Our Laboratory of Physics Education offers a broad range of school experiments in classical (and some in modern) physics. They are both of standard and computer-aided variety, of varying degree of sophistication. For our teachers we organize them in thematic blocks, preceded, followed and interrupted by didactical discussion, which also helps to evaluate their progress in the subject knowledge and, especially, in the subject competence. The intended outcome is experimental literacy, that can, hopefully, be also instilled in our teachers’ students.

The more detailed report from the program, the way it is realized and the outcome of its several editions will be presented.

Towards Effective Teaching of Weight and Gravitation at Schools

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Several researches in physics education demonstrated the problematic status of teaching the subject of gravitation and weight as well as of the knowledge of students at schools with respect to these concepts. Our study revealed the disruptive teaching of the subject in Israeli schools. Basing on that finding, we introduced the novel contents of teaching this subject (Galili 2001) and used for that the innovative method of Thinking Journey (Schur & Galili 2007). The latter is based on a dialogic teaching in the context of an imaginary journey. This paper presents several findings of a study in which we account for the results of application of the new teaching in several 9th grade classes (N=141). The study followed the pilot study applied on 14 students in 7th grade. Basing of the result of the pilot study, the experimental instruction addressed the representative set of physical situations, which can facilitate students’ construction of adequate conceptions of Weight and Gravitational-force. We were sensitive and tried to follow up: (a) The conceptual change from the alternative, pre-instructional knowledge in this conceptual domain, to the scientific one, implying construction and adoption of the adequate concept definitions and their application to particular situations; (b) The emerging ability of middle school students to distinguish between Weight and Gravitational-force and the
effectiveness of the applied teaching method to promote such conceptual differentiation; (c) The extent to which operational aspect of knowledge can help students to comprehend and analyze novel physical situations. A written open-format qualitative questionnaire was used to collect the data which were analyzed by means of quantitative (statistical) and qualitative (scheme-facets) tools. The same questionnaire was applied to 91 high school physics students who were exposed to the regular currently adopted way of teaching the subject of weight and gravitation in Israeli schools. The comparison between the students, although of limited validity as a control group for the different format and contents of instruction, may still be indicative with regard to students’ conceptual learning (conceptual change) in the subject of Weight and Gravitational force.

Simple mechanical model for phase transitions

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Usually the first experience with phase transitions is connected to the most spread substance on the Earth – the water. The melting of ice/snow and the boiling of water are the first phase transitions we are facing with in an everyday life. Through these phenomena we become aware of liquid, solid and gaseous phases of water.

The awareness of phases in other chemical substances is often compared to the properties water. When the states of matter cannot be connected to students’ experiences with water students are often in lack of knowledge and intuitive notions on these phases. An everyday example of these phases is liquid crystalline phase which can be found in displays of phones, notebooks, televisions, etc. Even though the liquid crystalline phase is ubiquitous, the results of the survey [1] show that undergraduate students are not familiar with the existence and properties of liquid crystalline phases. Moreover they recognize only the states of matter which they were already able to recognize on the primary school level. Although they use, experience or meet the technology that includes liquid crystals, magnets, superconductors they are not aware of ferromagnetic, superconductive and liquid crystalline phase of matter. Liquid crystalline states are for most of the students a complete discovery and even a surprise in the physics courses within undergraduate studies.

On the undergraduate level the liquid crystals can be used as an introduction and illustration of phase transitions in general. The thermo dynamical properties of matter in a vicinity of phase transition are rather abstract and seem to be difficult to visualize. For this reason it is worth to help students with a simple mechanical model. Although the model was developed for liquid crystals it can be used as a universal model for phase transitions at secondary school level as well as in undergraduate and graduate studies.

A mechanical model is a simple device made out of helical springs and/or elastic rods. Using the mechanical model one can visualize the difference between the first and the
second order phase transitions. The analogy between the mechanical model and phase transitions in liquid crystals will be discussed and generalized to other phase transitions. The parameters of the simple device (length, frequency, moment of inertia, amplitude, incline …) can serve as an analogy for the parameters in the theories of phase transitions [2, 3]. The simple mechanical model is also convenient for the presentation and visualization of liquid crystals ordering and can replace or supplement the commonly used computer simulations and animations.


Technological devices for physics approaching

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The technological devices actually used are the result of physics research in the past century.

The advancement in our life depends on current investigations, quantum effects, nanomaterials and other fields of the science bases on the current experiments, which a very important way to approach to physics is the technological retrospective.

Using interactive activities we try to explain how the modern appliances work, and for the most part, the way physics laws make them work.

Demonstrating basic principles of common used devices, we make a direct interaction between participants and scientists, or others mans of science which innovations facilitate the daily.

Actually the interaction has been adapted to the new ways to learn, actual multimedia sources are black boxes fills of indecipherable things. Now the use of new things don’t require knowledge of how it works.

The technological exhibitions are portals for the interaction, places where one can get in touch with new technologies, but they don’t offer explanation of the inner workings of all these innovations.

The robotic hall and technological by interaction activities search illustrates how physics is elemental for our life and why is so important the research on their new fields.
Starting with activities relates with the electricity, explaining what is the voltage and the electric current and the principal way to move the electric potential.

Then we aboard the semiconductor technology beginning with the diode, and the transistor, demonstrating how it works, and how it’s used to process data.

The statics machines are daily technological devices but with a transparent coverage with labels on the main components explaining what its function and what is the basic physics found that explains how it works.

**Semantic Analysis Based on Conceptual Meta-Model of Cognitive Architecture of Concepts**

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Physics education in the communicative conception is defined as the continuous transfer of the knowledge and methods of physics into the minds of individuals who have not participated in creating them. This process, called the didactic/educational communication of physics, is performed by various educational agents – teachers, curriculum makers, textbook designers, university teachers and involves teaching and instruction at all levels of the school system, the learning and cognition of pupils and students, the assessment and evaluation of learning outcomes, curriculum composition and design, the production of textbooks and, in addition, university education and the further training of teachers. The educational communication is carried out by the curriculum process of physics, which is a sequence of variant forms of curriculum mutually interconnected by curriculum transformations [5].

