Challenges and solutions

Plugins and apps for effective teaching

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SEFI - Société Européenne pour la Formation des Ingénieurs

PWG - Physics Working Group

I3N&IT&UA - Institute of Nanostructures , Nanomodelling and Nanofabrication

CIDTFF - Didactics and Technology in Education of Trainers

Editors Foreword

Challenges and Solutions, Plug Ins and Apps for Effective Physics Teaching, is addressed to all those who are interested in physics education. The contributions published here were presented at the 8th International Conference Physics Teaching in Engineering Education organized by the SEFI Physics Working Group and I3N, IT and CIDTFF of Aveiro University.

For the PTEE 2014 conference edition a more activating format was chosen. It consisted of a set of flexible workshops dedicated to the topics of Great Successes in Lectures and Labs, Activating Students in Large Enrolment Courses, Project Based Learning, Video Analysis and Open Themes. The various addressed communications were mainly focused on successful case studies, problem methodologies, students and teacher strategies, project environments, video solutions, pre-lecture assignments, homework, concept mapping and optical tools. In addition, a preconference workshop was dedicated to the engineering education potentialities of historical physics instruments.

PTEE2014 aimed to discuss effective physics teaching and to explore innovative solutions for next future challenges. We hope it will contribute to a more active and societal European networking in engineering physics teaching.

João Lemos Pinto, Chair PTEE2014
Greet Langie, SEFI PWG President

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Pre-conference workshop

Historical physics instruments - engineering education potentialities

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Abstract

In this workshop we will present some arguments to revisit historical instruments that have potentialities in the physics teaching of engineering education.

We will seek to inform and question the importance of different instruments, identify statutes historically assumed and analyze one or two cases where developments paved the way for issues such as the accuracy of measurements or the identification of properties of matter, topics of interest in the physics teaching context.

Keywords: Historical instruments; Physics teaching; Technology; Educational potentialities.

Summary

Old scientific instruments still enable a wide range of study for the historian of science, to the extent that in them converge knowledge and scientific / technical practices, revealing the context in which they have been designed and used, and on their protagonists.

Frequently they also allow a clearer demonstration of the concept(s) and/or property(ies) when compared with the modern black boxes.

They give evidence of the evolutionary path of experimental science in its own, and are important testimonies of the scientific culture in which we are immersed.

All these aspects are of great educative interest.

Introduction – Historical contextualization aspects

Modern science came up with a new paradigm: that it is possible to know and master nature through experimentation and through the use of instruments designed in purpose, combined with a possible mathematization of the observed phenomena.

The new scientific practice makes use of "objectives, specific languages and methods" that determine "attitudes, expectations and behaviors in the scientific community members themselves". For accomplishing this it makes use "of instruments that will allow a controlled experimental observation as one of the conditions for validation." However, before relying on the information given by these "artificial means", there was need to face them with skepticism until "the device could be accurately and thoroughly tested".(1)

Since the sixteenth-seventeenth centuries the use of scientific instruments formed the basis for legitimacy of research on natural phenomena, enabling the experimental repetition everywhere which led to the "acceptance of modern science as the cognitive device inherent to the culture of modernity."(2)

The status conferred to instruments differed over the centuries since the modern age. To philosophical instruments were assigned a greater importance compared to mathematical and navigation instruments, as those should illustrate the truths of nature. Their use was intended for the philosophers. The practitioners, cartographers, engineers, astronomers, navigators would resort to the other type in their practical tasks of measurement.

The emergence of the term 'scientific instrument' was studied by Deborah Warner, who dated the appearance of the English designation in the nineteenth century, motivated in part by commercial interests.(3, 4) Many of the objects that are now described as scientific instruments were produced and designated in the seventeen and eighteenth centuries, as 'mathematical', 'optical' and 'philosophical' instruments. To some extent these distinctions were related to instrumentalists' corporations, reflecting some specialized manufacturing practices from the standpoint of business and marketing. These designations also evolved over time.(2)

During the nineteenth and twentieth centuries, terms like 'science' and 'scientific instruments' were gradually and increasingly been used in contexts in which expressions like 'natural philosophy', 'experimental philosophy', and 'philosophical instruments' would have prevailed in earlier periods. The new terminology has been slowly adopted and replaced, while a set of objects described as scientific instruments also developed.

Maurice Daumas, historian of scientific instruments, was one of the first authors to emphasize the importance of natural philosophers and their artisans in developing a new culture where scientific instruments began operating.(5)

The nineteenth century witnessed, in a line clearly admiring and believing in progress, the importance of giving particular attention to science areas, in order to provide a new and solid education.

The attention to experimentation led to the acquisition of instruments whose function was to illustrate the phenomena or the start to the measurement techniques made possible by them. The reference to didactic/teaching instruments points out to those considered as "designed to show various physical effects and to assist the exposure of a scientific issue."(6) It often indicates they needed to be robust, of appreciable size, and made of good materials. Recalling Ganguillem, and on the diffusion of new scientific concepts, he held the nineteenth century as the popularization of science century.(7)

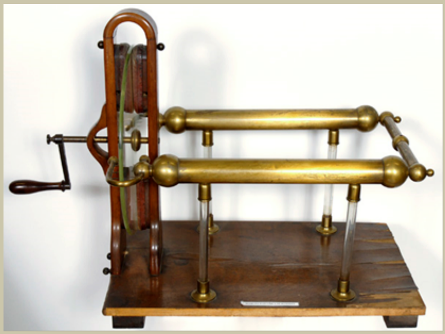
The action of a didactic instrument would not always be a proof for a scientific assertion just its illustration. But diversely, sometimes the important was to practice, to develop competencies of manipulation, measurement, and precision. The focus was using the instruments, put them showing some phenomena and still obtain, in some cases, the possible quantification to verify the subjacent physical law(s). It was then necessary to know the instrument through its description and learn on its manipulation in order to measure and obtain the values that would enable a deeper knowledge of the already established laws. Comparing some of the instruments existent in schools and some old instrument catalogues, one verifies the similitude between more recent instruments[1] (end of nineteenth/ beginning of twentieth century) and some of those used in the seventeenth-eighteenth centuries to illustrate phenomena/similar physical concepts, for instance the Ingenhouz apparatus to study thermal conductivity.[2] Other instruments illustrate or materialize recent discoveries or concepts, and do not possess a former correspondent and/or evolved to the discovery/ materialization of previously unimagined phenomena.

To meet them today is to revisit/ unveil their 'lives' from the objectives that led to their construction, to the producing processes, their inventors/ makers, to their circulation, finding them an educative meaning, old or new, when we look at them under the twenty-first century light or simply when we observe them, just leaving a sensitive approach, following a recent proposal by Arnold and Söderqvist.(8)

In a previous work dealing with scientific instruments, we tried a possible meaningful route connecting Oerstedt's needle with the Schweigger's multiplier, the Bourbouze galvanometer, the tangent galvanometer, Desprez's galvanometer, the one by Weber and by Thompson until the demonstrative galvanometer, the amperimeter and the voltmeter.(10) At the time we also tried the 3D replication using modern communication technologies in order to a better access to those old instruments, completing it with some 'history' and 'functioning' information. At present we illustrate some other possibilities from the ephemeral production of a spark with a friction electric machine to the Volta pile and then to the necessity of conceiving and measure the current and some of the instrumental achievements (Case 1).

Case 1 – Electric current - From its production to its measurement

Producing 'electricity'…



Figs. 1 and 2 – Ramsden's electrical machine and Volta pile - http://baudafisica.web.ua.pt

but … there exists something else (Fig. 3)

Fig. 3. Oerstedt needle http://baudafisica.web.ua.pt

Studying how currents act on each other… with an Ampère's table (Fig. 4) and amplifying the magnetic field with a Schweigger's multiplier

Fig. 4 – Ampère's table – http://baudafisica.web.ua.pt

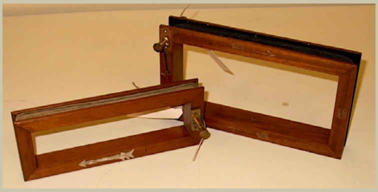


Fig. 5 – Schweigger's multiplier (11)

Fig. 6 – Nobili's galvanometer (11)

Detecting and measuring currents - Galvanometers developments

Two periods can be distinguished in the process of developing instruments able to detect and then measure the intensity of electric current. From 1820, we find out the so called "free 'magnet' instruments" that gave rise to the suspended magnet galvanometers. At first it was necessary to amplify the magnetic field created and that was possible with the Schweigger's multiplier to which followed some galvanoscopes as those proposed by Nobili (1826) and by Poggendorff (1826).

But difficulties arrived in quantifying the intensity of the electric current by deviation of the magnetic needle. Nobili's proposal included an astatic needles system so that the instrument is sensible just to the current magnetic field (Fig.6).

Poggendorf's proposal included an optical ballistic system in a mirror galvanometer to obtain a better measurement of the current intensity (Fig. 7).

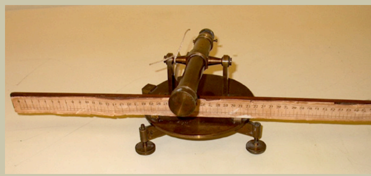


Fig. 7 - Optical ballistic system (11)

However there were difficulties in quantifying the intensity of the electric current by deviation of the magnetic needle, and some modifications were proposed as in the case of Pouillet's tangent (& sinus) galvanometer (1837), Weber's galvanometer (1842) or Thompson's (1851).

Thompson's galvanometer was improved with two smaller magnetic needles inside two coils; a torsion string; it possessed a quicker damping and an incurved magnetic bar to diminish the Earth's magnetic effect.

From 1851 on, some other perfection were introduced and some didactical instruments appeared as well of which Bourbouze's galvanometer was very common and also the projection galvanometer that was intended for projecting the detected current in the Nobili galvanometer to a larger audience.

Fig. 8 – Thompson's galvanometer (11)

Fig. 10 – Bourbouze's galvanometer (11)

Fig.11 - Projection galvanometer (7, 11)

Nevertheless, they met neither the electrical industry requirements, nor those of the developing research. From 1871 on a different propose emerged – the 'free' current instruments or suspended coil galvanometers to which succeeded later the capillary galvanometer and since 1881 the amperimeters and voltmeters.

Fig. 12 – Deprez D'Arsonval's galvanometer – A suspended coil galvanometer (11)

Fig. 13 – Discharge tubes -http://baudafisica.web.ua.pt

The electrical discharges in rarefied ampoules gave rise to one of the most fascinating adventures in the history of physics and chemistry, while at the beginning nothing could be foreseen.

From discharges in the 'fulminant tube' and in the 'electric egg' ensued discharges in different and embellished forms of tubes with different gases at low pressures to which was possible to count on glassware craftsmen capable of producing such wrappers. For quite some time, the discharges were produced just for the visual effects. Geissler's (1814-1879) invention using glass tubes with two electrodes for low pressure gas discharges came to give new impetus to this type of experience.[3] The use of more efficient vacuum machines, made it possible to achieve better degrees of rarefaction inside the tubes / ampoules. Since then it was resorted to something more elaborate than the use of the electrostatic machine, using the so-called 'Magnetic motor' for producing the discharge.[4]

In a few decades we follow the discoveries of cathode rays, and the impressive proposals towards the structure of matter.(9) (Case 2)

Case 2 - Identifying properties of matter

From the 'electric egg' to the discharge ampoules or from spectacle to the interior of atom

Producing 'electricity'… for spectacular effects (fig. 13) … to J.J. Thomson's (1856–1940) cathode ray tube and the discovery of a negatively charged corpuscle not yet identified then as the electron (1897). We find easily such a tube in our secondary schools (Fig. 14).

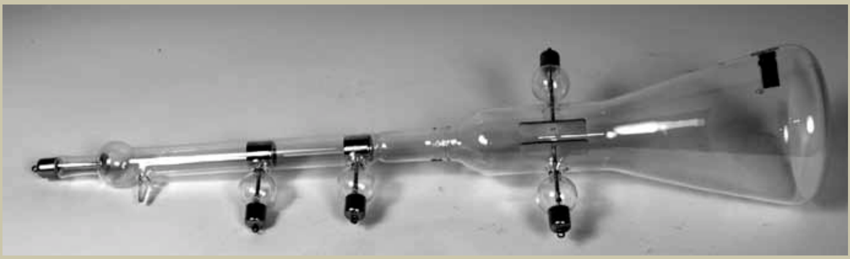


Fig. 14 – Cathode ray tube - http://baudafisica.web.ua.pt

At the same time, the development of electronic television systems was also connected with the development of the cathode ray tube. Karl Ferdinand Braun (1850-1918) in the same year proposed a cathode ray tube as a picture tube, although it was needed some decades until the commercial cathode ray tube for television was in the market place (in the 1930s) (Fig.15).

Fig. 15 – Brown's tube - http://baudafisica.web.ua.pt

When revisiting some of these old instruments, we find frequently the easiness to know what is happening inside instead of the black boxes that the modern instruments represent.

Concluding remarks

Historical physics instruments still have educational potentialities in the physics teaching

They were initially conceived to present the concepts in a more direct perception of what was going to happen

Engineering and teaching education may benefit from analyzing them in their potentialities to unveil the mysteries of the phenomena, elucidating on the experimental science trail assumed, or as icons of a given fundamental discovery

At the same time helps to educate students on the preservation of science material culture in which we are immersed in our daily life.

Acknowldgements

To the Portuguese Science and Technology Foundation (FCT) through the projects POCI/CED/60998/2004 - Old scientific instruments in the teaching and popularisation of Physics and POCTI/CED/36469/2000 - Precision Instruments and the Development of Experimental Physics Teaching in XIXth Century.

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Endnotes

1 - In the project 'Baú da Física e Química – Old Physics and Chemistry instruments of Portuguese secondary schools', we have studied several of those instruments still existente in many schools - <http://baudafisica.web.ua.pt>

2 - See different proposals for the Ingenhouz's apparatus at <http://baudafisica.web.ua.pt>

3 - See <http://baudafisica.web.ua.pt> – discharge tubes.

4 - See <http://baudafisica.web.ua.pt> – motor for discharge tubes.

WS1.

Great successes in lectures and labs

What defines a success in lectures and labs? Case studies in Physics teaching

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Abstract

The article describes successful results attained in teaching by a few people with miscellaneous viewpoints, by different means, various methods and in varied Physics teaching fields. A success has a different dimension for each of them. Four cases are discussed. More details can be found in the article.

Keywords: Teaching by observations and discovering; Teaching by developing; Teaching by involvement.

Summary

The individual results of mastering the teaching are convergent with PTEE hot topics. A coincidence?

Introduction

Authors of this article have over thirty year experience in teaching, except the last, young author. Such a long period must have provided findings and conclusions on what could define a success in teaching. Sharing these findings and considerations with others may be inspiring for a young generation of academic teachers.

Case study N°.1. Involvement of students to innovative thinking, even beyond the Physics.

Prof. Wlodzimierz Salejda lectures on Introductory Physics for Bio-Engineering students and Environment Engineering students (the first year of study). First-year students came to the university with various scores from secondary schools (a full range: from excellent pupils to very poor ones with much to make up and learn). The original idea how to activate students to learn more than a minimum level rose not so long ago. The idea is that students are expected to become mini-experts in a certain field. It does not relieve students of not learning the other parts of material. Being an expert is important and ennobling. Students discuss their original thoughts and dispute any doubts (with a lecturer and with themselves). They have innovative ideas and interesting looks (sometimes a little wrong) while reading physics books and publications. They feel they are responsible for understanding and knowing this particular single physics problem. This is a challenge for them. How do students prove they became an expert? They write an essay. Exemplary essay themes: “Physical properties of solid state matter to be used in energy conversion” or “Physical properties of optical fibres applied in optical communications”. The topics are selected to cover physics peripheries, focussed on technical applications and engineering solutions. No-one wants to be a bad expert (a psychological trick), so students do their best to learn much on their theme. Generally the essays are good and very good. But more important thing is that a student is convinced that being a mini- expert (1) is possible, (2) is available after some finite work, (3) can be extended to other fields (such as mathematics or waste recycling etc.). This helps first-year students to start learning more effectively (than they would do before), to start thinking (in a scientific way) which should not stop after the physics course. What is a measurable merit of Case N°. 1? Physics examination results. After the essays were introduced (with all their requirements and consequences) 80% of students passed the Physics examination while before only 50%. The success consists in showing a student at the beginning how to individually gain a small part of knowledge by himself in order to let him or her extend this accomplishment farther. And to show that one’s thinking pays. A huge knowledge mountain raised in front of the first-year student can be reached in small successful steps only.

Case study N°.2. Modifying versus creating.

What has become more effective?

Assoc. Prof. Beata Radojewska teaches Computer modelling and simulations of phenomena (various years of study). It has two parts: proficient programming in a computer language and deep understanding of the simulated phenomenon. These two halves most frequently are unbalanced. Just by chance it happened once that for a level compensation the background models had been given to students prior to their laboratory to establish standards to start up. The majority developed a task unexpectedly well and quickly (by an extension of the given model). So it became a routine: a background complete model and a more difficult task to solve on its basis.

Let me describe an example: a simulation of waves.

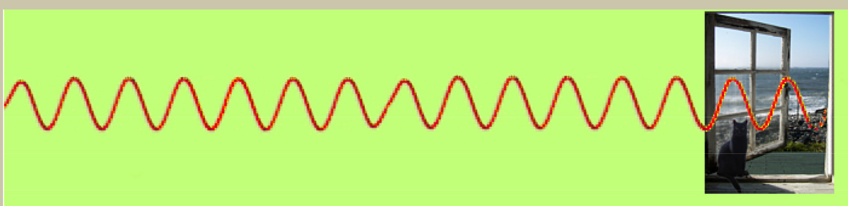

Fig. 1. One-dimensional transverse endless wave. Worked-out model to start modifications.