The semantic analysis and semantic mapping based on the triangular model of cognitive architecture of concepts [4] enables curriculum makers, textbook designers and teachers to visualize complete structure of scientific/common concepts and their semantic frames for the purposes of curriculum creation, textbook design, and, in addition, for better understanding of key concepts in instruction and learning especially in the model based instruction [3].

The triangular model of the cognitive architecture of concepts is a conceptual meta-model which shows a specific structure of common and scientific concepts and their semantic frames as basic cognitive units of conceptual models [1, 2] used as human tools for cognition in science, mathematics, and in everyday life. This structure consists of the concept core, concept periphery, the semantic frame, and the relations among all the components of this structure. The semantic frame consists of the meaning and the sense of the concept. The meaning is a set of all subordinated concepts and images. The sense is a set of all concepts which can be meaningfully connected with the given concept.
core in speech, thought or symbolic expression (except for subordinated concepts). The meaning and the sense are two disjunctive sets. Three developmental levels of common and scientific concepts are presented in a frame of the model: empirical, exact, and formal. The empirical is provided as level of the common concepts. The exact and formal are provided as levels of the scientific concepts.

The semantic analysis of several physics concepts at the scientific (exact and formal) level and at the empirical level for primary and secondary school will be designed.

1 It means the conceptual, intended, and project (written) curriculum.
2 Instruction and learning goes in a frame of the operational, implemented, and attained curriculum

**Keywords:** cognitive architecture, concept, conceptual model, conceptual meta-model, semantic frame, level of concept, semantic analysis.


**Video-analysis of flight of a model aircraft**

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In recent years, many research studies have pointed out that modelling environments, based on Information Technology, can supply effective pedagogical strategies dealing with complex real-world systems and everyday problem solutions. At the same time, physics teachers have discovered that video analysis is a relatively inexpensive and
worthwhile method of studying «real world» examples of phenomena. This kind of approach is often adopted to analyze sports physics.

The study of physics of aircraft flight can be considered a real-world topic belonging to the everyone’s common experience. For this reason, here, we use a video-analysis software in order to measure the main dynamic variables, like speed and pitch, describing the longitudinal behaviour of a radio-controlled model aircraft during the take-off, cruise and landing. These experimental results are compared with the theoretical steady-state configurations obtained by using the phugoid model for longitudinal flight. According to this model, the airplane is considered as a point mass subjected to four forces (weight, lift, propulsive thrust and drag), being the direction of all the forces in the model, except weight, dependent on pitch. The discussion is also carried out by showing the trajectories of the aircraft in the phase space. The most relevant effects on the model aircraft flight caused by actions on the radio-controls are examined and explained in terms of aircraft parameter variation. From a pedagogical point of view, this kind of tool can be used to build up several inquiry-based proposals aimed at making students aware of the reasoning procedures to describe, formalise and explain the behaviour of some real systems as the airplanes.

**Developing Pre-service Science Teachers’ Technological Pedagogical Content Knowledge through Microteaching Lesson Study by Utilizing Inquiry Based Interactive Computer Animations**

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The purpose of this study is to explore the development of pre-service science teachers’ technological pedagogical content knowledge (TPCK) in a computer aided science teaching course. During the course Microteaching Lesson Study (MLS) is used to develop pre-service science teachers’ TPCK. In an MLS a group of preservice teachers come together in order to design and scrutinize a lesson that targets specific learning outcomes and developed for the purpose of enhancing practical teaching skills. In this study a case study methodology is employed for investigating the following research questions: What is the impact of MLS on preservice science teachers’ TPCK? How is MLS providing opportunities for enhancing teaching skills? How can MLS be improved to meet the needs of the pre-service science teachers? During the study eight groups, each with three pre-service science teachers, teach the following physics topics from the upper primary curriculum by using inquiry based interactive computer animations (IBICA): subjects of mass and weight, electrical energy, mirrors in grade 6; subjects of absorption of the light, energy and frictional force, electrical current in grade 7; sub-
jects of density, properties of voice in grade 8. One cohort of 43 sophomore pre-service science teachers are the participants of this study. During MLS participants work in small groups with a computer in order to run the inquiry based interactive computer animations. Teaching to a group of peers (pre-service science teachers) during MLS provide a situated learning environment to experience teaching with technology. The data collection lasts for 8 weeks. As it is typical in an MLS research the following data are collected to determine the development of TPCK in pre-service science teachers’: pre-post interviews; observations during MLS; artifacts (lesson plans, journal entries, KWLH charts, word association tasks). Results and implications towards integration of IBICA in physics education are discussed.

**Keywords**: Physics, inquiry, science, TPACK, interactive simulations

**Motivational Effectiveness of Experiments in Physics Education**

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Physics school experiments play a crucial role in motivation of students. That is why innovation of physics education leads to the accent on physics school experiments. This study verifies the authenticity of motivational significance of experiments in physics and in science education. Physics school experiments can be used in all teaching/learning phases: motivation, exposition, fixation, application and diagnostics. The importance of experiments in physics education is investigated, with a focus on their different educational roles. Our research findings illustrate the fact, that experiments used by physics teachers are not always appropriate and sufficient for development of students’ physics knowledge and skills. We used the method of video-study, which is based on the analysis of video records of physics lessons.