A model of the one-dimensional transverse wave (as in Fig.1) can be described by the equation:

$$\frac{\partial^2 U(x,t)}{\partial x^2} - \frac{1}{c^2}\,\frac{\partial^2 U(x,t)}{\partial t} = 0$$ with U – the oscillation, c – the velocity *(1)*

After converting the equation to a conjugate system of first-order differential equations:

$$\frac{\partial V(x,t)}{\partial t} = c\,\frac{\partial K(x,t)}{\partial x} \qquad \frac{\partial K(x,t)}{\partial t} = c\,\frac{\partial V(x,t)}{\partial x}$$ *(2a, 2b)*

$$K(x,t) = c\,\frac{\partial U(x,t)}{\partial x} \qquad V(x,t) = \frac{\partial U(x,t)}{\partial t}$$ *(2c, 2d)*

and by discretizing the equations with the numerical differentiation (4^{th} order Runge-Kutta method), and imposing boundary conditions with initial conditions, a set of U(xi , tj) is obtained in a computer program. Students got the ready code. Then they knew what happened with a phase when the wave was not endless (two cases: a fixed end and a loose end of a wire rope, Fig.2). Students have to write

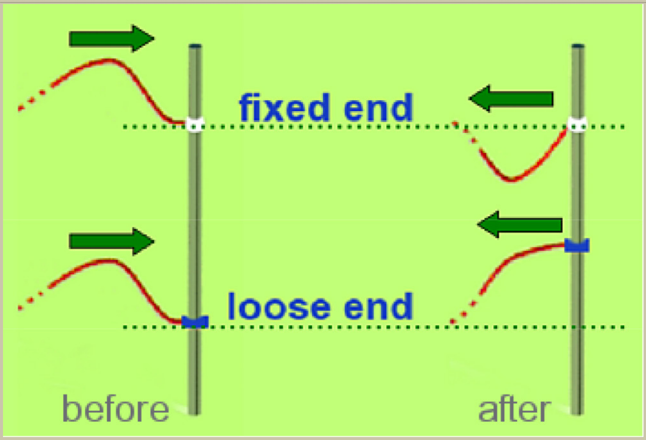

Fig. 2. A wave phase behaviour at the rope end for two case: a fixed end and a loose end.

a code which models U(xi , tj) for the two cases, assuming the wire rope length as L. This requires an extra insert to the existing code, not difficult, but without understanding the wave propagation, doing this is impossible. Advantages of the approach are numerous:

- faster teaching, not wasting time for basics (a basic solution is ready to use and given to students);
- wider range and higher level of knowledge reached by students this way;
- a real proof of good physics understanding and sufficient proficiency in programming;
- (when the task is done);
- greater involvement of students to the tasks (students blush ashamed when they cannot modify a ready simple thing, so they spend more efforts to learn in order to show they can complete the task).

If the students had been asked to create the final task from the zero level, they would not have completed the task in time or not at all. Starting from a certain level (given to them) and modifying the ready solution is more effective. Many years of employing this method confirmed the thesis that in Modifying versus Creation the Modifying won. There is a minor disadvantage: extra time spent to prepare ready to use examples. I use this method to all my courses, even database programming. Another side of the approach is to provide students with more fun to play with Physics. Here is one of examples how to make laboratories more attractive. A ready solution is: an analysis of vector forces acting on a skier (or snowboarder) in a quarter-pipe with a constant friction coefficient and a constant radius of the pipe (Fig.3). The slope changes with a position and a centrifugal force also acts. Students got a ready to use code giving a force map (with time and position).

The task this time was more surprising. They watched a video http://radojewska.net/ptee2014/ski/

and had to recognize and discuss forces acting on a skier (many rotations and a fall at the end), Fig.4.

Fig. 3. A snowboarder in a quarter-pipe with a constant friction coefficient and a constant pipe radius (in the left) and the vector force diagram of gravity, friction, reaction and centrifugal forces (in the right).

Fig. 4. Frame shots from a video with a skier making evolutions on snow (http://radojewska.net/ptee2014/ski/). A task is to analyse qualitatively forces acting on the skier at every stage.

After the students realized that a skier was their teacher, a discussion became more vivid, more excited and lively, interrupted with funny comments and laughter. Everyone wanted to add his/her considerations in this brainstorming. And it was only a video which activated the students. A success consisted in a video choice.

Case study No.3. Observations of the indivisible physics, not divided into handbook volumes.

Dr Jan Szatkowski lectures on Introductory Physics for Electronics students and Photonics students (the first year of study). A level of physics teaching in secondary schools is rather low. So the main burden of this falls on the first year of studies. Handbooks are to bridge a lecture. Most often the handbooks are published in volumes or arranged in specific chapters (Mechanics, Vibrations, Waves, Electricity etc.). But the surrounding world is not ordered this way, is completely intermingled. So lectures should follow such a perception to ease understanding of the surrounding world. The discussed problems should tie many physics chapters. It is even more important in case of physics demonstrations. The demonstration presented in a lecture must be simple (without black boxes), must show basic principles, must help students to explain observed phenomena and preferably must relate to more than one phenomenon. An explanation should not accompany the demonstration, only questions: what happens. Students by themselves should reach a correct model and principle through closer and closer approximations and findings. If they propose a wrong guess, a lecturer should guide to a correct one by disclosing questions, and not by negation. Students must find their fallacy themselves. This method can learn thinking through a critical analysis, can consolidate a uniform model of the surrounding world.

Charging an electroscope with an electrized stick and discharging with a flame is one of good examples of the mentioned demonstrations. Why does a friction charge a dielectric stick? How does the charge fill an electroscope? Why does hot air discharge the electroscope? The demonstration phases are shown in Fig. 5. The movie is also available: http://radojewska.net/ptee2014/electro/

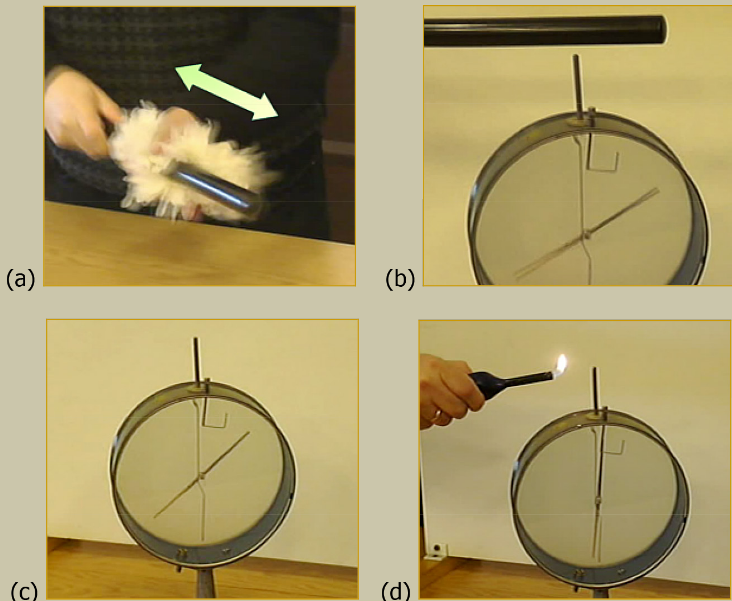

Fig. 5. Distinguishing phases of the demonstration: (a) a stick electrization, (b) charging an electroscope, (c) the electroscope charged, (d) discharging the electroscope with a flame.

It is not easy for students to explain all phases at the beginning. They need to combine many branches of physics at the moment. And this was the aim of the demonstration. Specific problem- oriented teaching like this one can develop complete thinking, can accustom students to seeing more than a single page in a handbook, can learn how to solve any future engineering complex problems. The success consists in a teaching of combined problems with many phenomena involved which usually occur at the same time or in a typical sequence, to show that physics is indivisible, just like the surrounding world, just like a future engineer's job.

Case study N°.4. Experiments which can show a beauty of the Nature, a cleverness of Physics and satisfaction of an educator

Prof. Ryszard Poprawski lectures on Dielectric Physics for Technical Physics Engineering students and Dr Agnieszka Cizman teaches in Solid State Physics Laboratory. No doubt that experimental physics is a necessary part of Physics teaching. There are physics laboratories at many, maybe all universities. Why is one experiment in such a lab better than other? The experiment should explain a physical mechanism of the phenomenon. The experiment should be related to phenomena applied in technology. The experiment should show future prospects and possible developments. The experimental set-up should not be expensive (taking care of the university budget). Looking for and finding such a kind of student experiments were the aim of Dielectric Physics Laboratory team. The team can point the most brilliant set-ups built (by the team) and used in the laboratory, for example: Set-up for temperature studies of the spontaneous birefringence in crystals (a diagram is shown in Fig.6). The set-up story reached only 2005. Ryszard Poprawski was a supervisor of Agnieszka Cizman's master's thesis on the set-up to be made within own (institute) capacity. A whole design was passed to Mechanical Workshops in Institute of Physics, to Mr Edward Ciupidro. All parts, made there, were then mounted and tested at our laboratory. Triglycine sulfate crystals, grown also at our laboratory, were used for tests, due to their ferroelectric properties with the second-order phase transition at 49^{o}C. The crystals are centrosymmetric in paraelectric phase, so the anomalous part of the spontaneous birefringence possesses a character of the spontaneous Kerr effect.

The set-up tests were successful (see Fig. 7). After the entire undertaking had been described in an article [Cizman *et al.* 2005], it brought an interest of Polish universities. After a few improvements the set-up was reproduced and sold to several universities. It is also an economical dimension of the venture.

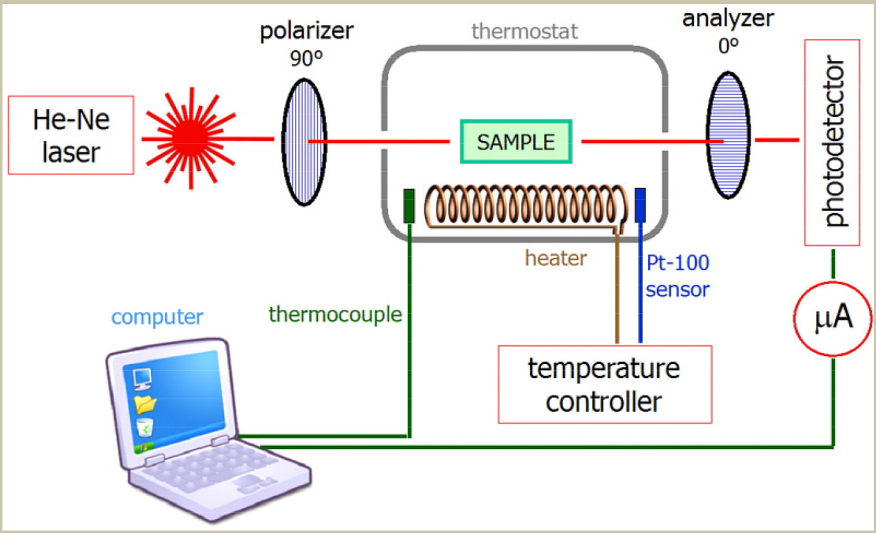

Fig. 6. Schematic set-up diagram for temperature-birefringence measurements.

The set-up is not only used in a teaching process, but successfully in physics research as well [Cizman *et al.* 2006, Cizman *et al.* 2007]. Due to this experimental set-up our students can learn optics of anisotropic media and ferroelectric phase transition mechanisms. The birefringence phenomenon is an important point in students engineering education due to its technical and medical application such as medical diagnostics and imaging, seismology tests, mechanical stress analyses, also widely used in mineralogy and fiber optics.

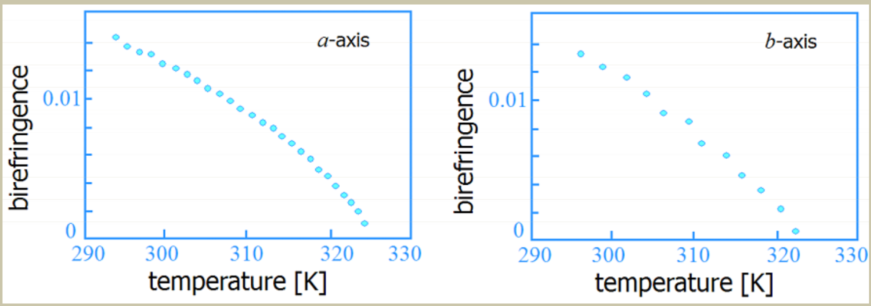

Fig. 7. Temperature dependence of the linear birefringence changes for triglycine sulfate crystals along the a-axis (in the left) and along the b-axis (in the right) [Cizman et al. 2005].

The measurements were carried out with a set-up shown in Fig. 6.

Our success consists in a contriving of an interesting experimental set-up, in producing a prototype and in profitable selling the set-up to other universities, and most important of all: in an enrichment of teaching infrastructure and research means. It is worth mentioning that on a basis of a bilateral exchange agreement between our university and Université de Strasbourg the French students have ability to study birefringence in our laboratory on their stay in Wroclaw.

Final remarks

A success in teaching has many dimensions and many faces. And after all it gives a great teacher's satisfaction.

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Enhancing scientific analysing and reporting skills - integrated physics laboratory course

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Abstract

Physics laboratory courses have always been included in the curricula of all engineering degree programs at Tampere University of Applied Sciences. Physics laboratory course is usually the very first course in which freshmen encounter not only measurements, but also uncertainty evaluation and scientific reporting. The versatility of the skills needed is large: laws of physics, measurements, uncertainty evaluations, reporting and yet skills in using MS Word and MS Excel. Despite the great interest the student have always shown in active doing in the physics laboratory courses, they have considered them as demanding and laborious. Therefore, the course contents have been changed to offer more support to analysing and reporting skills. Now the first physics laboratory course is called “Basics of measurements and scientific reporting” and it consists of equal amounts of physics, mathematics and communication studies, 1 ects each, instructed by a physicist, a mathematician and a communications teacher, respectively. The key idea of the course is to bring together all the basic skills a student – and an engineer to be – needs related to measurements and their reporting to an instructor or to a customer, for example. Furthermore, now the students get much more support and guidance. Students have this course scheduled in the same time at every week, but the classroom and the teacher changes. First they go to physics laboratory to carry out measurements. Next week they bring their measurement results to mathematics workshop, which content is related to the analysis of their results. In reporting workshop they learn how to report them in a correct way. This three-week circulation is repeated three times. As the course proceeds, the learning objectives are varied and they get more demanding. It is possible to generate a more cohesive and concise view to measurements and reporting aspects and prepare the students to the studies and work life to come.

Keywords: Physics laboratory course; Measurement skills; Scientific reporting; Integrated course.

Summary

Laboratory courses are sometimes considered as demanding and laborious. Therefore, the course contents have been changed to offer more support to analyzing and reporting skills. Now the first physics laboratory consists of equal amounts of physics, mathematics and communication studies, 1 ects each, instructed by a physicist, a mathematician and a communications teacher, respectively. The key idea of the course is to bring together all the basic skills a student needs related to measurements and their reporting. It is possible to generate a more cohesive and concise view to measurements and reporting.

Introduction

Traditional physics curriculum in Bachelor's level engineering education at Tampere University of Applied Sciences (TAMK) has always included some laboratory work, either as its own laboratory course or integrated within a theory course. Physics laboratory courses develop engineering, scientific, and reporting skills of the future engineers. According to the student feedback, physics laboratory work and especially writing reports is considered very time-consuming, even compared to the ECTS credits of the course. Despite the feedback, students very much agree that they have learned a lot of important skills during the elementary physics laboratory course. On the other hand, as physics educators, it was seen that the quality of reports needed to be improved further. In order to react to the students' and instructors' feedback, TAMK's system of implementing elementary physics laboratory courses is going through a continuous developing process. This paper describes the latest step of the process, a change in curriculum, to form an integrated course in order to achieve enhanced measurement and reporting skills of first year engineering students.

Background and reported methods to improve laboratory courses

Even though the learning outcomes from physics laboratory course are seen very important, some pressure is coming not only from the students, but from the financing. Laboratory teaching is more expensive compared to the theoretical methods of teaching. This raises the danger of reducing the amount of laboratory courses in the name of reducing costs. In some studies, students have reported laboratory experiences to be negative or dull, mainly because the tasks, working and the solution methodology are pre-stated (Das, B., Hough C. L. Jr, 1986). On the other hand, student feedback and a survey from Australia shows the opposite result: physics laboratory work provides students with many important skills that they think they do need in the future. Laboratory work is also seen to be useful, understandable, interesting and enjoyable by the students (Blathal R., 2011). In order to increase the students' interest in physics laboratory work, the idea of self-designed, poster reported physics laboratory experiment was implemented in Tampere University of Applied Sciences (Tiili, J., 2012). In that study, it was shown that the quality of reporting needed further improvement.

In some cases, modern ICT has been seen as one tool to reduce costs of laboratory working. Laboratory experiments can be done hands-off using videos or live streaming from an actual measurement (Abdel-Salam *et al.*, 2006). All different methods of laboratory work have their own advantages. Traditional hands-on laboratory work is initially needed to bring the sense of reality in the remote and virtual labs (Ma, J., Nickerson, J. V., 2006). Traditional hands-on laboratory work brings the important aspect of a direct social interaction to learning. To increase the collaborative nature and social interaction to reporting, Google Docs is reported as a collaborative reporting tool in The United States (Wood, M., 2011).

Traditional hands-on experiments have their strengths. To improve students' motivation, the method of implementing and reporting may vary. Mainly to increase students' motivation, Greer has reported the method in which laboratory experiments' traditional tasks have changed to challenge laboratories. In challenge laboratories, students work first in a traditional way doing measurements and calculating results. After that students face a challenge concerning the experiment (Greer, A. J., Bierman, J. D., 2005). As instructors, the most important challenge is to make sure that students' learning outcomes are up to date and relevant to their future studies and professional needs, no matter the method used.

Evolution of the laboratory courses

Physics laboratory courses have been changed many times during the past decades. Most of the time, there have been two physics courses, both yielding 2 ects credits. In this study all data is for the first physics laboratory course, in which the students encounter measurement data analysis and reporting for the first time. Major, curriculum-level changes are summarized in table 1. The amount of classroom time for one laboratory work has increased from 4,5 h to 10 h, as shown in table 1. This increase includes workshops and theoretical lectures in mathematics and reporting to support the ongoing laboratory works and their reporting. Now all the necessary skills are taught within the laboratory course, not in separate mathematics lectures and writing lectures.

Until year 2005, classroom time was almost entirely used for carrying out measurements. At that time, there was only a three hour lecture of reporting and uncertainty evaluation. The students were supposed to learn the analysis and reporting autonomously by just reading instructions and doing it. At that time, the step from a freshman's basic skills to the skills needed to complete the first report was huge, which created discomfort among some students and not all of them were able reach the needed level. In addition to writing a report of all works, there was also an examination related both to the topics and to data analysing methods of various works.

Thereafter, from 2005 to 2013, scientific reporting workshops and peer reviews were included to course content to offer some support and guidance to the students. All this was carried out by physics teachers. The laboratory work final examination was discarded and the evaluation and assessment of learning outcomes was based on the reports and portfolio. Feedback about the reports was also given more continuously, not only by the instructors, but also as peer review.

At the latest step in 2013 curriculum development, the structure of the laboratory course was changed more dramatically, as described in detail in next chapter. The course contents have been changed to offer more support to analysing and reporting skills. The first physics laboratory course “Basics of measurements and scientific reporting” consists of equal amounts of physics, mathematics and communication studies, 1 ects each, instructed by a physicist, a mathematician and a communications teacher, respectively. This course is then followed by “Physics laboratories”, which is extended to 3 ects credits and therefore the total amount of credits from physics labs is unchanged. The key idea of the new course is to bring together all the basic skills a student – and an engineer to be – needs related to measurements and their reporting to an instructor or to a customer, for example. With the new curriculum it is possible to generate a more cohesive and concise view to measurements and reporting aspects and prepare the students to the studies to come.

Table 1. Time usage of the first physics laboratory course.

Time usage	-2004	2005-2013	2014-
Total classroom time	27 h	33 h	30 h
Measurements	18 h	18 h	9 h
Intro, maths, writing, workshops	3 h	9 h	19 h
Feedback	2 h	6 h	3 h
Examination	3 h	-	-
Number of lab. works	6	6	3
Classroom time per work	4,5 h	5,5 h	10 h

Arrangements in the new laboratory course

The course “Basics of measurements and scientific reporting” has three measurement assignments, which each are followed first by a mathematics lectures and workshop and then by reporting lectures and workshop, as shown in figure 1. From the student’s point of view, the course proceeds as follows:

1. The concept, requirements and learning objectives are introduced (Intro).

2. The students carry out a measurement in physics laboratory working in pairs (Meas). The output is the measurement data, typically in the form of a log book. If the students have time after measurements, they can continue calculating the actual results. Time reserved for this stage is 3 h.

3. With the log book and data, the students go to mathematics lecture (Maths), which topic is related to the analysing skills the students need for the laboratory work. Typically, in the first cycle, this means error calculations. The lecture part is rather short and it is directly followed by a workshop, during which the students are able to carry out the necessary calculations with the help of the teacher. Again, the reserved time is 3 h.

4. In reporting lecture and workshop (Report), the layout and structure of a scientific report is presented together with the standards for the text. All the calculations needed for the report are already done, and therefore students can concentrate on producing text. During this three hour period of many students are able to finish the report. The deadline is, however, one week later, before the first reflection time.

5. Once the reports are ready, the instructror(s) read them and prepare collective feedback.

During reflection (Refl) the reports are given back to students. They are also provided with a list of requirements for scientific text and reporting. With the help of the list, they go through their own report and mark, which aspect are already well done and which need further improvement. This way, they are aware of their skills and are able to improve their text and reporting during the next cycle in a cumulative way.

One measurement-analysis-reporting set, or a cycle, lasts for three weeks plus one or two extra weeks for finishing the report. The three hour sessions are scheduled to the same time window in the timetable during successive weeks. After the second and third cycles, students have two weeks to finish their report. The learning objectives are getting more and more demanding as the course proceeds. For the second cycle, the objectives are linear regression and graphs in mathematics and the correct way in referencing in reporting. Again, students have the opportunity to write their reports in workshops with the help of maths and communication teacher, consecutively. During the third cycle the students learn how to use total differential method in error analysis.

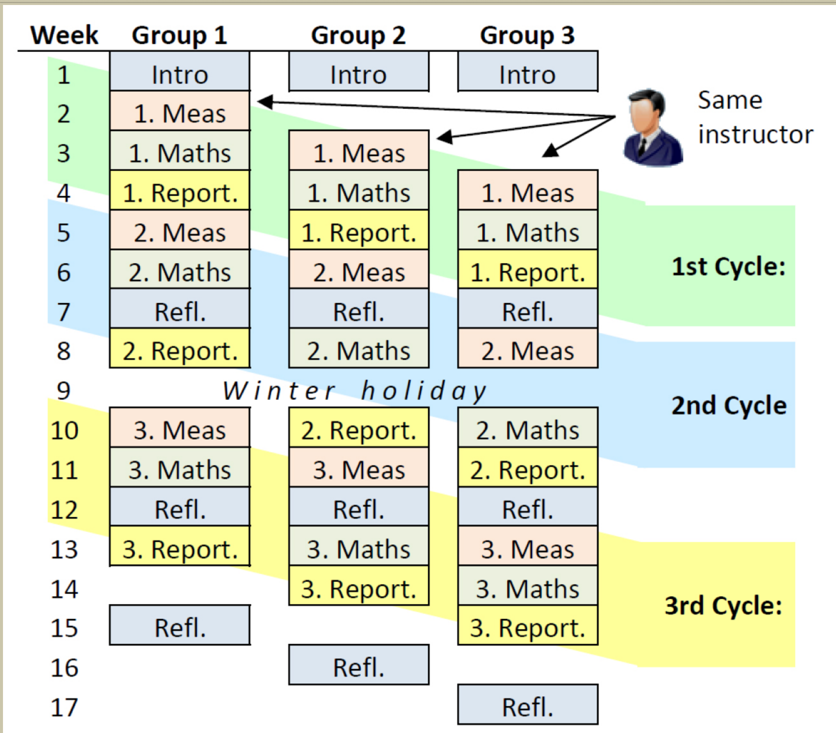

Fig. 1. Arrangements in the new laboratory course.

Like the student groups, the same time window is reserved for instructors every week. The difference is that a teacher has one group in first week, another in second week and yet third group in third week of a cycle. In this way, it is possible to fill in the time table of a teacher without unnecessary gaps.

Feedback and survey results of the new course

Feedback concerning experiences about arrangements and learning outcomes was collected from the students using questionnaires and some of the instructors of the course were interviewed. Figure 2 summarises the student feedback of their own learning outcomes. The students were asked how they experienced their skills to have increased during the course. The scale was from 0 (lowest) to 5 (highest). Most of the students rated their improvements as 4 in all other categories. In general, the feedback shows that most students feel that they have learned a lot during the course. The same conclusion can be made based on instructor experiences: physics teachers reported that especially last reports were better than before and, in general, they were handed out in time. Their layout and text properties also followed better the appropriate standards. Simultaneously, teacher's work load in reading and commenting reports has decreased.

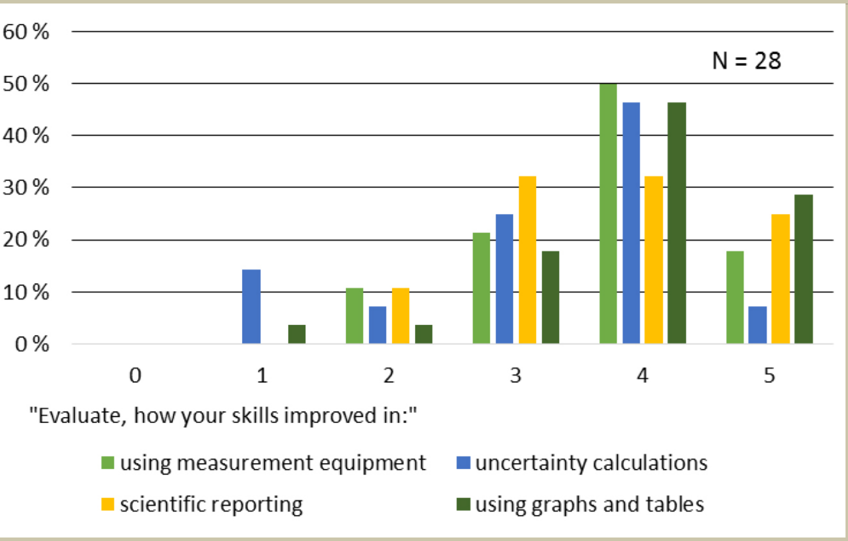

Fig. 2. Survey results of improvements in skills.

When a course has many teachers and many point of view to the same topic, there is a danger that the constituents remain separate, don't support each other and don't form an entity. Student experiences about this aspect were surveyed with a few questions and the results are shown in table 2. Majority of the answers (63 %) show that the teachers' contributions to the course were in line with the learning objectives and they were able to help the students to construct their knowledge and skills coherently. Moreover, the students felt that measurement and reporting skills are relevant to an engineer to be, as shown in figure 3.

Table 2. Student feedback about course constituents, N=27.

Question:	No. of answers
"Measurements, mathematics and reporting were separate and failed to form a coherent entity."	0 (0 %)
"Measurements, mathematics and reporting were somewhat separate."	1 (4 %)
"Measurements, mathematics and reporting were supporting each other, but the entity was somewhat unclear."	9 (33 %)
"Measurements, mathematics and reporting formed a cohesive entity which enhanced learning."	17 (63 %)

At least in this piloted case, the main challenges in this type of a course are not in the implementation, but rather in the planning stage. The management and planning of time-table and classroom reservations are rather complicated. All three parts need to be handled: 1) the student groups should have a clear schedule, the contact hours every week at the same time (but in different classrooms), 2) Unnecessary gaps in teachers' schedules should be avoided and 3) classrooms booked only for needed usage.

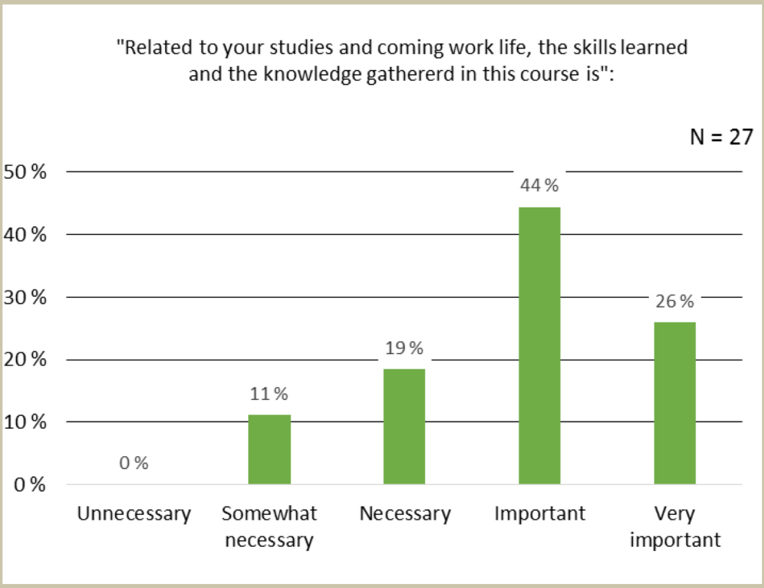

Fig. 3. Importance of the skills obtained in the course.

Conclusions

The new laboratory course implementation has offered the students much more support in data analysis and scientific reporting than before. Course implementations had 3-4 teachers: 1-2 physicists, a mathematician and a communications teacher. According to survey results, the teachers' contributions to the course were in line with the learning objectives and they were able to help the students to construct their knowledge and skills coherently. Most students feel that they have learned a lot during the course. Physics teachers reported that reports were better than before and they were handed out in time. Their layout and text properties also followed better the appropriate standards. Simultaneously, teacher's work load in reading and commenting reports has decreased.

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EFFECTS OF PBL METHODOLOGIES ON THE STUDENTS PERSONAL COMPETENCES

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ABSTRACT

To meet the challenges that are currently being faced by Higher Education Institutions (HEIs) either in terms of the required roles for teachers and students, or of teaching and learning processes, it is pointed out, more than the reformulation of the (theoretical) mission of higher education, the recasting of the practice of the institutions that comprise it. In the present study we highlight PBL methodologies (either in a project-based learning or a problem-based learning perspective), based upon the principle of using contextualized problems of a professional nature as a starting point for the acquisition and integration of knowledge. This article reports on the effects of PBL methodologies on the students' personal competences in a simulation environment for the business reality. The case study for our investigation was the course of Business Simulation (BS) at the Higher Institute of Accounting and Administration of the University of Aveiro (ISCA-UA), as a PBL-type methodology. The generic objective of the course is the applied and contextual integration of previous information, in a global perspective, in order to prepare qualified professionals able to work in organisational environments. The research made use of theory, data and methodological triangulation. While semi-structured interviews were made to tutors, students and graduates' data was informed by questionnaires. Based upon some reflections we have been establishing, it is possible to consider new perspectives, capable of contributing for the activation of a debate around the dynamics of self-development competences, associated to the use of PBL methodologies. As it was observed, we identified two trends in the perceptions evidenced by the interviewees and the respondents. On the one hand, students, graduates and tutors support that PBL methodologies were important mainly at the level of resource use (management, planning and work methodology) and of knowledge construction (critical analysis, grounds for decisions and initiative). Another conclusion of the study is the fact that communication skills (oral and written) appear far less valued, when compared to the remaining items for self-development. On the other hand, for the employers, one can easily detect a persistent tendency to recognize PBL methodologies as responsible for the valorisation of more consistent grounds and more confident attitudes, but not directly responsible for an improvement of graduates' personal competences, in general. To some extent, this aspect recognizes that methodologies have the ability to foster students' self-esteem, and self-confidence. Also and particularly interesting, seems to be the suggestion that, maybe, PBL methodologies can be related with the idea of self-employment and entrepreneurship. As literature does not approach this matter, it seems possible to us to sustain the possibility of inserting the entrepreneurship logic, motivated by PBL methodologies, in the existing theories. Once, mainly in vocational higher education, learning methodologies tend to become more reactive to the needs of employers, it seems important not to forget the mission of HEIs and so, we suggest a carefully analysis of the balance between the theoretical conceptualization and its practical applicability.

Keywords: PBL; Personal competences; Students; Academics; Employers; Higher education institution.

Summary

This article reports on the effects of PBL methodologies on the students' personal competences. On the one hand, students, graduates and tutors support that PBL methodologies were important mainly at the level of resource use (management, planning and work methodology) and of knowledge construction (critical analysis, grounds for decisions and initiative). On the other hand, for the employers, one can easily detect a persistent tendency to recognize PBL methodologies as responsible for the valorisation of more consistent grounds and more confident attitudes, but not directly responsible for an improvement of graduates' personal competences, in general

1. Introduction

The new economic challenges, the speedy developments in information and communication technologies (ICT) or the emerging globalization, are some of the challenges that businesses are facing today. These rapid changes meant that business education must equip students to deal with increasing competition in a global marketplace, and to face the requirements of multi-facet skills. As a consequence, there is an increasing importance on the quality of the learning experience being provided to business students (Byrne & Flood, 2008; Mohamed & Lashine, 2003). To achieve this, higher education institutions (HEI) need not only to understand student learning but also to realize how employers value graduates and their capabilities(Archer & Davison, 2008). Within the context of skills development, lifelong learning, collaborative strategies and other concepts, the discovery and deployment of new teaching and learning methodologies become an authoritative task (Chaparro-Peláez, Iglesias-Pradas, Félix, Pascual-Miguel, & Hernández-García, 2013). A possible way to foster and supplement the change of a traditional lecture-based method is the usage of a PBL methodology (either in a project-based learning or a problem-based learning perspective), supported by a business simulation context. The main goal of this study is to contribute for the theoretical discussion of the key factors affecting the students, tutors, graduates and employers' perceptions of learning using simulation-supported PBL. More specifically, we did limit our field of study to the context of personal competences. The structure of this document is as follows: in the first section, an introduction to PBL and business simulation is presented. After having established the theoretical foundations, a description of the case study and the instructional methodology is made. Then, data analysis is performed in order to evaluate the influence of PBL methodologies supported by a business simulation context in the personal competences of the students. Finally, conclusions from the data analysis are summarized, followed by a discussion of the findings from the study.

2. Competencies and PBL methodologies: the changing paradigm

Lifelong learning concepts, skills development and self-directed learning are concepts of growing importance in higher education agenda. Within the background of these educational trends, the positioning of new learning methodologies becomes an authoritative task (Chaparro-Peláez *et al.*, 2013).

As developed countries struggle to produce the intellectual capital required to compete globally, the more businesses' requirements of graduates' competences inflate. The effects of the expectation that new graduates can have the ability to add immediate value to businesses result in a growing interest on the current state and future of graduate skills. To assure that students acquire strategies, particularly in transferable skills which allows them to learn effectively and throughout their lives, organizations are tipping the balance of the responsibility of skill development to HEI (Jackson, 2010).

So, and mainly in vocational education, HEI need to produce graduates with the soft skills believed essential for increase productivity and innovation in their future workplace. So, and as several authors claim (e.g. Archer & Davison, 2008) there is a need for action by HEI and employers to address both skills deficit in the graduates. Even if the blame of inadequacies of the schooling system is consistently directed at the content, the design or the structure of undergraduate programs, the question of the methodological preparation of the future graduates is a central point (Jackson, 2010).

Different learning orientations and conceptions of learning have been explored in connection with different methods of learning, giving rise to the refinement of the concepts and their development in relation to specific educational contexts. In fact, if in the 1970s, studies that supported surface approaches to learning (memorization and rote learning), rather than deep approaches to learning (active construction and focus on meaning) arise, more recent studies in the 2000s (e.g. Fyrenius, Wirell, & Silén, 2007), show that understanding can be conceived of and attained in various ways. As the concept of understanding and of students' approaches to learning evolves, the surface and deep dichotomy is being replaced by entangled and collaborating activities. The expectation that education must be built on learning to know, learning to do, learning to live together and learning to be, is shared in the Jacques Delors' report (Unesco, 1998). At the same time, accepting that optimal teaching and learning occur when teaching styles align with learning styles, it seems possible to tailor both by integrating interactive simulations to support face-to-face classroom (Proserpio & Gioia, 2007). On the other hand, if traditional lectures are predominantly oriented by learning to know and, specifically in vocational training, by learning to do, several authors (e.g. Fyrenius *et al.*, 2007; Unesco, 1998) argue that it is necessary to provide education with designed methodologies able to involve, also, learning to live together and learning to be. Among several disadvantages pointed out to traditional schooling, the lack of connection between one element to the others, the lack of teamwork or the lack of knowledge transfer motivated by no research investigation among students, are some of the most cited (Kaufmann, Mense, Wahl, & Pucher, 2011). In the Portuguese case, the binary higher education system distinguishes between a polytechnic approach (identified with a professional orientation) and a university approach (identified with a more conceptual and theoretical orientation). So, and particularly in polytechnic education it is possible to understand the importance to adjust training to the professional needs demanded by employers. In order to strengthen such a position, new pedagogies centered in the relation between pedagogical practices and professional practices have been revealing themselves as an important methodological paradigm (Musal, Taskiran, & Kelson, 2003).