Different kinds of physics motivational teaching techniques can be based on observation and experimentation. From the pedagogical constructivist point of view it is important to select appropriate physics school experiments. Combinations of motivational teaching techniques result in an upgrading of students’ motivation for physics education. Additional upgrade of motivational effectiveness can be realised especially by interdisciplinary relations. Concrete examples of these physics motivational teaching techniques as hands-on and minds-on experiments, application of experiments in everyday life, entertainment-edutainment experiments, science family experiments, experiments supported by ICT, action research based on experiments etc. are presented. All presented physics motivational teaching techniques based on experiments are verified by our empirical research and school practical experiences. These educational applications of physics school experiments can support ungifted students and can help to identify and to develop students gifted in physics. Results of our research should be inserted into
Teaching of energy – Outlines for a vertical curriculum

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Energy is such an important and basic concept that a variety of attempts have been made to introduce it earlier in the thinking of physics. Agreement on the importance of a sound understanding of energy has been accompanied by growing awareness of the existence of serious learning difficulties, even among university students. This has stimulated a great amount of research and discussion about how to teach this field of knowledge (Arons 1999, Duit and Haeussler 1994, Millar 2003, Trumper 1993, van Huis and van den Berg 1993). At the 2008 GIREP Conference held in Nicosia, Paula Heron and Marisa Michelini held a symposium which explored different perspectives on the need for a vertical curriculum on energy, starting from the elementary grades. Many educational researchers assert that the energy concept should be introduced as early as possible, and a vertical curriculum about energy starting from the elementary grades should be developed. The outlines of such a curriculum, from primary up to secondary school, are presented in this paper. The rationale underlying this proposal is based on the following premises:

1. The overall pattern of students’ conceptual development shows that younger students associate energy mostly with living things and processes. (Liu and McKeough 2005).

2. Students from a young age need to acquire a qualitative and scientifically valid notion of the concept of energy, which can be elaborated gradually so as to become more quantitative and increasingly aligned with scientifically accepted ideas.

3. Through the history, the abstract energy concept became meaningful only by the establishment of the principle of conservation of energy in all its generality (Elkana, 1974) and it should be taught as such (Feynman et al., 1963).

Three hierarchical and spiral stages of concept development are proposed:

1. A descriptive, semi-quantitative stage (grades 5-7, ages 10-13).

2. The scientific, quantitative stage — «learning energy through its conservation» (grades 8-9, ages 13-15).

3. In the more advanced study of physics, energy should be treated as an already defined concept. Its forms, quantitatively defined in stage 2, should be used as part of the set of «initial concepts» which serve as a starting point for the structuring of a new theory (like mechanics and thermodynamics) and for the defini-
tion of certain new concepts (grades 10-12, ages 15-18).

Such a vertical curriculum is a means by which students, as they progress through school, can revisit topics at more sophisticated levels in a spiral way. In the specific case of the concept of energy, several guiding principles for all stages seem appropriate.


**Different types of physics statements:**

**How and why to choose them?**

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Comprehension implies the construction of different levels of mental representations. We propose a comprehension model for Physics that posits the existence of three levels of representation with different ontological elements and different levels of abstraction: A Situation Model (referential, non-abstract world representation of objects and events), a Conceptual-Physics Model (abstract, in terms of laws, principles and scien-
Expert physics knowledge implies the construction of these three mental representations and the two-way transition from one to another.

Our aim is to study how efficient academic problems are in the classroom to create these expert skills in physics students. Most of these problems are word-problems, i.e. problems with a small story statement. Our hypothesis is that the particular statement characteristics of the problems affect the problem solving processes and therefore, the skills to be developed.

A small sample of academic physics professors participated in an exploratory study on problem solving skills. Subjects were audio and video-taped during a problem-solving interview. Records were analyzed to study similarities and differences in the solving processes of different types of word-problems.

We use a set of two pairs of problems in the study. In every pair, both problems involve the same physics subject-matter and the same suitable explicit/implicit physics model. In other words, one statement tells a story in terms of ordinary world terms (objects and facts) but the other statement tells the story in terms of physics concepts. A set of indicators were used to determine the number of actions and time spent in each stage of the problem-solving processes.

The analysis of the interviews supports the hypothesis that differences in statements generate different solving processes. Differences appeared associated with Conceptual-physics modeling skills. This highlights some significant differences to be considered by teachers when selecting problems. We discuss criteria to guide the selection of one or another type of statement.

1 Partial results were submitted to the AAPT 2010 Summer Meeting.

Model algorithm for applying situational methods in physics teaching for medical students

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As one of the sciences, creating the scientific basis of medicine, physics is taught worldwide as part of medical curriculum. A major problem in modern medical education is the successfully integration of the basic (“pure”) and applied sciences into the medical curriculum. Therefore in medical
faculties in Bulgaria the course in physics for medical students is profiled – students are introduced to new and widely used physical methods in diagnosis and therapy, the influence of physical factors on the human body and physics principles of a number of medical devices and applications. However profiled training, the motivation of students in the study of this discipline is not high, because the lack of interest and of physical knowledge does not allow students to connect more meaningful physical terminology and mathematical apparatus used in the actual phenomena to understand the nature and role of the achievements of physical science for the development of modern medicine. This requires the introduction of non-traditional, innovative educational forms, methods and approaches, in combination with traditional in order to better utilization of the curriculum, increasing student interest and motivation.

Modern methodological systems give preference to productive and creative activities with active participation of students in the learning process. Therefore, recently more and more widely are available so-called situational methods – problem-solving situations and case studies, didactic games etc., that motivate and stimulate activity of students in the process of acquiring knowledge and skills [1-3].

The main purpose of this study is to create a model algorithm for applying situational methods, training and activating cognitive activity of medical students in learning physics case-method end didactical games.

The model algorithm is created keeping in mind that is must determine: the developing of physic case studies and games for medical students; order of the stages of training and arrangements for monitoring and evaluation of knowledge. The main methods used in this study are: pedagogical observations – open, direct and indirect; surveys, interviews and discussions with students and teachers in different stages of experimental research; educational experiment to verify the developed theoretical models of case situations and didactic games; different methods for monitoring and evaluation of knowledge, statistical methods etc.

In determining the content that is the basis for the realization of the chosen situational method, it is necessary to meet the following requirements: information in the didactic material must be relevant and scientifically accurate; it has to:

- be with an interdisciplinary nature;
- contain elements of unexpectedness;
- relate to the life experiences of student and enrich its objectives;
- be up to date;
- ensure activation of a wide range of participants etc.