Several authors establish the benefits of problem solving skills in relation to a better understanding of the future professional activity (Karantzas *et al.*, 2013; Papinczack, 2009; Tate & Grein, 2009), and they call for a deeper relationship between employers organizations and HEI. These same skills are thought to enhance graduates' capacity to deal with novel and blurred problems and their ability to make connections between learning and practice (Karantzas *et al.,* 2013). Besides, as Clifford and Montgomery (2014) claim, problem-solving is important in enhancing students' ability to think and act as global citizens.

The PBL model, firstly developed by Howard Barrows and Robyn Tamblyn in the late sixties, was initially associated to medical schools. Nowadays, the PBL methodology has been used in various professional areas and programs, gathering more than 40 years of experience (Nel *et al.*, 2008). Even if the concept of PBL varies somewhat in the literature (e.g. Moesby, 2006), there are key elements common to most descriptions of this methodological approach. Using PBL, teachers firstly present students with a problem that require students to go beyond rote-learning. In fact, after analyzing the problem and identifying the necessary information to begin the analysis, solving the problem should require students to actively engage in research, analysis and exchange of ideas. In this methodological orientation, teacher does not provide answers. Instead, he acts as a facilitator or tutor as he provides crucial assistance by helping students develop their problem-solving skills (Chaparro-Peláez et al., 2013; Prince, 2004). In PBL, students are the center of the learning process as they are responsible for their own learning as well as for identifying their knowledge shortcomings and determining how to overcome them. Given the collaborative nature of the methodology, in PBL students usually work in small groups. All through the process, students are not only supposed to understand and critically explain the existing literature on the subject, but also to communicate with others and to develop self-learning competences. Accepting the perspective of several authors (e.g. Tate & Grein, 2009), the active nature of PBL call for a committed participation of the learner, which is a central point in knowledge reconstruction. As a result, it is possible to refer the acquisition of technical, (regarding the processes), personal (regarding questions of organization and communication), and social (regarding interpersonal relations) competences (Albanese & Mitchell, 1993; Musal *et al.*, 2003). Therefore, problems are used not only as a way to develop the skills needed to solve them, but also as a means to achieve knowledge (Savin-Baden & Major, 2004).

In general, the learning cycle begins with the presentation of the problem to the students. Afterwards, students have to analyze the problem and identify the most relevant facts about it. As they begin to understand the problem, and hypothesize possible solutions, they need to analyze the different strategies and decisions they must take in the process. The identification of knowledge shortcomings is an important part of the cycle. In fact, to do that, students have to research through a self-directed learning process (facilitated by teachers), search for relevant information to answer the questions that arise, reflect on the hypothesized possible courses of action, identify which concepts are need to be researched in detail and bring together all the information acquired (Chaparro-Peláez *et al.*, 2013).

3. PBL methodologies supported by a business simulation context in accounting

The enormous developments in ICT, the new economic challenges, the requirements of multifaceted skills and the rapid spread and acceptance of globalization technology, are some of the changes that have brought new challenges not only to business but also to business education (Kavanagh & Drennan, 2008; Mohamed & Lashine, 2003). The perception that graduates, in general, are not equipped with generic skills and attributes for the workforce of the twenty-first century, is a significant issue and some studies in this area can be consulted (e.g. Archer & Davison, 2008). In the accounting area and as a consequence of the changing business environment, this is a major problem. An evidence of the increasing focus on generic skills and attributes in accounting is the considerable body of research in this area (e.g. Jones, 2010; Kavanagh & Drennan, 2008). If business schools are responsible for closing the gap between the sills required by the markets and the ones acquired by its graduates and the environments for which graduates are prepared change, the issue that arises is that of knowing how education is preparing future accountants capable enough to cope with these same challenges (Mohamed & Lashine, 2003).

Like other disciplines, accounting belongs to a community of practice and so shares a set of knowledge, skills and ways of negotiating meaning and communicating with others. Therefore, and besides skills which are shared with other disciplinary areas, accountants are infused with their own language, structures, knowledge and practical skills. To know that generic attributes must be understood as part of the scholarly and professional practice, has profound implications for accounting education (Jones, 2010) and has been the subject of much debate (Kavanagh & Drennan, 2008). In other words, generic attributes in accounting must be taught as integral to disciplinary practice and are influenced by the accounting profession and the needs of employers. This means that there is the need of planning for the teaching and assessment of generic attributes all along the accounting curriculum.

Trying to provide accounting students with the knowledge and skills that raise their competency level to meet that required by the market, Mohamed and Lashine (2003), identified some skill sets and presented some curriculum design. Looking at accounting education from a client-oriented perspective, these same authors recommend a change from a knowledge based education to a process oriented one. In order to provide students with personal and social competences that prepare them for a better understanding of business in today's global environment, Mohamed and Lashine (2003) list the following categories: communication skills, computer skills, analytical and intellectual skills, multidisciplinary and interdisciplinary skills, knowledge of global issues, personal qualities and critical thinking. The question of a client oriented perspective is crucial, because in the absence of a client oriented focus the relevance between what the job market requires and what is being taught does not exist. Also Kavanagh and Drennan (2008) claim that HEI should prepare their students with a more all-inclusive range of skills in order to lay the foundations for a lifelong commitment. A significant finding of Kavanagh and Drennan (2008) indicates that although employers are still expecting strong analytical skills and a good understanding of basic accounting skills, they are also requiring business awareness in terms of the real world. Particularly interesting, is the fact that both employers and students report that many of the non-technical and professional skills and attributes are not being sufficiently developed in HEI accounting programmes. These same ideas are aligned with the ones of Kelly, Davey and Haigh (1999). In fact, these authors suggest that what accounting academics are attempting to achieve is the adoption of alternative approaches to educational practices.

Particularly interesting is the recent work of France (2010). After introducing the idea of contemporary practices (as opposed to the traditional practices consistent with management accounting practices prior to the 1990s) as those that appear from 1990s onwards, the findings of France (2010) contrast with the pedagogical assumption that the skills required by accountants have to go beyond technical practices and emphasize personal and social skills. For the purposes of the discussion, the classification of traditional and contemporary practices used by France (2010), distinguishes between economic value added, balanced scorecard and activity based costing and management (contemporary) and other practices. The work of France (2010) concluded, on the one hand, that for those seeking a position as a management accountant, traditional management accounting practices (financial accounting, analysis, forecasting, budgets, reporting, costing and variances) are required. On the other hand, in contemporary management practices none appeared more salient than others. The conclusion of France (2010) is that it is critical for educators to know the practices that are required by employers, and to reflect those practices in the educational curricula. The dilemma remains in the association between theory and the real world arena. In other words, to understand the demands of employers, it seems necessary to have three different points of view: teaching, research and curricula that involve contact with practitioners and real life situations. Which lead us to the question of knowing what should also be taught to management accounting students, and what do accounting educators need to decide what to include in the curriculum beyond the common body of knowledge. Business educators who are looking for alternative methodologies to lecture based ones, may want to try PBL. In particular, some studies of PBL in the accounting area can be consulted (e.g. Hansen, 2006; Milne & McConnell, 2001).

Resuming to the call for a need to revisit accounting education from a client oriented perspective it is vital to strive for a methodological process that ensure effective learning. In order to help students relate the subjects to prior knowledge acquired an incorporate concepts and principles, a business simulation context in accounting can be used. According to Clarke (2009), business simulation exercises are one way of enhancing skills most valued by companies: problems solving skills, capacity for innovation or high order leadership skills. The question that worries Clarke (2009) is the capacity of business simulation to deliver the learning outcomes desired by employers. If, traditionally, accounting education programs have adopted the functional silos that provide the outline of the curriculum, and business problems hardly ever present themselves in the compartmentalized silo supply-driven structure, there is a question of concern. So, the main problem is of how to provide students with a conceptual understanding in cross functional decision making. The business simulation suggested by Clarke (2009) encompasses an integrative approach that goes beyond the convectional lectures through learning by doing. Likewise, the simulation of the work environment in which students have to work in future, should provide them with the critical ability and ethics needed to make the right decision at the right time (Mohamed & Lashine, 2003). This methodological feature, as Mitchell (2004) says is more and more receiving attention either for the increasingly refined designs or for their promotion of student attention. Theoretically, the concept of simulation encompasses any artificial environment that is created for training purposes. In turn, training is the systematic acquirement of rules, knowledge, attitudes, concepts or skills that should result in improved performance (Salas, Wildman, & Piccolo, 2009). So, simulation based training can be conceptualized as any practice environment that is produced in order to provide trainees with the opportunities to develop and practice those competencies. Salas, Wildman and Piccolo (2009) suggest that simulation based training offers many advantages to management education, in general. In their work, by engaging in a simulated scenario similar to the future professional context, students show evidence of being able to contribute to the effectiveness of the problems more quickly and openly. In other words, simulation based training allows for the development of skills at a much faster pace than usual. As a hands-on approach, simulation based training presents an advantageous opportunity for improving the quality of existing curricula. The work of Salas and his colleagues (2009) delineate several of these distinct advantages. Also Wynder (2004), in extolling the advantages of business simulation, stresses the way learners can immerse themselves in the accounting context and learn by doing. The nature of experiential learning is an important part because of the active engagement with the context and because of the benefit of providing students with the opportunity to experience the consequences of their actions. As a consequence, students are able to see interrelationships between diverse approaches to managing performance, and the way in which they match or conflict with each other. The individual reflection that derives from the opportunity to continually revise decisions and see the consequences, is pointed out to be one of the major benefits. Another benefit of a simulation context is that it can compress time and space (Wynder, 2004).

Finally, and even though literature about PBL is not scarce, there is little research about learning methodologies that combine PBL with simulation contexts (Chaparro-Peláez *et al.*, 2013). This lack of studies is even more noteworthy in the case of accounting. The need for realistic situations to develop PBL strategies has been mentioned by some authors (e.g. Chaparro-Peláez *et al.*, 2013). Several arguments can justify the usage of simulations in a PBL process (Chaparro-Peláez *et al.*, 2013). In fact, the importance of the context of a PBL problem is a critical ingredient to successful learning within a PBL approach. So, the capability of simulations to present a meaningful context makes them an ideal tool in the upkeep of PBL methodologies. Another argument is that simulations match the criteria for an adequate problem to be used in PBL, since business problem contexts characteristically lack sufficient information, and problems are often unclear with several ways to solve them.

4. Instructional strategy and methodology

The motivation for this study is to show how such a combination of PBL and simulation has produced implication on personal competences in vocational higher education. Starting from a PBL within a simulation business context, the study focus on (i) the role that methodology plays in the development of students' personal competences; (ii) how the methodology improve graduates' personal competences and (iii) the construction of a graduate profile for the third millennium.

4.1. The case study of the Business Simulation course

The BS course is underpinned on the notion that graduates from ISCA-UA would have to increase their competencies in order to satisfy the ones required by employers. Within the vocational path of ISCA-UA it become imperative the need for building bridges between theoretical knowledge and professional accountancy practices. Such a context revealed itself a window of opportunity for the BS model inspired in PBL methodologies supported by a business simulation context.

The generic objective of the course is the applied and contextual integration of previous information, in order to prepare qualified professionals able to work in organizational environments. So and strategically, BS is placed at the end of the undergraduate accountancy programme. Apart from generic objective, more specific overall objectives can also be defined: (1) to consolidate and integrate knowledge acquired in previous academic years; (2) to provide a practical overview of the accountant profession; and (3) to allow the approach between professional ethics and business ethics. Additionally, other objectives may be mentioned: (4) to develop the ability to work in a team and under pressure; (5) to improve oral and written expression; (6) to provide an overview of the accounting activity; and (7) to perform a critical analysis of both the own work or the work of peers. The course was firstly introduced in May 1996 and has the duration of a semester that corresponds to a virtual year of work.

The foundations of BS lays in a simulated market of virtual enterprises, which small groups of students must manage and undertake. Each group consists of a firm or a public entity that is connected to an economic activity. The existence of suppliers and customers assures competition, such as in real life situations. Very important is the web platform that supports the simulation of the business reality. BS is also recognized by the professional association of accountants (OTOC), which means that ISCA-UA is one of the schools which is exempt of the training period requested by the OTOC in order to have access to the enrolment as a chartered accountant. As that training period has the triple goal of supplying professional experience, complementing social and professional competences and enabling a stronger articulation between academia and business, the BS fulfils, according to the OTOC's perspective, the goals established for a training period. So being, it brings an added value to the profession of the future graduates of ISCA-UA.

4.2. The research design

The present research elected a case study methodology. Yin (2009) refers the fact that the most important aspect of a case study is not the statistical generalization of the phenomenon, but rather the analytical generalization in itself. So being, it can either confirm or complete conceptual knowledge about PBL methodologies supported by a business simulation context in accounting. Our paper focuses on the teachers, employers, students and graduates' perceptions. While selecting the teachers, we choose to include all those who had at least four years of experience in the subject, assuming that punctual collaborations would result in less limited perspectives. Fourteen interviews were made. In order to ensure the most broaden possible overview, we choose to retain only entities with graduates from ISCA-UA who were carrying out duties related to the accounting area, but spread out in several departments. Such a choice returned five entities, which corresponded to thirty-two graduates (twenty-three of which had attended BS as opposed to nine who hadn't). In this study we also involved all the students enrolled in the subject when the empirical part of the project was developed, which meant a total of 138 students. The return rate achieved was of 96%. Given that is was quite relevant to streamline the questionnaires to all the graduates from ISCA-UA who had attended BS, the 881 graduates present in the process since its beginning were taken into account. In this group, the return rate was of 84%.

The research was carried out making use of three cross-referencing sources in order to allow findings to be interpreted from different perspectives. The first is theory triangulation, as several streams were used in the literature review. The second is data triangulation since the views of students, graduates and academics were analysed. The third is methodological triangulation as it articulates quantitative and qualitative methodologies. While semi-structured interviews were made to tutors, students and graduates' data was informed by questionnaires. The scripts for the semi-structured interviews made to teachers and employers were basically outlined according to the literature review and to the specific object and goals of the research. All through qualitative data collection respondents were free to express facts and convictions in their own language, therefore assuming the role of informants rather than of respondents (Lessard-Hébert, Goyette, & Boutin, 1990). All interviews were recorded with the proper consent of the authors and their answers were studied with the QSR NUD*IST software (Non-numerical Unstructured Data Index Searching and Theorizing). All questionnaires were prepared for an optical reading and the answers were examined following descriptive statistics. The software used was the SPSS (Statistical Package for Social Sciences).

5. Results and discussion

As a prior point, it is fair to say that embracing a PBL learning approach represented a substantial change to both students and teachers of ISCA-UA, as it emerges, all of a sudden, as a methodology opposed to traditional methods. In fact, with all the curricular units of the accounting degree running according to traditional teaching methods, the methodological organization of the BS suddenly supervenes as a model which opposes to the traditional one. This factual situation gives place to an inevitable comparison between the methodological philosophies inherent to the two models. As a consequence, students, graduates and tutors tend to compare their PBL experiences with the traditional ones that they are more familiarize with. So, the fact that students, graduates and teachers tend to compare their traditional methodological experiences with the PBL experience of the BS, presents itself as a unique opportunity which adds up to the research the possibility to understand every opinion reported under the light of PBL methodologies versus traditional teaching methods. Also employers tend to compare PBL graduates with non PBL ones they are more familiarize with. So, as a preceding point, we can say that all the conclusions of our study must be read by the light of PBL methodologies versus traditional ones.

5.1. The perspective of students

The perceptions of students regarding the question of the influence of the PBL methodology supported by a business simulation context on the development of their personal competences, seems to revel strong positives answers (see Table 1).

Table 1. Degree of alteration or non-alteration of the personal competences (students' perspectives)

Degree of alteration or non-alteration of the personal competences at the level of	Tendency to increase (%)	Unaltered (%)	Tendency to decrease (%)
written communication	64	31	5
oral communication	61	35	4
critical analysis	78	15	7
time management	80	8	12
task planning	80	12	8
synthesis capability	70	27	3
creativity	70	26	4
setting of goals	67	27	6
decision reasoning	75	21	4
initiative capability	74	21	5
personal organization	60	31	9
dynamism	74	24	2
work methodology	75	22	3

At a first level of analysis, it is possible to find an accentuated positive influence of the methodologies implemented in two terms: on the planning and organization (time management and task planning); and on knowledge construction (critical analysis, synthesis capability, creativity, decision reasoning, initiative capability, dynamism and work methodology). At a second level of analysis, the empirical study points to the development, although slightly less accentuated, of competences referring to communication (oral and written), setting of goals and personal organization. An hypothetical interpretation of the less valued competences may refer to the fact that competences regarding communication and personal organization transit, in a more direct manner than the others, from the traditional learning methodologies previously used by students.

5.2. The perspective of graduates

The perceptions of graduates regarding the question of the influence of the PBL methodology supported by a business simulation context on the development of their personal competences are very similar to the results attained with students (see Tabela 2).

Tabela 2. Degree of alteration or non-alteration of the personal competences (graduates' perspectives)

Degree of alteration or non-alteration of the personal competences at the level of	Tendency to increase (%)	Unaltered (%)	Tendency to decrease (%)
written communication	52	46	2
oral communication	62	37	1
critical analysis	80	19	1
time management	82	15	3
task planning	83	14	3
synthesis capability	65	33	2
creativity	63	35	2
setting of goals	76	22	2
decision reasoning	79	19	2
initiative capability	73	25	2
personal organization	65	33	2
dynamism	68	31	1
work methodology	78	21	1

The data gathered seems to expose different valorisations of the items under study, somehow allowing the creation of a hierarchy of two distinct answer profiles. So, graduates bring up an accentuated positive influence of the PBL methodology supported by a business simulation context mainly on critical analysis, time management, task planning, setting of goals, decision reasoning, initiative capability and work methodology. However, there is also another shade in the opinions of the graduates. According to this second profile, it is possible to detect more moderate positions which, surely, continue to express the perception that there is a positive trend which promotes oral communication, synthesis capability, creativity, personal organization and dynamism. The written communication item appears to be unaltered by the methodology implemented in BS, meaning that the methodology seems not to influence this competence.

5.2. The perspective of teachers

As teachers assume the role of informants no formal questions were verbalized. Framed by the topic of personal competences, teachers expressed their opinions in their own language. From the interviewees, it was possible to understand that: the methodology allows students to develop their critical reasoning in a constructive perspective (as students have to analyse and incorporate different perspectives all throughout the problems' resolution); the difference of opinions among teachers is an important element to promote synthesis mechanisms and analytical capability among students; the methodology enables students to develop the ability to consolidate the resolutions he/she chooses to take (as students have to consider and integrate different perspectives all throughout the problems' resolution); the endless flow of work encourages personal organization aspects; the methodology has the potential to improve synthesis mechanisms upon students (once they need to manipulate a vast set of information); it is possible that self-development mechanisms are encouraged (namely creativity, initiative capability and dynamism); the methodology has the potential of working written and oral competences (as far as the evaluation process includes written reports and oral presentations); the active learning process of the methodology generates a reflexive potential; the methodology provides students with self-esteem and self-confidence competencies (as students find themselves self-oriented and responsible for their own learning processes); the methodology has the potential of encouraging business opportunities and starting off careers by ones' own (as students need to deal and learn with their own mistakes). This particular point is a very interesting one as far as it is not identified in the literature.

5.3. The perspective of employers

As well as teachers, also employers assume the role of informants. Framed by the topic of personal competences, employers expressed their opinions in their own language. From the interviewees, it was possible to understand that: the methodology enables graduates to develop their ability to reason decisions (limited not only by theoretical concepts but also by practical aspects which have already been experienced); the methodology renders graduates more confident and secure of their actions; graduates who attended the curricular unit of BS present themselves more valued and professionally acknowledged (when compared to other colleagues who did not to attend the subject); personal organization is not a competence which benefits from the attendance of the methodology.

Noteworthy is the fact that all employers who were interviewed were aware of the existence of the methodology of the BS unit at ISCA-UA, which seems to reveal the attention of enterprises with HEI, mainly in their recruitment arena.

6. Conclusions

This study explores the expression modes of the use of PBL methodologies supported by a business simulation context at the level of personal competences. We analyse the perspectives of students, graduates, teachers and employers. It is not our intention to generalize results. In fact, the collected data does not allow it. Nevertheless, it is possible to conclude that the learning and teaching methodologies grounded on PBL models validate some conceptual propositions on the subject. However, there are others which do not seem to be validated by the practical results gathered.

In line with the literature review, students, graduates and tutors support that PBL methodologies are important mainly at the level of management, planning and work methodology and of critical analysis, grounds for decisions and initiative.

Not so aligned, communication skills (oral and written) appear far less valued when compared to the remaining items for self-development. One may perhaps find a justification in the fact that traditional methodologies already explore these aspects in written and oral examinations.

The influence of no uniform solutions is not surprising. In fact, the circumstance that teachers may not present identical solutions can encourage the debate among students. Consequently, it seems that the discussion of ideas which often occurs endures an underlying methodology which significantly increases the argumentative power of students, though they appear to develop more comfortable attitudes in more traditional environments.

Particularly interesting seems to be the suggestion that, maybe, PBL methodologies can be related with the idea of self-employment and entrepreneurship. As literature does not approach this matter, it seems possible to sustain the possibility of inserting the entrepreneurship logic, motivated by PBL methodologies, in the existing theories.

The results show that in this study some new perspectives can be understood, as not all personal competences have the same significant impact on perceived learning by various agents involved in the educational process (students, teachers, graduates and employers). Such as it is observed, we identify two trends in the perceptions of the interviewees and the respondents.

On the one hand, students, graduates and tutors support that PBL methodologies were important mainly at the level of resource use (management, planning and work methodology) and of knowledge construction (critical analysis, grounds for decisions and initiative).

On the other hand, for the employers, one can easily detect a persistent tendency to recognize PBL methodologies as responsible for the valorisation of more consistent grounds and more confident attitudes, but not directly responsible for an improvement of graduates' personal competences, in general. To some extent, this aspect recognizes that methodologies have the ability to foster students' self-esteem and self-confidence.

The results achieved with the analysis of the data collected also require some lateral reflections.

If, as the European Centre for the Development of Vocational Training refers, the forecasts for employability for Europe in 2020 point at eighty million jobs, the top problem that arises is to understand what kind of competences will be necessary to fulfil these vacant jobs, according to the employers' needs. So, maybe we need to know how to assure the early identification of competences which will secure the needs of a multifaceted market. If, mainly in vocational higher education, learning methodologies tend to become more reactive to the needs of employers, it seems important not to forget the mission of HEI and so, we suggest a carefully analysis of the balance between the theoretical conceptualization and its practical applicability. Therefore, we are before the pressure of a flexibility exercise at the level of competence management, not only professionally, but, more intensely, at a non-cognitive level and, particularly, at a personal one.

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Activating students in laboratories. Trusty and reliable solutions.

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Abstract

The article describes successful methods used in my laboratories to activate, animate and inspire students for more efforts, interests and engagements in the laboratories. A few cases are described. The first one consists in making a reading materials for labs more attractive. The next uses a unique competition method which activated most students in the lab. The next one involves one of the students to show his hobby and to arise an essential discussion with a scientific background. Last year university event resembled that students preferred practical exercises so by a choice of the problem range we could activate students as well. Having few students in the lab to teach at a moment there are much more possibilities to make them more active than in a lecture. But some solutions, described in the article, can successfully be extended to large-enrollment classes.

Keywords: Activating students; Teaching with astonishing extras; Continual challenges for students.

Summary

An activation of students for greater efforts and engagements in learning should be a goal of each teacher. It helps not only talented students to develop their skills above average but also mean ones to achieve higher level than they would attain other way. The students response to an activation process is positive, so let us take advantage of it.

Introduction

Computer laboratories are carried out in small groups, usually with 16 students (at our university). Laboratories do not belong to large enrollments unless the number of groups is ten or more for a given course. But still 16 students at a time. Having only 16 people to teach at a moment there are much more possibilities to make them more active than in a lecture. But some solutions, described below, can successfully be extended to large-enrollment classes.

Surprising extras added to a mandatory reading material (or a problem list to do).

I prepare complete reading materials for my classes with many detailed threads and examples. This may seem a little boring to students (when compared with a good crime story). Much to read every week. The material is published (www) 5 days before labs. I usually insert funny pictures (as in Fig.1) between explanations, or between conclusions. The aim of such a "decoration" is to wake up a presence of mind, a small relieve in a thought concentration. Sometimes I place a link to YouTube video (as one in Fig.2) which plays the same role, and also illustrates a problem in an amusing way.

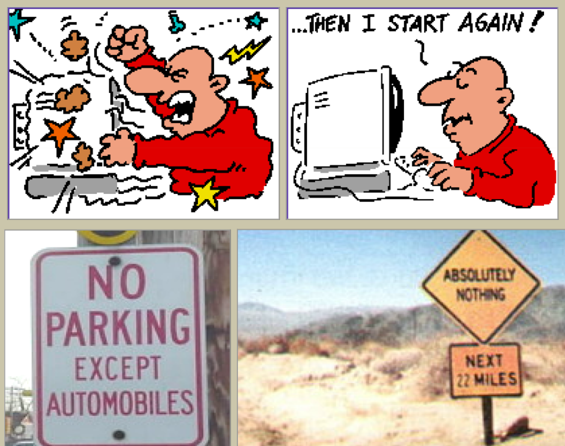

Fig. 1. Examples of amusing pictures inserted into a reading material in order to wake up a presence of mind.

Fig. 2. Example of an amusing youtube video which is to illustrate a physical problem. https://www.youtube.com/watch?v=2OTOgTZRmNw

Opinions of students (of the Numerical Methods in Physics): They anxiously waited for the material publication day to open and see images for the coming week. Therefore they had five days to learn, otherwise they would open and read a day before the lab at best.

Virtual awards for the first best solutions or student's tasks well done.

Tasks themselves to be done on my labs are revealed at the beginning of the lab. Students can earn their score with equal chances. Some tasks, particularly in the second half of the course, are complex and students are divided into two-person teams. I announce a competition between teams: who is better, who is faster? It usually in the past did not rise much emotions unless I once added that the winning team would get zozole candies (I had some with me by chance, popular fruit candies). The score result was not so important as candies for the winning team. Students behaved like kindergarteners, they wanted the candies more than anything else. They accelerated their work on the task, no waste of time for facebook visits. I realized that this could be a very efficient method for activating students to do their best on the lab. So selected tasks now have an inscription at the end of the task description, as shown in Fig.3. I buy zozole candies every semester.

Fig. 3. The inscription in the laboratory task (in Polish: zozole candies wait for the best team!)

Opinions of students (of the Web Technology Lab): They called the candies as a "taste of the triumph" and they felt almost as in Olympic games. The award was unparalleled and infrequent to them, so they partook in this competition with all their heart.

A deliberate usage of students hobbies (recorded to a video if possible for lab-room use)to arise an essential discussion.

I frequently ask students what they are interested in, what is their hobby. If I find an uncommon one, I invite this student and the rest of the group for video recording to document special skills and to look for problems and issues which can be modelled in a computer program or at least discussed on a scientific background. I found that when students had to discuss anything connected with his or her colleague they became more open and less shy as if they wanted to make a pleasure to the colleague. The example of such a video is available at http://radojewska.net/ptee2014/bike/

The frame shots are shown in Fig. 4. The video was entitled "Physics by bicycle, there and back" (meaning a bit mysteriously that physics is able to cycle and even in both directions).

The student on the bike was a member of the "Nabla" Student Scientific Circle and he was proud that he could promote his Circle at the student community forum and he could show his uncommon skills.

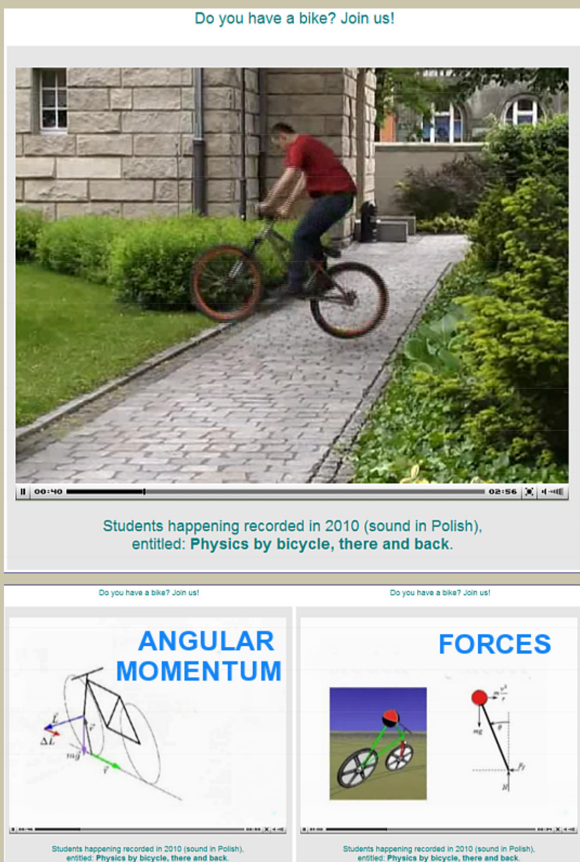

Fig. 4. Frame shots from the video: Physics by bicycle, there and back.

Opinions of students (of the Computer Modelling Lab): They had a little trouble with a question on how many parts were rotating in a bike. They liked the happening very much. They admired their skillful colleague. A few joined Student Scientific Circle.

Search for surrounding circumstances which may be included to activation schemes.

In 2013 our University launched a gondola (named Polinka, Fig.5) to join university buildings on two riversides (the bridge is quite far). This event was famous in media. Everyone wanted to travel in Polinka as a university attraction.

Fig. 5. Polinka – the university gondola linking two riversides (built in 2013).

I used this fact to resemble that five years earlier, when students were frequently late for my lecture due to a crowd in a tram near the student hostels at 9:00 (five large hostels at one place far from the university). I joked then that students should design a gondola to commute. Afterwards one student came and said: I shall design. And he did it in 2008 as his engineer's diploma. He focussed on the gondola fastener to the rope, made calculations, drawings and a model. Then he animated the gondola travel from students hostels to our university campus, frame shots are shown in Fig. 6.

The animation is available at http://radojewska.net/ptee2014/gondola/

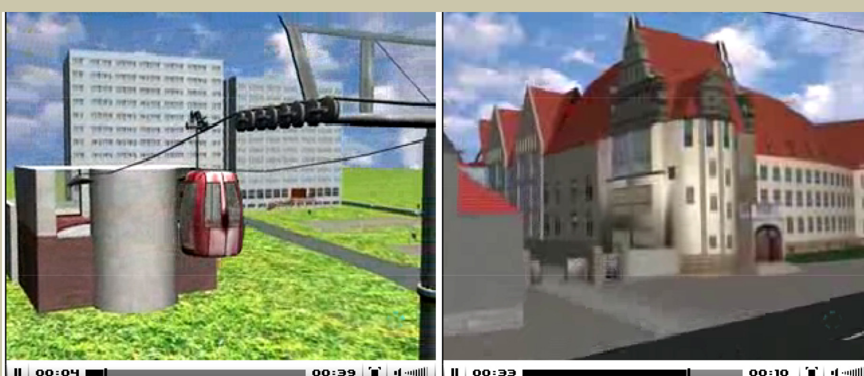

Fig. 6. Frame shots from the gondola animation. A part of the diploma by M.Rak.

Student hostels in the left and campus buildings in the right.

No-one expected that our university would have a real gondola within five years. Polinka gondola does not, however, travel to the students hostels, only to the other riverside (two minutes of the ride).

But our students could overtake time! This gave a basis for a discussion on: Is students laboratory work needful or useless (beside teaching)?

Students preferably would rather do more practical exercises. So a range of the taught matter may activate students as well.

Final remarks

An activation of students for greater efforts and engagements in learning should be a goal of each teacher. It helps not only talented students to develop their skills above average but also mean ones to achieve higher level than they would attain other way. The students response to an activation process is positive, so let us take advantage of it.

WS2

Activating students in large-enrolment course

Activating students or activating teachers?

Tormen, G.

Abstract

Although we can learn without a teacher, and - unfortunately - we can teach without anyone learning, I believe teaching and learning should exist in symbiosis. The old adagio: “teaching is useless unless it is unnecessary” should be seen under the new light of teachers as guides who can activate students’ individual and collective learning. This probably requires more effort than traditional lecturing, but the many resources available today make this effort feasible; in exchange, students activation provides immense return in term of student-teacher rapport, boosts motivation to understand the world in physical terms, and hopefully also provides a better long-lasting learning experience.

I will be presenting the structure of a standard introductory physics course for first year engineering students (mostly Mechanics & Thermodynamics) I am teaching this semester. Course material and homework activities are based on the Moodle platform. The course tries to blend in a meaningful way work in class and at home, group activities and individual work. I adopted the Peer Instruction model (Mazur, 1997) with a Just-in-Time strategy (Novak *et al.*, 1999). The course material includes textbook reading, web video resources, animation and simulation applets.

Finally, I will show how I used Moodle to try activating students before the course, and to keep contact with them and with their learning progress during the whole semester.

Activating Students in Large-Enrolment Courses: scope of the workshop

Bohrmann, S.

Abstract

The situation: in class, you allow access to all kinds of materials which may support and facilitate the solution of a problem you have posed: students' notes, teacher's manuscript, textbooks, handbooks, internet access (smart phones) - you even present the contents relevant on a screen while the students should try to work out the problem.

You wait for the start of an open discussion with first suggestions on the way to proceed and what to look up. The students' reaction: don't move. Avoid eye contact. Freeze. Just wait what is going to happen - sooner or later the teacher will lose his patience and start to present the solution by himself.

It seems all relevant study techniques - curiosity, open discussions, use of information sources and tools - are buried; even worse: not just the techniques are invisible, the students themselves try to be invisible. Quite obviously, a black hole seems to swallow all class traceless.

The workshop shall collect experiences and search for ways out of the dilemma. Do you confirm the above observations? What can be done about the phenomenon described? Can we fight the black hole in class, and if so: how, or should learning of study techniques be shifted to extra courses outside -before- university studies?

What measures are taken at universities, and how successful are they?

WS3

Project Based learning

In project-based learning (PBL) environments, learning is triggered by real-life problems, which are usually complex, multidisciplinary and open-ended, in the sense that there may be more than one possible solution. The learning process unfolds while students attempt to solve those problems, in a self-directed effort. This type of setting also creates the necessary environment for the development of personal and professional capabilities: students work in small groups, plan their own tasks, search for information autonomously, in a context which is close to the requirements of the challenges of the real life working place.

The workshop addressed PBL focusing on the following dimensions:

i) Context (including Engineering requirements, employability needs, Bologna process); ii) Project-Based Learning (project characteristics, project-based learning typologies, project-based learning challenges and gains); iii) Project-Based Learning implementations within the Portuguese context: the UMinho case and the ESTGA-UAveiro case.

Project-Based Learning in the Polytechnic School of Águeda

Oliveira, J.

Abstract

The first-cycle technological programs held at the Polytechnic School of Águeda have been running in a project based learning environment since 2001. The whole curricula have been designed and developed to support such an environment and students go through ten different projects over the course of three years, in teams of five students.

Project-Based Learning in the Industrial Engineering and Management Integrated Master degree at the University of Minho

Alves, A.

Lima, R.

Abstract

Industrial Engineering and Management (IEM) of University of Minho had been implementing project based learning since 2005 in the 1st year and 4th year. Students must develop a project, to solve a problem proposed by the coordination team in 1st year and by a company in the 4th year, involving all curricular units of the respective curricular semester. Both projects must be developed in teams of 6-9 students.

WS4

Video analysis

Video analysis of motions

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Abstract

Video analysis using program Tracker (Open Source Physics) in the educational process introduces a new creative method of teaching physics, makes natural sciences more interesting for the students (Brown, 2009). Exploring the laws of nature in this way can be amazing for the students because this educational software is illustrative, interactive, inspires them to think creatively, improves their performance and it can help in studying physics. With the help of a high-speed camera (for the preparation of motion files - video experiments) and the program Tracker the students can study certain motion in detail. The video analysis gives the students simple and easy way to understand the process of movement. The program Tracker seems to be a useful modeling tool, too. The computer modeling enables the students to relate the results of measurements to theory, showing relations between the graphs obtained using a model and a measurement. A post-instruction assessment of the students' ability to interpret kinematics graphs indicated that groups which used video analysis tools generally performed better than students taught via traditional instruction (Beichner, 1996). It has been confirmed that the competencies of the students have been more developed and their knowledge has been more increased through working with program Tracker as opposed to groups taught by traditional methods (Hockicko, 2012). Video analysis and modeling help the students to understand the natural sciences principles and natural phenomena more deeply, develop skills of abstraction and projection, awake curiosity towards nature and the surrounding world and make physics a lot more fun.

Keywords: video analysis, conceptual thinking, ICT – in education, attractiveness of education, computer aided learning

Summary

This paper deals with increasing the key competencies in engineering by analysing real life situation videos (physical problems) by means of video analysis and the modelling tools using the program. Video analysis, using the program Tracker (Open Source Physics), in the educational process introduces a new creative method of teaching physics and makes natural sciences more interesting for students. This way of exploring the laws of nature can amaze students because this illustrative and interactive educational software inspires them to think creatively, improves their performance and helps them in studying physics.