Based on the established algorithm specific materials have been developed for situational methods – case studies, events and games, including the necessary physical knowledge in the form of complex problem situations, which could be used for the development of creative, logical and associative thinking of the students and for creation of similar algorithms in the training of students and other basic science course in medicine.
Besides science centers, museums, and field trips, a new type of informal learning facilities has been established throughout Germany: extracurricular science laboratories for school students. In these labs, school students usually participate in one-day science projects, which are more formal than visits to museums or science centers, but which are still informal in comparison to school instruction. Founded and run by universities and other research institutions, these science labs aim at a. supporting schools in teaching modern science topics and concepts, b. at increasing students’ interests in science, and c. at gaining future university students in science and engineering domains (Guderian & Priemer, 2008; Priemer, 2008; Priemer, 2006). Many science labs for school students also follow more or less explicitly the aim of positively influencing pupils’ views about the Nature of Science (NoS) and therefore also of „improving` young peoples’ images of sciences, which are often inadequate (Lederman, 2006). Thereby, authentic learning environments of field trips are often believed to transport adequate epistemological beliefs more or less “automatically”. However, studies allow the conclusion that adequate beliefs about the NoS cannot be conveyed without being made an explicit topic of discussion (Lederman, 2006; Uhlmann & Priemer, 2009). Therefore a project, which directly and explicitly combines both, physics knowledge and the reflection on NoS, has been developed. The main focus lies on the experimental work at school and at research institutions. Apart from experimenting by themselves, the pupils also actively communicate with scientists of the faculty in interviews about physics content and about various ways of gaining knowledge (Uhlmann & Priemer, 2009). Beside this epistemological focus in the project, there is also a focus on the field of plasma physics. The pupils do experiments with plasma spheres. By using a common hand-spectrometer the pupils answer the question, what gases the plasma sphere contains. In a pre-post-follow-up-design the general research interest is to show that it is possible to convey sub-dimensions of NoS aspects in relatively short instructions in combination with physics contents in a science lab by making them an explicit topic of discussion. More than 200 pupils participated in an exploratory study which aimed at answering, amongst others, the following question:
Which views concerning scientific experiments in research institutions in contrast to experiments carried out at schools do students at the age of 16-18 have, and how do these views change if they take part in an authentic, explicit and reflexive project addressing aspects of the Nature of Science? To measure the views about NoS of the chosen subdimensions, a paper and pencil test was developed and used. Several control-variables, such as “interest in physics”, “gender”, “content knowledge in general”, “content knowledge in plasma physics” and school-marks were gathered, as well.

The results show that it is possible to change pupils’ views about NoS in relatively short interventions (about 6h project) as long as the NoS focus is well dimensioned and an explicit topic of discussion. Furthermore, the study revealed the conclusion that the additional focus in the field of NoS (together with the content focus) does not affect pupils’ learning of physics contents. The influences of the above mentioned control variables on pupils’ views about NoS and the change of these views during the project will be put forward to discussion. The possibility of transferring these results to other informal learning facilities and to school will be discussed in the talk, as well.

TPCK – a prerequisite for successful integration of technology into the classroom?

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The recent implementation of technology in the classroom is probably one of the most challenging innovations that many teachers have to confront today. A growing number of studies are discovering that both new and experienced teachers feel inadequately prepared to use computers and other forms of technology in their classrooms (VILLEGAS-REIMERS, 2003).

Recent review of the effect of ICT (Information and Communication Technologies) teaching activities in science lessons has shown that teachers will need training and continuing professional development in the use of ICT to carefully integrate ICT into the teaching and learning process and to be able to provide appropriate guidance (HOGARTH ET AL., 2006). Key findings from a review of studies of ICT impact on schools in Europe show that teachers do not yet exploit the creative potential of ICT and do not engage students more actively in the production of knowledge (BALANSKAT ET AL., 2006).

The thoughtful pedagogical uses of technology require the development of a complex, situated form of knowledge that Koehler & Mishra call TPCK (Technological Pedagogical Content Knowledge) (KOELHLER & MISHRA (2005). Shulman’s idea of Pedagogical Content Knowledge (PCK) for bridging most effectively the relationship between students and specific content, e.g. developing a deep understanding of the content, is
extended to the domain of technology (SHULMAN, 1986). Teacher training should not just encompass ICT skills but rather a full understanding and complete mastery of ICT as pedagogical tools (PUNIE et al., 2006).

A case study is presented: Nine Physics teachers who volunteered for using TI technology in combination with a motion detector used these tools in the classroom in grades 6, 9 and 10 (total of 14 classes) to teach mechanics/kinematics. While the same support (courses, accompanying material, individual tuition) was offered to all nine teachers, not all of them participated to the same extent. Tests taken before and after courses showed that classes progressed further when their teacher was more extensively trained. Teacher training correlated positively with how well students judged the new tools.

Participation in Teacher Training had also a significant impact on students’ enhancement of autonomy, stimulation of activity, experiencing competence, endurance and willingness to achieve and quality of learning motivation. The use of technology seems to effectively enhance students’ learning. Students were actively engaged in learning as they made predictions, took measurements, analyzed their data and made decisions about presenting their work. Beside these motivational benefits the technology-enriched learning environments had positive impacts on the learning outcomes, which were assessed with TUG-K, a test of Understanding Graphs in Kinematics (BEICHNER, 1994).

On some similarities between students and teachers in describing the practical laboratory work

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This paper presents the analysis of interviews with students and teachers about the role of Laboratory Practice (LP) in courses of physics at the Universidad Nacional de General Sarmiento (Argentina).

This research began with the aim of knowing how teachers and students saw the role of LP in university physics courses. Semi-structured interviews were conducted for teachers, for advanced students and for students who had finished their first university physics LP one week earlier. The interviews had been analyzed separately. This paper presents a cross analysis of both sets of interviews.

Some results of the students’ interviews (Montino et al., 2008) were that the students:

- have difficulty in understanding the goals set by the teachers, and to give meaning to the tasks and perform LPs in general,
- have some difficulty in describing an LP that they have done. They can describe the procedure for assembling the device and their subsequent actions. They lean heavily on gestures, which may be attributed to a memory of the experience more closely linked to visual representations than to conceptual ones;
- do not show a positive view regarding error calculation. They grade it as the most complex task they had to perform.

In their interviews the teachers mention error propagation and use of statistics as the main teaching goal in an LP. They are identified as essential topics in basic courses and become the purpose which justifies the implementation of LPs (Antúnez et al., 2008).