Introduction

Many authors confirmed that during the last two decades, entry-level engineering students' basic abilities in Physics (and Mathematics) have decreased dramatically (Tilli *et al.,* 2013; Krišťák *et al.*, 2014). Physics and technology are often considered to be difficult subjects. The main reason is that it is not easy to explain empirical laws and dynamic phenomena by means of textbooks. Multimedia technologies have already shown their potential in teaching scientific subjects. New techniques attract students' attention. If studying physics is accompanied by a computer program, a new form of very attractive education arises (at all stages of the educational process - starting at primary schools and ending up at universities) (Hockicko, 2010). It is very important to use multimedia tools in other subjects, including primary education, to make science and technology more appealing and to address the scientific apathy crisis of young people (Bussei *et al.,* 2003). Online literature, online tutoring system simulation and the association of the remote experiments can result in an online practical course, which can be very useful in engineering studies and can be helpful for engineering students throughout their academic studies and during their engineering careers (Khachadorian *et al.*, 2011). Physics is based on experimental observations and quantitative measurements. The fundamental laws are expressed in the language of mathematics - the tool that provides the bridge between theory and experiment. Teachers constantly work on improving students´ understanding of various phenomena and fundamental laws. One of the new creative methods of teaching physics which makes natural sciences more interesting for the students is video analysis using the programs Tracker (Open Source Physics) or Coach (Brown *et al.,* 2009). Collaborative projects based on digital video analysis provide an educational, motivating, and cost-effective alternative to traditional course-related activities in introductory physics (Laws *et al.*, 1998).

Several innovative methods in physics education were described and evaluated and the impact of these methods on the learning outcomes of physics students was investigated. In the 1980's David Hestenes and Ibrahim Halloun (Halloun *et al.*, 1985) published papers on didactic research, whose object were students of secondary schools and universities, dealing with misconceptions in Newtonian dynamics. One of the research results was the test (Force Concept Inventory (FCI)) (Hestenes *et al.*, 1992) containing questions from Newtonian mechanics dealing with everyday life. The authors decided to research whether students understand the basic mechanics concepts sufficiently; how they are able to work with them and apply them into various everyday situations. The global test results showed that the traditional teaching of the Newtonian mechanics in the early years of university studies eliminates the wrong perception of students acquired during their secondary school studies only to a small extent. One of the most important features of FCI is that it can be used to notice the common-sense misconceptions students have when trying to apply Newtonian mechanics ideas (Martín-Blas *et al.*, 2010). It was also shown that traditional lectures or seminars help to acquire only basic knowledge without deeper understanding and ability of problem solving; the students do not show conceptual understanding of the subject which should result from a sufficient number of solved quantitative tasks and from logically clear lectures (Redish, 2003).

This paper deals with real life situations video analysis using programs Tracker.

Tracker and video analysis of motion

All we need for a video analysis is a camera (mobile phone, tablet) to prepare motion files - video experiments. With the help of a high-speed camera and the program Tracker students can study certain motion in detail. They can observe various characteristics of the motion and learn the basics of classical physics while having fun. Video analysis gives students a simple and easy way to understand the process of movement. These activities are made possible by integrated ICT (information and communication technology) tools that use videos (via point-tracking) to measure.

A Casio Exilim Ex-FH25 and EX-ZR1000 cameras were used for preparing the video files; we assigned this task to students. These cameras allowed us to record videos with 30, 120, 240, 420 and 1000 frames per second (fps) (these cameras are cheaper than a professional high-speed camera).

The main task of a video analysis is to build the right conception of the natural phenomena and in the next step to use them for physical analysis. All we need is:

- a final video in the following formats: avi, mov, mpg;
- to know the video´s number of frames per second (fps) (for calculation of Δt);
- real dimensions in the video, for example 1 meter.

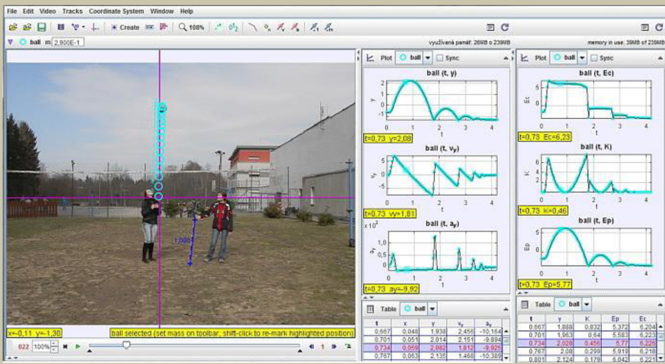

Fig. 1. Video analysis of a thrown ball in y-direction using program Tracker

Students can find some important parameters in a description of a task (e.g. mass), other parameters can be found only by carrying out the task using the programs Tracker (e.g. velocity, acceleration, momentum, energy).

By means of the Tracker (or Coach) students can detect the relationship between physical quantities and describe a motion using time dependencies. The Tracker offers time dependencies of 22 physical quantities (and/or we can define other) and data processing by means of graphs and tables. From the number of frames per second (30 fps or 120 fps usually) the time is deduced ($\Delta t = 0.033$ s or $\Delta t = 0.0083$ s) while the position can be measured in two dimensions (x, y) using a calibrated video image. The autotracking function in this program allows accurate tracking without a mouse. The studied motion can be divided into two parts: the horizontal component and the vertical component (Fig. 1). These two components can be analysed individually and the results can consequently be combined to describe the total motion (x(t), y(t), vx(t), vy(t), ax(t), ay(t)).

One of the tasks for students: analyse the motion of a ball after throwing it into the air. Find the expression for the speed and the position of the ball as a function of time (the effect of air resistance has been considered to be negligible). What is the acceleration/deceleration of the ball in different positions (in move up of the ball, in maximum position and move down)?

By means of the program Tracker (Data Tool) we can apply infinitesimal calculus and the program calculates velocity and acceleration from the time changes in different positions. The students can fit the time dependencies of position (Fig. 2), velocity (Fig. 3), acceleration and other time variables using a data tool which provides data analysis, including automatic or manual curve fitting of all or any selected subset of data. The position and the velocity can be plotted and fitted to see the correlation between the real data and the kinematic equations (Hockicko 2010, 2012).

Figures 2 and 3 show the analysis of position (squares) and velocity (circles) of the volleyball ball in the vertical direction. By doing a mathematical fit (Fig. 2) students can observe that the trajectory of this ball (squares) is always a parabola which can be described by means of the equation

$y = at2 + bt + c$. (1)

The projectile motion of the ball in the vertical direction can be mathematically described by equations valid for motion at a constant acceleration ayy = 1/2ayt2 + v0yt + y0 . (2)

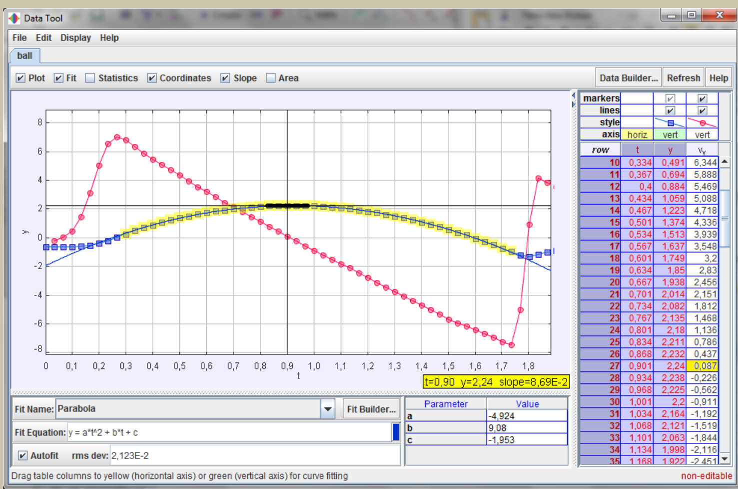

Fig. 2. Analysis of a y-position of a thrown ball using program Tracker (Data Tool)

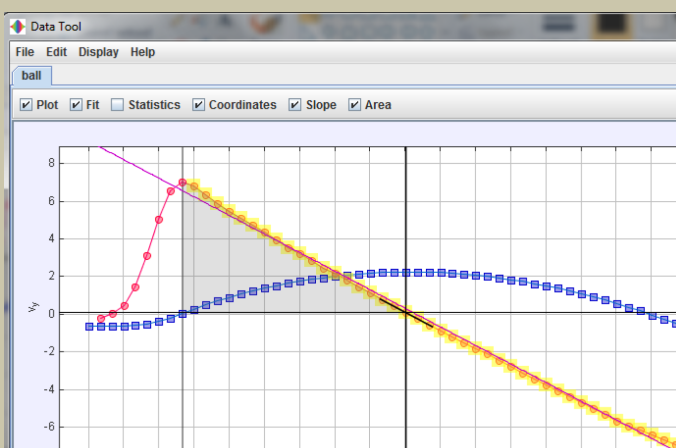

Fig. 3. Analysis of a y-velocity of a thrown ball using program Tracker (Data Tool)

Comparing equations (1) and (2) gives a = 1/2ay, b = v0y, and c = y0. From this fit students find out that ay = - 9.848 m.s-2 which is in a good agreement with the value of the free-fall acceleration. The second parameter b = 9.08 m.s-1 corresponds to the initial velocity (v0y) of the ball in the vertical direction after throwing it into the air. The third parameter c = -1.953 m corresponds to the initial position (y) of the ball (it can be changed by modification of the position of axes; in ideal case we can determine initial position y(0)).

Analogically the mathematical fit of the velocity of a ball in vertical direction (Fig. 3) is always a straight line which can be described by the equation

vy = at + b = ayt +vy0 . (3)

Eq. 3 gives ay = - 9.871 m.s-2 which is in a good agreement with the value of free-fall acceleration, too. The second parameter b = 9.194 m.s-1 corresponds to the initial velocity of the ball in the vertical direction (we can find it using extrapolation of linear fit).

Using the functions Slope and Area in the program Tracker, one can demonstrate the mathematical connection with the derivative and the integral of functions (the first derivative of the function y(t) at t= 0.90 s shows the value 0.0869 which is the same as the velocity at this time (see the table in Fig. 2). Integration of the function vy(t) in the range from t8 = 0.267 s to t27 = 0.901 s shows the value area = 2.20 (Fig. 3) which is very close to the difference of y-positions at these times (y27 – y8 = 2.24 m – 0.038 m = 2.202 m). Function Slope shows the value -9.92 which means the value of the free-fall acceleration at the time t27 = 0.901 s (vy(0.901) = 0.09 m/s which is very close to zero velocity in the maximal vertical position of the ball). As students can see from Fig. 3 the position (velocity) of the ball in the y-direction increases and decreases (decrease and increase) in the time interval (0.267 s – 1.74 s) but the acceleration of the ball (slope) is the same in the whole investigated time interval. (Not zero, as the majority of students wrongly think about acceleration in the maximum position of the ball!)

Next motivation for analysis is: “What was the force exerted by the student throwing the ball?” Program Tracker offers two types of models: analytic and dynamic. The analytic one defines position functions of time, while the dynamic one defines force functions and initial conditions for numerical solvers. The students have analysed the motion of the ball after throwing it and defined position functions of time and force functions with initial conditions in two directions. The students have thought about the accelerated motion (with free-fall acceleration) in the vertical direction. The only force acting on the ball was the force of gravity (the effect of air resistance has been considered to be negligible).

Feedback

Students were asked to make comments on the learning carried out by means of video analysis and modelling tools. What have they considered to be positive about this form of education?

- cooperation with the teacher, professor's individual approach to each student, supporting the self-reliance of the individual;
- quick explanation of the principles of problems, quick and clear form of the studied problems, time saving;
- not only one student was solving a problem the blackboard, all students worked independently on solving the problem using the computer;
- comprehensibility (picture information), the large number of solved problems during practicing, I think that it will be good to continue with this form of education;
- accessibility of information (equations) and solved problems, availability of instructions for solving new problems, an opportunity to find information in a short time;
- a very advantageous form of learning, if I don't understand anything, I can ask quickly but I have to think and find the information individually;
- I usually participated in discussions, when I discussed with the others, I learned more. In my opinion, discussion made the lessons more motivating – I've had new ideas. Finally, the answers were discussed with the teacher and it was important for the learning;
- the learning was very good, lively, congenial atmosphere, gingering us up, something new for us, it was quite a good change, I was delighted with this form of learning, I liked this form of learning;
- these tasks were unusual, they did not require calculations like normal exercises do but knowledge of concepts;
- I have learned and understood a lot but just the exam will show if it was enough.

Conclusion

The use of interactive methods in teaching physics have significantly influenced the level of students' knowledge. The students´competencies can be developed and their knowledge can increased by working with the program Tracker.

Students have declared that the video analysis and modelling tools helped them to understand the natural sciences principles and phenomena more deeply, developed their abstract thinking and projection skills and their understanding, aroused their curiosity towards the surrounding world and nature, interconnected physics with the real word and made physics a lot more fun.

Acknowledgement

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Using video solutions and "hi-score-list" to increase and to monitor student's homework

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Abstract

New method to study introductory engineering physics at Tampere University of Applied Sciences was presented in SEFI 2013 conference by the authors. The key idea is to engage students to study actively. The active engagement covers not only physics lectures, but also learning outside classroom. Significant part of the new method is to emphasize continuous assessment instead of only one final examination. Therefore, weekly exams form half of the course assessment. To arrange enough time for week-exams, peer instruction and other activities in the lectures, some routine-like activities, like exemplary calculations and answers to homework exercises are implemented using video streaming technology (YouTube). In the new method, the homework exercises themselves do not give any points for the course assessment. As the exercises themselves are not a part of the course assessment, there is a concern that students do not actively do them, or just passively watch the solution videos. To increase the homework activity, a concept of hi-score-list is introduced. In the concept, the students register their homework activity in the shared Google-docs spreadsheet document in which they can follow, not only their own but also the other students' homework activity. Students can compare their performance to that of the others. To collect data of the students' homework activity, the weekly backups of the hi-score-list are used together with Moodle's activity reports. By taking backup copies weekly, the accumulation of the homework accomplishments can be monitored throughout the course. As a result of this study, the watching activity of the exercise solution videos is presented. Data from earlier courses show that the video streaming activity is the highest close to week exams and the final exam. The accumulation of the completed homework assignments using the data from the hi-score-list is presented, as well as feedback-based students' opinions about the importance of hi-score list to form positive pressure towards better homework activity.

Keywords: Increasing homework activity; Hi-score list; Active engagement;

Summary

Active engagement of the students is recognized as the key factor to enhance students' learning outcomes. In order to activate students also outside lectures and to monitor students' homework activity, the combination of solution videos and hi-score-list is used. Continuous assessment is applied implementing week-exams for every two weeks throughout the course. As the result, the week exams and the solution videos have the most impact on students' activity. Hi-score-list is not seen as activating by the students, but a valuable tool to monitor students' activity.

Introduction

Hi-score-list is the list of the best scores and the people behind them in a computer or videogame, which is shown on the screen after the game or between games. The key idea of the list is to present publicly the top scores achieved in the game. To be on the top of the list gives the player honor among other players. Player can benchmark his or her own result to the others. The same idea is now adopted in introductory physics homework activities. The goal is to increase and to monitor the students' homework activity during introductory physics course. Students are also encouraged to practice with homework problems using solution videos streamed via YouTube. Because students' post-lecture homework activity is not examined during face to face sessions and it does not give any points for the final assessment, monitoring high score list is a way to follow students' activity outside classroom. One aspect in this study is to find out, whether the hi-score-list enhances activity by raising positive competition within student group.

Activating students

The active engagement during lectures is recognized as one of the key factors of successful physics education. The learning outcomes, especially if conceptual understanding is measured is reported to be significantly better with active engagement methods compared to the traditional lecturing. (Hake, R., 1998). The active engagement methods are methods that stimulate students actively process information towards the correct concept formation in lectures. The reported methods are for example Peer Instruction (Crouch, C. H., Mazur, E., 2001) and Interactive lecture demonstrations (Sokoloff, D.R., Thornton, R.K. 1997). Different kind of pre-lecture textbook reading assignments, pre-lecture assignments and tutorials is used to activate students prior to the lectures and to achieve sufficient prior knowledge to cope with active engagement lectures (Crouch, C. H., Mazur, E., 2001). The pre- lecture activities can also be implemented with the help of video tutorials (Callens et al 2011). To support students' homework activity after the lectures, the homework activity or completed homework tasks may be recognized as a part of the final assessment.

The new method to study introductory physics at Tampere University of Applied Sciences in engineering education was reported in SEFI2013 conference by the authors and some of its results in other conferences (Tiili, Suhonen, 2013) (Suhonen, Tiili, 2014). In the new method the homework activity does not give any points to final score. The decision was made based to the earlier experience which shows that despite the extra points earned for the final exam, only a part of the students did the homework properly and plagiarism was common. The checking of the homework took also too much valuable lecture time. The continuous assessment is taken care with week exams during the course. The homework problems are recognized as valuable practicing method and therefore a system to encourage and to monitor the homework activity is a valuable tool to enhance students learning outcomes.

Increasing the homework activity using solution videos and high-score list

The aim of this study is

- To describe the idea of hi-score-list and solution videos to increase and to monitor the students';
- homework activity;
- Find out impact of the use of hi-score-list and solution videos as activators;
- To present the results of students' homework activity through 14-weeks introductory physics course.

Tampere UAS has strongly developed its introductory physics courses towards active engagement of the students. As a part of the development the activation is wanted to extent outside lectures in order to achieve better learning outcomes. The elements to support the development are:

- Week exams
- Solution videos
- High score list

The idea of week exams is to force the students to study actively throughout the course, not only a few days prior to the final exam. The weight of the week exams is therefore raised up to 50 % of the total points for the final grade. Week exams and the active engagement activities need a lot of valuable lecture time. In order to release the time, the homework activity is monitored using the hi- score-list, and the solutions to the homework problems are presented to students using unlisted (not public) videos in YouTube. The solution videos raise the threat that students do not put enough active effort to find solutions to the problems, only passively watch the videos. Therefore, the score of individual solutions and the score of video-assisted solutions are presented separately in hi-score- list.