The difficulties of the students to describe an LP can be attributed to the fact that they do not identify its aim. Teachers do not show clarity about which LPs they have used in their classes. When they try to describe an LP, they are unclear and they gesticulate like the students. This was striking because we assume that teachers do know the purpose of the practices they perform. We also note that teachers do not distinguish between the LP’s didactic objective and its scientific one.

It is interesting to note that, upon hearing that there will be an LP, students often express disgust. But in the interviews they say that the LP was useful and that they liked it. When teachers evoked their LPs as students, they had unpleasant memories because of their complexity and demands. Despite that, they tend to repeat the classical LP format.
These similarities show that we must rethink some of the assumptions made when analyzing the interviews separately. There are new questions and new scenarios:

- Both students and teachers will resort to procedural and gesture descriptions when they have no clear goal of the LP.
- Teachers may be very clear about the purpose (teaching error propagation), then which LP is implemented becomes irrelevant because it is a means to an end and therefore they do not remember it nor can describe it.

LPs are indeed a complex situation with many variables. They are full of uncertainties for students and, surprisingly so, also for teachers.


**A modelling learning path, integrated in the secondary school curriculum, starting from the initial phases of physics education**

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**Problem definition**
Attention for modelling in physics education is growing. However, educational results of modelling activities do not always meet expectations. Students do not automatically connect contexts, models, experiments, concepts and underlying theories (Doerr, 1996; Schecker, 2005). More insight is needed into the way students can develop skills and understanding of mathematical and physical concepts by means of modelling (Lijnse, 2006). A series of modules in which aspects of modelling can be addressed one by one is required (Ormel, 2010).

So far most research has been focussed on modelling at the highest levels of secondary education and on a project base. Preceding curricula do not prepare for, or anticipate on modelling. In this study we investigate the effects of integrating modelling into the physics curriculum right from the start, which in the Netherlands is in the second year of secondary education (13-14 years). We combine modelling with experimenting, video measurements and animation, in order to make the connection between concepts and contexts in an explicit way.

**Research questions**
The underlying research question is:
How can a combination of measurement, modelling and animation help to bridge the gap between realistic contexts and the relevant physical concepts and methods in school practice?

Secondary questions are:

- What is a good sequence of steps on a modelling learning path?
- What conditions should be fulfilled for each step?

Important aspects of modelling are the interpretation of graphs and the evaluation of results. Therefore, important secondary questions are:

- How can a combination of measurement, modelling and animation be used as a tool for students to learn to interpret graphs?
- How can a combination of modelling and experimenting be used to stimulate students to evaluate their results?

Method

Educational materials on kinematics, energy, vibrations, dynamics, and heat have been developed for the second and third year of Dutch secondary education, as a kernel for the modelling learning path. We made use of the possibility of our learning environment, Coach 6, to connect graphs, sketched by students, to models and animations.

We have tested these materials in class-room. Observations, audio-recordings and screen recordings were made of multiple student groups. In addition, written materials and assessments have been collected.

Results

Results indicate that developing modelling skills in this holistic way at this age is possible. Not too many new concepts and skills should be addressed simultaneously. The integration of modelling in the curriculum changes the way of physics teaching in some aspects. In our paper we will discuss these and more results.


**Keywords**: Modelling, Learning path, Animation, Graphs
A photonic crystal consists in a periodic arrangement of low-loss dielectric media having different refractive indices. In this case the reflection of light at the interfaces produces the same phenomena for photons as the atomic potential does for electrons in a solid state crystal. A primary characteristic of the photonic crystals is the existence of a photonic band gap, that is, a frequency interval within which, for certain directions and/or polarizations, light cannot propagate through the periodical arrangements and is completely reflected. Study of 1D photonic crystals is crucial for the development of a wide range of optical devices such as sensors, filters, switches and lasers. Just as in solid state crystals, if defects are introduced in the photonic structure, then allowed modes for light propagation appear in the gap, that is, crystal defects can confine light in localized modes. In our case we translate the study of photonic crystals to the electromagnetic wave propagation in a coaxial cable because it can be a very illustrative approach to the study of waves at the undergraduate level. We show how to make a one-dimensional photonic crystal by connecting several segments of coaxial cable with distinct characteristic impedances. With the same type of arrangement we have also studied the number and location of defects in the lattice. In summary these types of experiment on one-dimensional photonic structures are simple systems that require inexpensive equipment, -which is available in most laboratories-, represent a way of experimentally investigating wave propagation in locally periodic media and provide a good introductory analysis toward understanding the three-dimensional photonic crystals. These experiments are useful for designing teaching experiments for physics and engineering students in order to explore the effects of multilayer dielectric optical coatings, and wave interference phenomena in locally periodic systems.
An undergraduate modern Physics Laboratory Course for Physical Engineering Students

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The engineering students at the undergraduate level at the Universidad Autónoma Metropolitana Azcapotzalco (México) attend to courses where usually the teacher explains both theoretical and practical concepts. In this type of courses the students are not keen on doing bibliographical research, nor reading book sections or introductory scientific articles. They use their computers only to “search” for an answer, and frequently they just “copy and paste” the required information via the web. A more critical situation occurs in the Modern Physics Laboratory course (part of the Physics Engineering curriculum), which consists in one three-hour session per week during a trimester period. It is the only laboratory course dedicated to Modern Physics, and it is hard to explain to the students the basic concepts of the quantization of energy involved in the experiments if they do not have a previous or at least simultaneous theoretical course on modern physics. The typical experiments in the modern physics laboratory take several hours to carry out and in some cases the students need to repeat the experiment because they applied a defective technique, or because they did not get any useful data. In these circumstances the students need to exercise extra care when performing the experiments again, but this is boring for them. With the aim at solving the aforementioned problems, we take a modern approach: we decide in favor of the automation of the experiments by means of Virtual Instruments, using the hardware and LabVIEW software both of National Instruments to collect the data and control the instruments in the experiments. As examples, in this work we present the Franck-Hertz, Photoelectric effect, and Ionization Potential experiments implemented in this manner. Now the students set up the experiment and collect the data in less than one hour. The students are involved in at least three experiments during a trimester. Into the same course we have organized a seminar after each experimental session, where we discuss how modern physics was born and developed, and observe how the students explain the experiments they conducted in the previous session. It is a very good experience for the students to learn modern physics in a discussion class, where all the students and the teacher are involved and can formulate and answer questions. It is possible that at the beginning of the course the students have misinformation or misconceptions but, as the course advances, they feel more confident and really try to understand modern physics concepts. They are allowed to use diverse multimedia material to expose their ideas and results. They are invited to elaborate for each experiment a Power Point presentation, where they may include pictures and in some cases videos from the web, and most importantly, they can explain in this way their work and results to their fellow students. In this interesting approach, we reduce the number of experiments in order to have enough time to discuss the experiments.
Prospective primary teacher facing the relative motion and PCK analysis

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The approach focused on the intersection of subject content and teaching methods (PCK-Pedagogical Content Knowledge) allows to identify the distinctiveness of the body of knowledge needed for teaching (Shulman, 1987). During the course of Physics for Educators for prospective primary school teachers in Udine, study of the relative motion and a PCK test were proposed to second year students. This activity, aims to give them an awareness of which are the conceptual knots that characterize the specific thematic and which are the ways to address them.

As part of the course, particular attention was given to the analysis of cinematic and dynamic aspects of the relative motion and, in order to analyze the conceptual knots, it was suggested to analyze particular situation.

As regards the relative motion is analyzed the need to start immediately with a discussion of two-dimensional problem. This frames the problem of the motion by means a vector description and requiring attention to the role of the reference system in the study of motion. That allows to prevents the born of misconceptions concerning the definition of the reference system (which often is identified with its origin) and the principle of composition and decomposition of displacement vectors of motion (one-dimensional treatment can’t address it effectively). Moreover, face two-dimensional problem, prepares students to the analysis of relative motion by means the compositions of motions.

The activity of PCK has also allowed prospective teachers to explicitly and address conceptual knots on relative motion allowing them to develop the skills necessary to follow a learning path specifically designed to prevent the occurrence of the treated misconception. In this way teachers learn to reinterpret the subject that they had to teach basing on the different dictated by the students’ preconceptions (Anderson, 2008).

Exploring the sources of magnetic field and the interactions between them to interpret electromagnetic induction: a proposal of conceptual laboratory

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Today electromagnetic phenomena are part of everyday life. Scientific terms as “magnetic poles” and “magnetic field”, become part of the common language. This popularization of physics terminology however has been obtained through a loss of accuracy than what is their real physic meaning. In scientific knowledge the problem of the correlation between the everyday and the scientific knowledge is one of the main problem of learning (Pfundt & Duit, 1993), is therefore necessary to project inquired based learning path (McDermott, 2004) in which students are personally involved in minds and hands-on experimental activities (Michelini, 2005). With the aim to investigate how pupils develop interpretative ability to explain situations and artifacts from the results of several phenomenological investigation of physic quantities, an experimental activity was done in an informal context during a science festival – Mediaexpo2009 – involving 155 middle school students (from eleven to fourteen years old). Initially, pupils, following an inquired based learning path, use compasses as explorers of the magnetic field to perform a series of investigations that allow them to recognize the presence of the Earth’s magnetic field and the presence of other magnetic field around some everyday objects. Starting from the identification and the cataloguing of the objects that having a magnetic field, students highlighted the presence of a magnetic field each time that an electric current is present within an object (i.e. the presence of an electric current implies the presence of a magnetic field). Exploring subsequently if the reverse implication is true (i.e. if the presence of a magnetic field implies the presence of an electric current), students, experimentally, observe that the implication is not true and highlight the transient nature of the reverse phenomena identifying the physic quantities and the parameters involved into the process. During the explorative phase students work in small group using inquired based worksheets in which the proposed methodology of experimental analysis is divided into four steps: experimental phenomena exploration, analysis of the observation, organization of the different results and interpretations of the phenomena. After that, students, taking into account their interpretations, had to describe and analyze an artifact. This artifact, in our case an induction torch, is offered to students without any introductive explanation; the only instructions gave to students is concerning the methodology that they had to follow: initially students had to describe the artifact only looking at it, after that, when all group had finished the first part, they can touch it and, if they think it’s necessary, they can improve their first description. Working in this way several secondary goals, or research question, was investigate. In
particular attention is focused on three aspect: 1) how an operative exploration may help students to identified and organize electromagnetic phenomena; 2) how the exploration and the comparison between phenomena is useful to help students in the interpretation of artifact; 3) how exploratory elements are reused by students in the interpretation of artifacts.


Human eye, web camera and physics experiment

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Computer interfaces and sensors are usually needed for effective use of computers in physics experiments. Instead of relatively expensive equipment, in some cases an ordinary web camera or digital photo camera can be used to collect the data, which can be further analysed by a computer program. Comparison of some characteristics of the human eye and a simple web camera in physics experiments is discussed, and some of their advantages and disadvantages are explained. The presented example shows the possibility of obtaining the speed vs. time graph of uniformly accelerated motion. The data needed is extracted from a video record of a trolley moving down an inclined track. Successive changes of the position of the trolley are obtained through the analysis of successive frames from the video, and the corresponding time intervals are given by the frame rate of the video. The simple artificial sense of sight, realised with an inexpensive web camera and a computer program, could be a promising way of collecting data also in some other school experiments, since besides the program one only needs an ordinarily equipped personal computer. The algorithm as a base of the computer program can be short and relatively simple when the video is taken in a manner where the moving object has a simple geometric shape and appears in a good colour or brightness contrast with respect to the background. It can be realized with just a few program lines and is easily understandable to the students.
High speed - slow motion I: new insights for hands-on experiments in mechanics

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There are quite a number of fascinating hands-on experiments which are performed very fast, such that details of the physics behind are sometimes difficult to grasp. A typical example of such an experiment dating back to the 16th century which belongs to the standard repertoire of hands-on experiments since the 19th century [Tis81] concerns inertia. A wooden rod (which may or may not have needles fixed to the ends) is lying on two easily breakable objects, e.g. on two glasses, on two raw eggs or hanging in two paper loops, such that the ends of the stick are supported (see Fig. 1, after [1]).