The implemented hi-score-list is a shared Google docs spreadsheet document, embedded in Moodle, which students can edit themselves. The key idea of the list is to provoke some competition in homework activity among students in a good spirit and enhance awareness of the activity of others. Students are asked to register the amount of completed homework exercises divided in two categories, the exercises made by themselves and the exercises made using the help of the solution videos. The cumulative percentage of the given exercises is presented as the score of the student. The registration of the exercises is voluntary but strongly encouraged. Because the score does not affect the final grade of the student, there is no reason to worry about cheating. Every lecture session begins with overall view of the list. During the course, backup copies of the list were taken, so the time dependence of homework activity can be presented. The other method to study students' homework activity is to monitor the activity of the YouTube channel using Google Analytics and the log files of the course's Moodle pages.

The study was implemented in a physics course named "Oscillation and Waves, Atom and Nuclear Physics, 3 cr", which had 38 participants, who were second year bachelor-level engineering students in Tampere UAS.

Results

The hi-score-list was accessed 267 times by students during the course. The hi-score-list based, combined students' homework activity during the first 12 weeks course, when the lectures were held, is presented in figure 1. The figure presents the percentage of all possible homework done during every week.

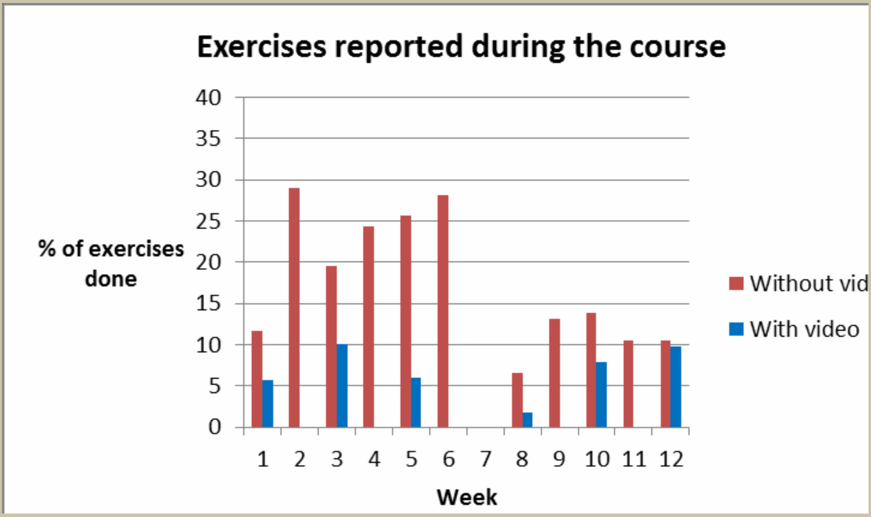

Fig. 1. Exercises reported weekly

The figure 1 shows that reported homework activity is close to 25 % of all possible homework during the first six weeks of the course. After the one week's holiday (week 7), the homework activity drops dramatically. To compare the reported amounts of exercises completed without videos and with videos, the amount of exercises done without videos is about three times higher than amount of exercises done with videos.

The final exam was held in the week 14 and students were asked to continue to fill in the hiscore-list during the remaining two weeks' time when they were practicing for the exam by calculating the previous weeks' exercises. The final reported percentages of the weekly homework exercises are presented in figure 2.

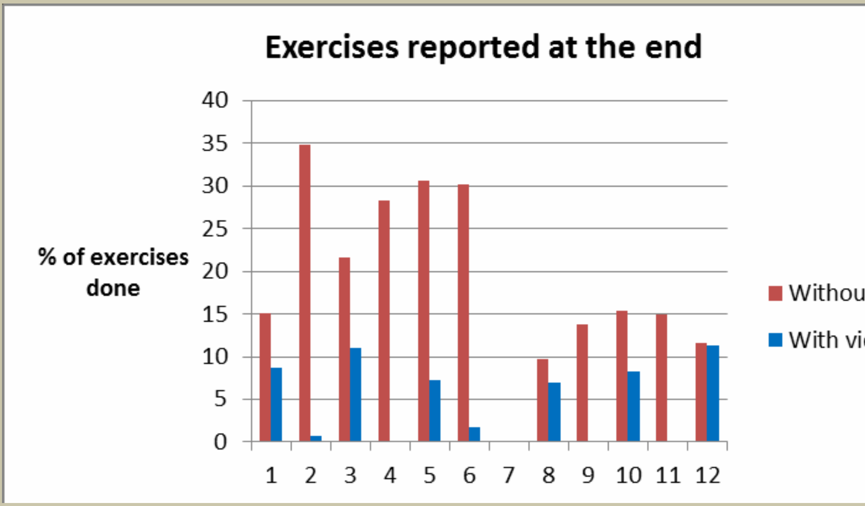

Fig. 2. Exercises reported at the end of the course

When figures 1 and 2, are compared, figure 2 shows slight improvement for every week on completed homework exercises. This is a result of students' practicing for the final exam during the weeks between lectures and final exam. The difference between figures 1 and 2 also shows that the help of the videos have been used slightly more than earlier part of the course.

The students' video watching activity was monitored using Moodle's log files. The log files show that students accessed the solution video files 915 times during the course. The real watching activity is much higher than reported activity in hi-score-list. The daily video watching activity during the course is presented in figure 3.

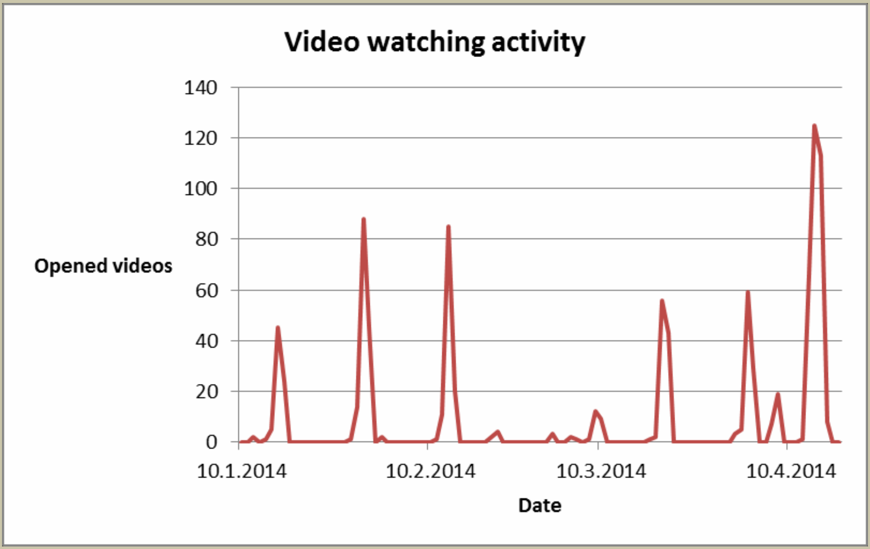

Fig. 3. Video watching activity during the course

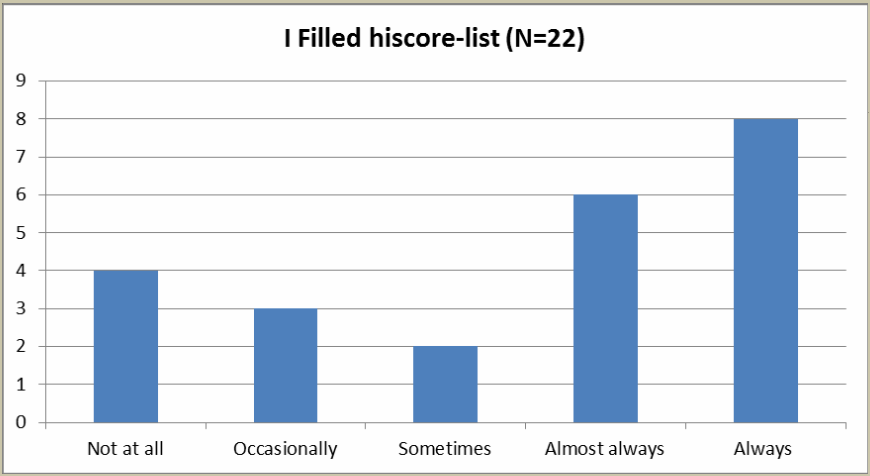

Fig.4. Hi-score-list usage, according to survey

Figure 4 shows that the hi-score-list is not always filled by the students. Therefore it gives only indicative information of the real activity of the students. The conclusion from the students’ open text answers concerning hi-score-list shows that the list is mainly seen as a tool for the teacher to monitor the homework activity of the students.

Students were also asked about the activation effects of different methods used during the course. The question was stated that "How much did the following element of the course activate you to study during the course". The answer distribution of the question is presented in figure 5.

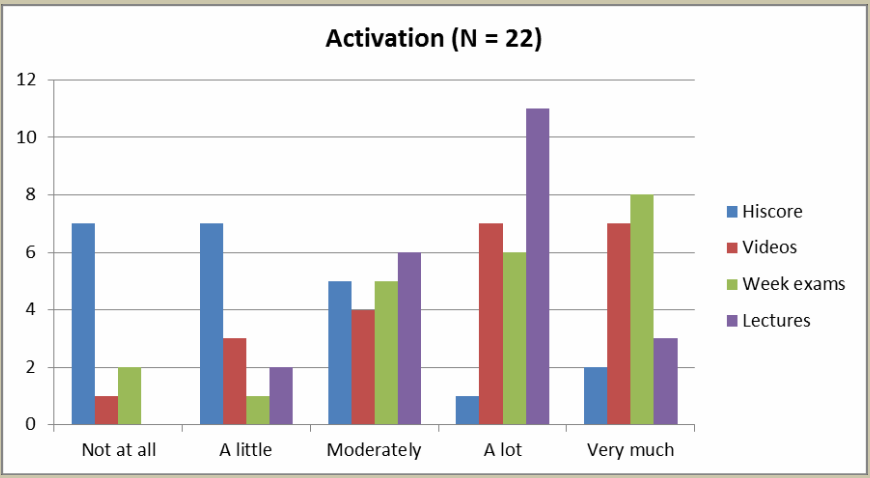

Fig. 5. Activation effect of the course elements

The distribution presented in figure 5 confirms the conclusion on the effect of assessment – studying for an exam seems to be the strongest motivator. The videos and week exams were reported to activate students as much or even more than lectures. In the open answers of the students, the solution videos got very positive feedback. They were seen as the help for the problem-solving, which is always available through internet. The videos were watched mainly because a student had got stuck in the homework problem.

Conclusions

As the conclusions of the study it can be said that assessment has very strong impact on student activity. Week exams held every two weeks activate students to study throughout the course. Student activity is strongly connected to the exams. The availability of solution videos is reported to be very activating by the students. They are seen to be very helpful aid for homework problems, if they are used wisely. Of course there is a temptation to just passively watch the video without student's own processing of the problem. According to survey of students' hi-score-list is not seen as activating item as solution videos or week exams, but mainly as teacher's tool of monitoring students' homework activity. As a teacher the hi-score-list is seen as suitable tool to monitor and to wake students' activity.

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WS5

Open Themes

Using pre-lecture assignments to enhance students learning in introductory physics

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Abstract

The prior knowledge of a student is always the inception to his/her learning. Recognizing and increasing students' prior knowledge advances both student and teacher to construct better learning processes, no matter what kind of teaching methods are used. Recognition helps in both cases, traditional lecturing and active engagement methods. In the teacher point of view recognizing students' prior knowledge helps teacher to plan teaching and methods suitable for students. In students' point of view recognizing prior knowledge prepares to the face-to-face sessions of any kind. In Tampere UAS, introductory physics teaching is strongly going towards active engagement of the students. The activation is extended also outside lectures, in which the pre-lecture assignments play a role. The nature of pre-lecture assignments varies from conceptual questions to calculatory problems, some of which are equipped with solution videos. The main objectives are to recognize and increase students' prior knowledge, to activate students between lectures, to use lecture time more efficiently and actively and to be able to concentrate on more demanding aspects of the topic during lectures. Pre-lecture assignments are not a part of course assessment, but strongly help students to prepare to week exams and final exam. As the pre-lecture assignments are not a part of course assessment, students are supposed to voluntarily report the number of completed assignments in the shared document, from which they can monitor their own and other students activity. Based on data gathered from students:

- Prior knowledge of the topic in question is recalled to active memory.
- Students are able to recognize totally new concepts on subject matter.
- Students are able to recognize physical phenomena and laws concerning the subject matter.
- More effort is needed to activate students to do pre-lecture assignments.

Keywords: Active learning; Pre-lecture assignments; Prior knowledge.

Summary

Active learning methods are the key to better learning outcomes. Using pre-lecture assignments students can be activated before and between lectures and teacher can focus on more demanding aspects of the topic during lectures. However, students easily think that they should get some extra points or pre-lecture assignments should be more or less compulsory so that they find motivation to do them. In this case study we present feedback from students and discuss how to activate students more.

Introduction

Tampere UAS has strongly developed introductory engineering education towards active engagement methods (Suhonen, S., Tiili, J., 2014). As a part of the development process, the pre-lecture assignments are used for several purposes to support the active engagement learning environment. The use of pre-lecture assignments was piloted in the first year engineering physics course “Electricity and Magnetism” in spring 2014. This paper describes one way of using pre-lecture assignments and how students react to assignments. In the end of the course students were asked by a few questions how often they did the given tasks and did they find them useful.

Activating students prior to the lectures

Activating learning environment is reported to be the key solution to achieve better learning outcomes. Students studying in active learning environment have been reported to achieve better learning outcomes compared to students studying in traditional lecture classes (Hake, R., 1998). The active learning methods, for example Peer Instruction (Crouch, C. H., Mazur, E., 2001) and interactive lecture demonstrations (Sokoloff, D.R., Thornton, R.K., 1997) require that students prepare themselves to the lectures beforehand. This preparation may be taken care with textbook reading assignments, tutorial video clips (Callens, R. *et al.*, 2011), online pre-lectures (Sadaghiani, H., 2012) or other pre-lecture assignments. Pre-lecture assignments are also useful in traditional lecturing (Kolari, S., Savander-Ranne, C., 2007). It is always an advantage if students are prepared to the subjects concerned beforehand.

In order to improve the learning outcomes of the engineering students’ introductory physics courses, the new method to study introductory physics in engineering education was reported in SEFI2013 conference (Tiili, J., Suhonen, S., 2013). The key points in the new method to study physics in Tampere UAS are active engagement during lectures, the use of week exams to emphasize continuous assessment and to use solution videos to homework problems in order to release time for week exams and active engagement in the lectures. The students' active role is wanted to extend outside lectures, so students are encouraged to study beforehand using pre-lecture assignments. The main objectives of the pre-lecture assignments are:

- To increase students' prior knowledge;
- To perceive students' preconceptions;
- To concentrate on more demanding aspects of a topic;
- To concentrate more on examples concerning students' own field of study during lectures;
- To use lecturing time more efficiently;
- To motivate a student to spent more time on studying.

In the course of "Electricity and Magnetism", pre-lecture assignments were given to students one week before lectures. The assignments included both conceptual and calculus-based problems. Students carried out the assignments and registered their accomplishments to a shared spreadsheet document in an e-learning platform Moodle. The model solutions to calculus-based questions were distributed using links to YouTube videos. The assignments themselves were not a part of the course assessment. An example of one week's pre-lecture assignment is stated below:

Topic for the next week is electric potential and voltage, book's chapter 1.4. Find out (e.g. in groups) the meaning of electric potential, voltage, the work done by electric field and how to calculate the potential of a point charge (see example 1.17). Calculate exercises 1.29, 1.37 and 1.38. Video solutions are also available if you need extra help.

The whole class was divided to six groups, six students in each group. The students were encouraged to work in groups also outside the classroom. For this purpose one classroom was reserved one hour per week for the whole duration of the course. On the basis of discussion with students, they also worked in groups, at least before the week exams.

Results

In the end of the course students were asked by a questionnaire how well different methods work in practice and how to improve the teaching methods used. 27 of 36 students gave their feedback. Questions about pre-lecture assignments were:

- How often did you do pre-lecture assignments?
- How much did the pre-lecture assignments activate you to study?
- Assistance of the pre-lecture assignments to the learning outcomes?
- What was the usefulness of the pre-lecture assignments if you did them? If you didn't do them, how can you be activated?

The results for the first question are shown in figure 1.

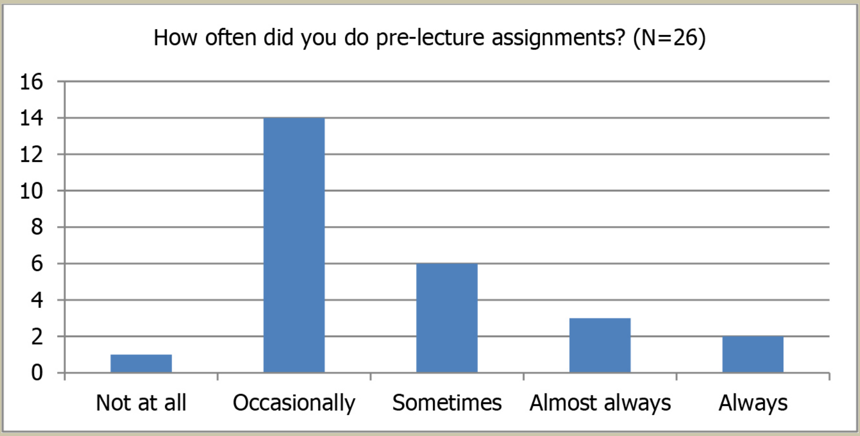

Fig. 1. Activity of completing the pre-lecture assignments. Total number of answers is 26.

Students' activity of doing pre-lecture assignments was not as active as wanted. Most of the students did them only occasionally. However, they realize the usefulness of pre-lecture assignments for their learning but motivation was still rather low. Here are some examples of students' feedback:

> *"I learned a lot. I was better prepared for the lectures because I had a small vision of the topic."*
>
> *"It's much easier to follow lectures when I was oriented for the topic beforehand."*
>
> *"I would have done the pre-lecture assignments if I was forced to. Secondly, I was already familiar with the subject."*

> *"I didn't do any assignments. I'd be motivated if part of the assignments were obligatory and I got*
>
> *some extra points."*

The second question was associated to the same aspect, do the pre-lecture assignments activate students prior the lectures. Figure 2 summarises the student feedback. According to answers the activation could be increased if students get some benefit for the final course assessment. "*If I get some extra points!*" Most of the students are oriented to collect points for final assessment and they maybe do not realize the worth of studying before lectures. Students were told that week exams might include even same problems. For some reason this was not motivating enough. On the other hand, this is also a question of assessment; you get what you assess. When the final grade is based on accumulation of points from week and final exams, it guides student a lot. Some other evaluation methods must be brought into use in addition to exams.