Fig. 1 left: historic illustration of the breaking stick experiment (after [1]); right: in class demonstration recorded with a high speed camera using 1000 frames per second. The two images are separated by 8 ms.

Hitting the rod in the middle very hard leads to breaking of the rod. Subsequently, the two parts fall down without damaging the supports. This is usually explained such that after breaking either part of the rod is only supported on one side. Due to the pull of gravity it starts to rotate around its center of gravity, thereby lifting off the support. Since the movement is very fast, one is not able to catch the breaking and lifting off with the naked eye. Using however a high speed camera easily allows to study the process in slow motion, revealing the physics behind, which needs another ingredient [2]. The paper will discuss this as well as a number of other selected well known and sometimes less well known surprising hands-on experiments in the field of mechanics in detail. They were analyzed with a modern high speed camera allowing to give correct qualitative and where possible also quantitative explanations of the physics behind. Due to the fast development in camera technology, rather inexpensive cameras with already moderate frame rates are becoming available such that high speed imaging may enrich physics teaching not only in universities but also in schools in the near future.

High speed - slow motion II: more experiments using gases, fluids, heat and electromagnetism

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We present more fascinating hands-on experiments recorded with high speed cameras in the fields of fluid and gas dynamics, thermal physics and electromagnetism. For example, water droplets in free fall oscillate in shape. When hitting a water surface, they dissipate their kinetic energy into first kinetic energy of initial spray but second to the building up of a liquid column, which later separates into droplets (Fig. 1, left). The latter process can be understood quantitatively from energy conservation. In contrast, huge water droplets can be formed by rupturing a water filled balloon. This also allows to study the speed of fissures in rubber (fig. 1, right).

Fig.1 left: Water droplets falling into a glass filled water; right: an exploding balloon filled with water

Two more examples from the field of electromagnetism are the visualization of the 50Hz oscillation of the filament of a light bulb operated with 230 V due to the Lorenz force of a nearby magnet (Fig. 2/left) or studies of spark discharges from a Wimshurst machine (Fig. 2, right). The results of these and other experiments - recorded and analyzed with a high speed camera – will be presented.

Fig.2 left: filament of light bulb oscillates with 50 Hz due to Lorenz force; right: spark of a Wimshurst machine.

Furthermore we will also present first experiences from in service teacher training seminars in Switzerland and Germany focusing on this topic.
Investigating Effectiveness of Multimedia Package in Physics teaching at undergraduate level

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Previous researchers have demonstrated significant improvement in students’ conceptual understanding of basic physics using interactive engagement methods of instruction. In the present study, efforts have been made to convert traditional classroom instructions into active learning experiences using multimedia package in the classroom. We have used interactive multimedia-instruction package to teach concepts of electrostatics in the classroom at third year undergraduate level.

Diagnostic pretests of the materials have been conducted to obtain data concerning students’ understanding of electrostatics. The diagnostic test consisted of 15-multiple choice items. The diagnostic test was administered to 125 students and data was analyzed. The average difficulty index and average discrimination index of the test was found to be 0.42 and 0.32 respectively. The reliability coefficient of the test was $r = 0.704$. After the pretest, the students were randomly divided into two groups; experimental group and control group with 53 students in each group. After the use of multimedia package, the posttests were conducted and pretest posttest data were analyzed. The result showed that the mean score at the posttest of experimental group was significantly different than control group at 0.01 levels. While few misconceptions persist, the overall results indicate that students seem to have acquired a good general understanding of these concepts using such package. Hence, the use of computer-assisted instruction package in classroom is practical, effective and amenable to widespread implementation.

A Discussion about STS through Visits to the Pelletron Particles Accelerator

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Visits to Physics research labs can stimulate discussions about the relationship between Science-Technology-Society. As an example, we can use the exposition work that is been developed at Physics Institute of the University of São Paulo, which involves Physics teachers, under graduation and high school students.
At the present work, aspects related to the selection and organization of the contents to be approached in the visits to the Physics research labs are presented before, during and/or after them. Thus, stands out the necessity of articulating the different contexts involved, regarding the lab and the school.

Under this perspective, members of the Nuclear Physics Department from the Physics Institute of University of São Paulo have been organizing monitored visits to the Open Lab of Nuclear Physics, more specifically, to the Pelletron particles accelerator.

It is understood that this kind of visits can contribute to the beginning of a society which is scientifically and technologically literate, capable of evaluate and act in situations connected to the scientific-technologic development.

Thus, those visits objective is not only to start a discussion about the scientific contents involved on the accelerator’s working process and on the researches that are developed there, but also to make the public more familiar with the building of science itself, which means, with the production of the scientific knowledge context.

This concern implies arguing about some contents and giving up others. The focus debated in this work is about the way we found to select these contents. In other words, we discuss the elements to be considered on the selection and organization of the contents that will be presented in visits to scientific labs. We intend, when we present elements born from practicing, to contribute to the research universe that focus on the development of a science-technology literate society.

The program of the tour starts with an approximately 30-minute multimedia presentation of the research that is done in the accelerator, focusing on the physics phenomena involved in them and on how the Pelletron works.

After that, the visitors will see the 8 floors which the accelerator is composed of, during this time, subjects discussed in the multimedia presentation are brought up again. The visits end with the view of the 0,33 UD prototype, which is a machine smaller than the Pelletron, in that moment, we start the accelerator again.

Important to say that those visits are under change. Since they begun, there have been many visits with students from technical and public schools, teachers from government schools and Physics graduations students. These experiences, added to the results from evaluation questionnaires that are answered by the visitors, are being used in the changes made. One of the results is the necessity of deepening the discussions started during the visits, we understand that these visits can be used as stimulators of the discussions that involve the triad STS, but in order to do that, another discussion becomes necessary, to be performed in the schools context.

Finally, the fact that the discussions presented here refer to a particular context and theme, the Pelletron accelerator, we understand that they can contribute to other experiments of the same nature, which use visits to research centers as a tool to stimulate discussions about the relationship between STS.

1 The prototype 0,33UD, has this name because of its proportional relation to the terminal of the Pelletron accelerator, which is 33% of its original size.
Expectations and Physics Learning of Students with Different Performances

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Studying student expectations about physics, such as the structure of physics knowledge, connections between physics and the real world, approaches to problem solving and to learning physics is important because they influence motivation and affect the selection of learning strategies by students. There have been a number of studies of student expectations showing that correlations between student’s expectations and his or her learning do exist. Students who came to a class with more expert-like expectations were more likely to achieve high learning gains. However, studying correlation between students’ expectations and their learning, physics education researchers ignored considering differences of student performance. It would be interesting to know if there is a difference in correlations of student expectations and learning between two groups of students with difference performance. In our project we attempted to determine if students whose performs differently on physics course are different in terms of the correlations between their expectations and learning and whether their expectation scores as measured by Maryland Physics Expectations (MPEX) survey could be used to predict their learning in a physics course or not. During the first semesters of academic years 2007 and 2008, we administered the MPEX survey to first-year university students in introductory physics course to learn their expectations at the beginning of the course and a conceptual test, the Force and Motion Conceptual Evaluation (FMCE), as a pre/post test to investigate their conceptual learning. Additionally, the student final exam score was used as a part of their learning. We then studied the correlations between the students’ original expectations and their normalized gains they made in the conceptual test and their scores in the final exam. We found differences in the correlations of student MPEX scores and their learning between two groups of students with different performances. The first student group entered the university through the national admission system and the other through the university quota system. Both groups of the students performed significantly differently on FMCE and final examination. The results presented that students with high performance (quota) show significant positive correlations between their expectations and FMCE normalized gains while those students with low performance (admission) do not show significant correlations. The same correlation results between the student expectations and their final exam scores were also found. Thus, it could be concluded from this results that the MPEX scores have better prediction of student learning on those students who have high performance than other with low performance.
Development of Physics Demonstrations in Nagoya University

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The method of science demonstrations is one of the traditional methods in physics courses which have continued from the middle ages [1]. In Japan, physics demonstrations are performed by many of the teachers in order for students to learn physics through experience in a lecture. Physics faculty members of Nagoya University, including us, have also developed and conducted physics demonstrations, however, we have done it independently, and have not shared the knowledge and know-how of physics demonstrations among ourselves in the past.

In response to this state of affairs, we have developed a handbook to share the knowledge and know-how of the physics demonstrations in Nagoya University. The methods we used to develop the handbook is as follows: surveying the articles concerning physics demonstrations ([2,3] etc.), doing interviews to the physics faculty members in Nagoya University, doing action research to develop physics demonstrations by ourselves. We have summarized accumulated knowledge and know-how and have edited the handbook fitting to Nagoya University.

The summarized knowledge and know-how consist of two parts; one is the characteristic feature of the outstanding physics demonstrations, for example: to be associated to daily experience, to be simple in structure, to be checked by the faculty members, etc. Another is the method to conduct the physics demonstrations effectively, for example: to set the clear objectives to conduct demonstrations, to offer more opportunities for students to think about the demonstrated phenomena, etc. In this talk, we explain these knowledge and know-how, and show a few of concrete examples of physics demonstrations which we have developed in this study.

The faculty members in Japanese universities have not often developed physics demonstrations collaboratively. Nor have the methods of developing and conducting physics demonstration been paid attention in Japan. One of the features of our study is to address these affairs from the dual-views, from the physics researchers’ view and from the higher education researchers’ view.

As future works, we have plans as follows:

• Investigating the scales and the methods to measure the effectiveness of using the science demonstrations for the teaching and learning science
• Building a server to share the knowledge, know-how and videos of physics
demonstrations, which is easier to be accessed and to be updated than a handbook
• Holding workshops on physics demonstrations in Nagoya University with the
physics faculty members in universities around Nagoya to accumulate more
knowledge and know-how of physics demonstrations

We would also like to report the state of these plans.

[3] D. M. Majerich, J. S. Schmuckler and K. Fadigan, Compendium of Science Demonstration-

Case-based Learning in Physics for Future Physicians

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A tendency to integration of basic and clinical science and practice exists in
modern medical education, but this integration has never been easy.

In the medical curriculum in Faculty of Medicine in Sofia University the disciplines are
ordered from basic to clinical training with increasing complexity and clinical orienta-
tion. Although profiled, training in most of the preclinical disciplines, including phys-
ics, do not lead to high motivation of medical students and to their active participation in
the educational process. The reasons for this fact are varied and are the subject of much
comment in the literature [1].

Therefore a number innovative educational methods are used to encourage active
rather than passive learning by individually according to the needs of each student.
Teaching methods must be appropriate for the curriculum in medical school with less
emphasis on factual knowledge and more on scientific and professional kopetentnost
which would require future medical practitioners.

Case method is extremely popular method of training, repeatedly proved its effective-
ness. It is widely used in the training of managers, humanities, medicine. The main
advantages of the method are: requires acquisition of new scientific knowledge to solve
the problem raised, work on development of analytical, associative and combinative
thinking; moisture emotions that make teaching attractive, help people make decisions
etc., which are extremely valuable in building an excellent future physician.
We apply this method in Faculty of Medicine of Sofia University striving for awakening the interest of medical students to classes in physics, as our cases have medical orientation. In the present study the opportunities of applying of case method in teaching physics to medical students in order to stimulate interest in the subject, and analysis of the efficiency of this method, are under investigation.

In the course of carrying out scientific tasks of this pedagogical experiment we used different methods such as interviews with students, incoming and outgoing tests etc. The work is concluded by analysis and assessment of the results obtained.

The results show that the use of case method substantially increased interest of medical students to the physical knowledge. They adopt a lot more knowledge with big will, as evidenced by very good results in evaluation. An inquiry with the students shows that students approve this method of teaching. Case method proved very suitable for the development of creative, logical and associative thinking of the students, promotion of self-education, critical thinking and evaluation of scientific evidence [2].