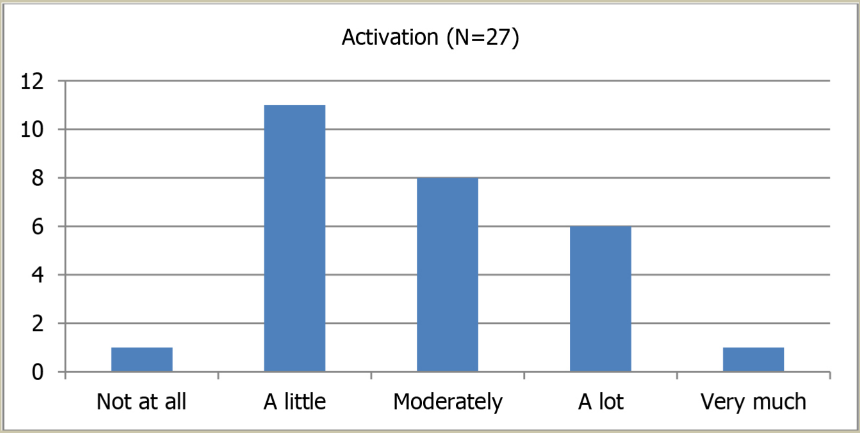

Fig. 2. Students' feedback for activating effect of the pre-lecture assignments. Total number of answers is 27.

As a third question students were asked, whether the pre-lecture assignments helped them to achieve the learning objectives and improved their learning outcomes. Figure 3 summarizes the results.

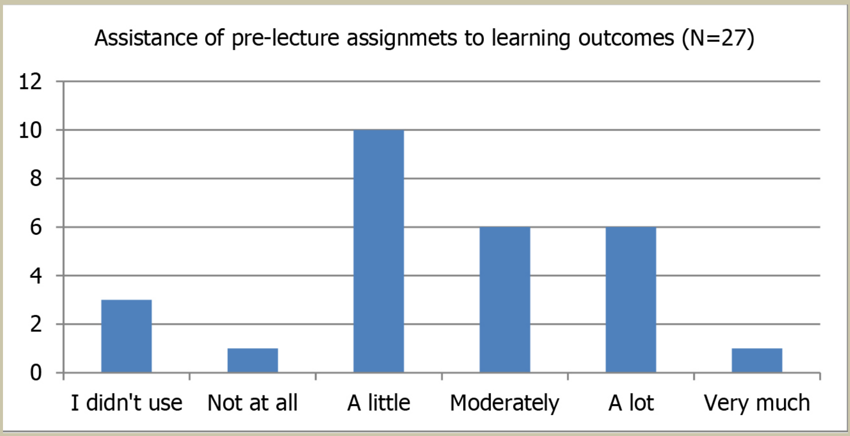

Fig. 3. Assistance of assignments. Total number of answers is 26.

Students who had made at least a few pre-lecture assignments find them useful. Their knowledge increased at least a bit, they were able to recognize physical phenomena and laws concerning the subject matter.

"I had no previous knowledge of the course topics so it was useful to be somehow prepared for lectrures."

"Pre-lecture assignments are a good way to get students to study."

"Pre-lecture assignments improved my skills for calculating exercises."

"It was easy to find the more important subjects."

Conclusions

Students do realize that pre-lecture assignments are good way to prepare themselves for lectures and increase knowledge before lectures. They can recognize totally new concepts on the subject matter. Benefits are clear. However their activation for doing the assignments was not as high level as wanted. For the next course some of the assignments might be compulsory and preliminary work could be discussed in groups in the beginning of the lectures. Hence the teacher can also give feedback to students. Some of the assignments could also be reviewed by returning the completed assignments to the e-learning platform. Checking each students' or groups' assignments needs of course time and effort. A peer evaluation of pre-lecture assignments between student groups could be an interesting solution. Anyway, pre-lecture assignments will be taken in active use for most of the courses in the future in Tampere UAS.

Based on instructor's experience from previous years, pass rate of the course was observed to be higher than on average. However, there is usually rather large variation between student groups and therefore it cannot be assigned to pre-lecture assignments alone.

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Concept mapping for physics engineering

Leitão, C.

Abstract

Concept maps are graphical tools for organizing and representing knowledge. They are used to identify the relationship of concepts and they can serve as a dynamic and engaging teaching tool. The maps are used to answer a focus question, by including key concepts, usually enclosed in boxes or circles, connected by lines that specify the nature of the association, referred to as linking words or phrases. This presentation will start by introducing the fundamentals of concept mapping and how this tool can be applied in the teaching/learning dynamics. A specific example will be discussed, with the use of this tool in a PhD thesis in Physics Engineering. Finally, some software tools for concept mapping will be presented.

Fiber sensors for optical training courses

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Abstract

Laboratory experiments for graduate optical disciplines of different engineering courses and training schools of short duration have been implemented and developed. The work has been focused on the development of general optical competences and its applications on innovative engineering solutions.

The polymeric optical fibres have emerged almost simultaneously with traditional optical glass fibres, in the 60s of last century and are usually produced in polymethylmethacrylate, rigid and transparent thermoplastic polymer. The sensors characterized in these experimental works use the changes in the attenuation value, on the coupling region between two polymeric optical fibers, due to external disturbances, related to the parameter to be measured. The obtained results was analysed and discussed and its impact that such projects can have on engineering education, namely on the students who attend summer courses or discipline of optics

and optoelectronics in graduate and postgraduate engineering physics courses.

Keywords: Polymeric fibers; optical signal; attenuation, optical losses.

Summary

The work developed had main focus for the development of general optical skills and its applications on innovative engineering solutions, and yet on the students who attend summer courses or discipline of optics and optoelectronics in graduate and postgraduate engineering physics courses.

Introduction

In the last years many optical sensors capable of monitoring the deflection and elongation of various elements, the distance between points of a structure, level and flow rate of liquid, relative humidity, electric current, pressure, temperature, refractive index and others have been proposed (Peters, 2010 & Birlo, 2007,2011). In spite of the polymeric optical fibers (POF's) data transmission over long distances being limited, it is possible to use sensors within a reasonable distance (tens of meters) from your interrogation system.

Therefore, it is possible to apply the technique of monitoring in numerous situations in which the use of electrical sensors can cause some problems, such as environments with high humidity, corrosive, flammable (Antunes *et al.*, 2007 & Leitão et al, 2011). In this sense, it is important the development and or optimization of optical sensors based on polymer optical fiber, in order to meet the needs of a demanding industry of construction and maintenance of infrastructure. These sensors have some advantages compared to conventional sensors such as being compact, lightweight, robust, and potentially with lower cost (Peters, 2010, Birlo, 2007, 2011 & Leitão *et al.*, 2011).

In relation to the electrical sensors, the optical sensors have considerable advantages because they are immune to electromagnetic fields, there is no risk of a short circuit (can be used safely in flammable environments), can be used in water environments.

The polymeric fibers are composed of two distinct regions, designated core (were optical signals propagate) surrounded by a region called the cladding (Antunes *et al.*, 2007). The optical signal is guided by total internal reflection, mostly inside the core.

The fibers can be classified into two categories, taking into account the propagation modes permitted for the optical signal, namely, the single-mode fibers and multimode fibers, (the single-mode fibers have a core of smaller diameter about 10 μm, while the diameter of the multimode fibers can go up to 2 mm).

Attenuation, α , can be defined as,

$$\alpha (dB) = 10 \times \log_{10} \frac{P_i}{P_0}$$

where, Pi and P0 are, respectively, the input and output power of the optical signal (Arrue *et al.*, 2007 & Ziemann, 2008). The polymeric optical fiber used throughout these experimental works presents a core diameter of 1 mm and typical attenuation 0,22 dB/m.

The main advantage of the polymeric fibre for glass fibers are ease of connection and handling, which results from its large diameter thereby enabling the use of connectors with low precision and low cost, and spectral window of operation of these fibers (the spectral region where attenuation is minimal) happens in the visible, resulting in a reduction in the cost of optoelectronic components used, particularly in optical sources and receivers (Antunes, 2007, Birlo 2007 & Leitão 2011).

The development of mini projects was implemented on the 3rd OPTICWISE Training School on Optical Wireless Communications which took place in University of Aveiro, in april 2014.

Experimental Systems

The attenuation in the coupling between the polymer optical fibers has a dependency to external disturbances applied.

The characterization process involves injecting an optical signal into a fiber subject to external disturbance; and the detection of this signal at the other end of the fiber, making it possible to quantify the attenuation resulting from the propagation. The linear position fiber sensor has as main objective, monitoring up to 15 mm through fibre light coupling losses (dB).

This sensor consists of two metal parts, where one of the parts slides through a slot in the other. As displayed on Figure 1, two polymer optical fibers are glued to the sensor, one on each side, in the groove aligned along of the two parts. As show, one can see a schematic diagram of linear position fiber sensor. One of these fibers is connected to a LED (light emitting) and the other fiber connected to a photodiode (receptor).

In order to be able control the existing offset between the optical fibers, a micrometer was used. And to optimize the laboratory tests, LED should be used for the blue (430 nm) light since it has the greatest optical power.

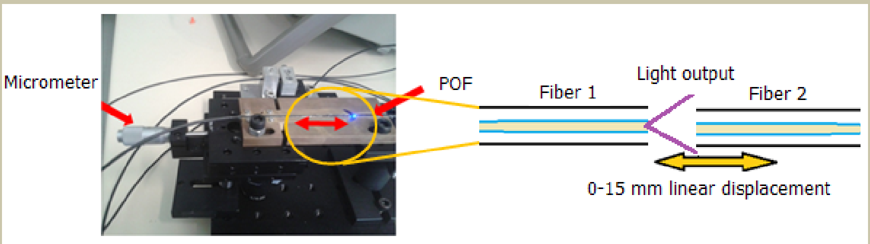


Fig. 1. Experimental Systems and schematic diagram of linear position fiber sensor.

The experimental systems used for linear position fibre sensor was: 2x1 m plastic optical fibre, 1 blue LED (model IF E92A, Industrial Fiber Optics), 1 Photodetector (IFD91, Industrial Fiber Optics), 1 Single Axis Translation Stage (Accuracy: 0,01 mm), 1 Oscilloscope (HEWLETT PACKARD 54600A) or Data acquisition board (NI USB6008) associated with Software Labview ®, and 1 Power Supply (12 V). The polymer optical fiber used in both mini projects has a core diameter of 1 mm, numerical aperture 0,47 and typical attenuation 0,22 dB/m (Avago Technologies - HFBR-RUS100Z).

The angular position fiber sensor has as main objective, monitoring up to 50º through fibre light coupling losses (dB). The angular displacement has an effect over the light waves that travel from the horizontal fiber to the angularly misaligned one, causing optical losses. These losses depend on the wavelength of electromagnetic radiation that travels in the fiber, since every wavelength has its own propagation mode. The sensor is based on light coupling losses, due to rotation of two fibers aligned in the same horizontal plane. When the angular movement varies up to 50 , there will be some optical loss due to the intrinsic divergence of the beam. The angular gap between fibers is manually controlled with a rotary positioning stage, as shown in Figure 2.

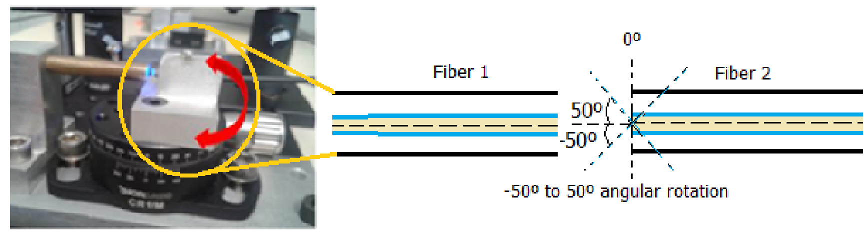


Fig. 2. Experimental system of angular position fiber sensor.

The experimental systems used for angular position fiber sensor was: 1 blue LED (model IF E92A, Industrial Fiber Optics), 1 Photodetector (IFD91, Industrial Fiber Optics), 1 Rotary positioning stage (Range: 50 Accuracy: 0,1), 1 Oscilloscope (HEWLETT PACKARD 54600A) or 1 Multimeter, and 1 Power Supply (12 V).

Experimental Results

The results presented here reflect the results of mini projects developed by the student on the 3rd OPTICWISE Training School on Optical Wireless Communications. Here groups of three students for a limited period of time performed the mini projects and swirled with each other to perform all the works. The results will show the linear and angular displacement. All projects were implemented within the set time, once they have managed in a short time carry out and realize these mini projects.

In Figure 3a the curve of the normalized voltage with the displacement and in Figure 3b, the curve of the optical losses due to the distance between the two fibers obtained experimentally is shown.

The measurements were performed with a step of 0,5 mm for a total of 15 mm between the optical fibers.

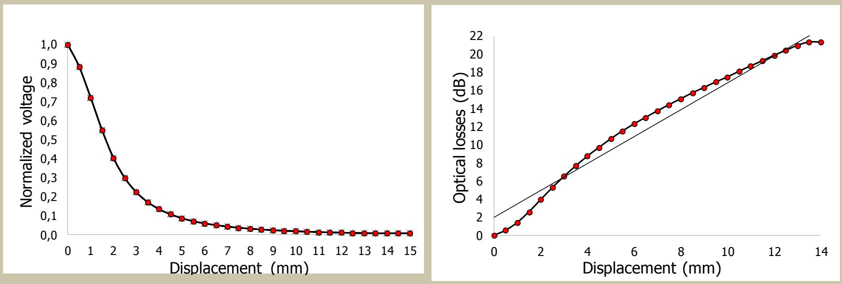


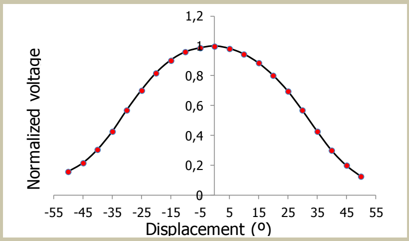
Fig. 3. (a- Normalized voltage with the longitudinal displacement; b- Optical losses versus the longitudinal displacement).

Based on Figure 3a, it is possible to check that the sensitivity of the sensor depends on the distance, and is more sensitive in the area 0,5-3 mm. From the start 3 mm losses vary with the least distance between two fibers. With respect to the sensitivity can be yet assess which of 0-3 mm, there is a sensitivity in the reading the displacement of 2,16 db/mm whereas the 3-14 mm, the sensitivity decreases to 1,34 dB/mm, hence it is possible to better visualize the distribution of normalized voltage.

Regarding Figure 3b, while the distance between the fibers is small (less than 2 mm) losses are minimal since most of the optical signal provided by the emitting fiber is still in the direction of the receiving fibre acceptance cone.

With reference to figure 3, can be pointed out that the correlation factor was higher than 0,96.

Then in Figure 4a displays the curve of the normalized voltage with displacement and in Figure 4b the curve of the optical loss due to the angular distance separating the two fibers obtained experimentally. The measurements were performed with an interval of 5° to 50° in total for each side.



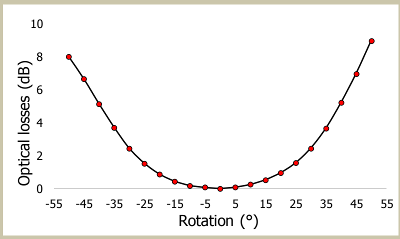


Fig. 4. (a- Normalized voltage with the angular displacement; b- Optical losses versus rotation of the angular displacement).

From the results shown in Figure 4, the sensitivity of the measurement of the optical loss can be analyzed from -50° to 50°. It can also be seen that there is a greater sensitivity in the detection of optical losses between 25° and 50° and between -25° and -50°. Data analysis was gauged that from 0° to 25° and 0° to -25°, there is a sensitivity of 0,062 dB/° and 0,061 dB/° respectively, while the 25° to 50° and from -25º to -50º sensitivity increases to 0,297 dB/° and 0,259 dB/° respectively.

As expected, there is an almost symmetry between positive and negative rotation.

Conclusions

This work may be considered an added value to engineering education, providing an important training on plastic optical fibre technology, and promoting working group skills. The execution of these mini projects on training courses received positive feedback from students. At the end of the laboratory work, these students left some written comments like “the experiments were very interactive”, “were accessibly executable”, and “the development of this work was an enriching experience”.

The interaction of students with these types of sensors allows them to get a sense of how the monitoring of structural health, ie the effect resulting from the application of forces to a structure, either internal forces (weight of the structure) or external forces (earthquakes, wind, bumps with structure) can be made. The implementation of these mini projects is expected to assist the laboratory work of students of Physical Eng. MSc, in the discipline of Optoelectronics. The contact of the students with this kind of work, will allow them gain some experience and skills in the area of sensors, which can turn out to be a real asset in these professional carrier.

Acknowledgement

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Water Level Optical System for Integrating Comptences

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Abstract

This paper reports a short project designed and carried out for laboratory work of graduate and post graduate disciplines with the main focus on integrating physical and engineering competences.

A plastic optical fiber liquid level sensor is presented. The sensor is a low cost solution to be used in the measurement on the monitoring of groundwater or levels of precipitation in meteorological stations. A periodic indentation on the polymeric fiber was made removing the protective coating and part of the fiber core, disturbing the propagation of optical signal. Each indentation induces an increase in the optical signal loss. The amount of radiation loss depends on the external environment surrounding the indentation and the dimensions of the grooves. Thus, any external disturbance to the surrounding environment produces a measurable effect on the signal optical power at the fiber output. A sensitivity of 13.5±0.05 mV/groove was estimated for the implemented sensor. This level sensor may provide a practical solution to implement the physics teaching in order to acquire competencies in this area.

Keywords*:* Plastic Optical Fiber; Level sensor; Optical signal.

Summary

Water level optical sensor was tested for teaching the basic principles and applications in order to acquire competencies in POF based sensors and related technology. The sensor can be used in the measurement on the monitoring of groundwater or levels of precipitation in meteorological stations.

Introduction

In the latest years, polymeric optical fiber (POF) has been studied and used for the control of liquid levels due to its main properties. An importance arises in how these properties are taught.

Nowadays, the main technologies used for liquid level measurement, are the capacitive, ultrasonic or hydrostatic (Simon, 1993; Fraden, 2010), but the optical technologies are also gaining place among those sensors, due to its properties like the immunity to electromagnetic interference, the possibility of remote sensing, the inexistence of electrical signal at the sensor head and the compactness.

POF are already being used in numerous types of sensors, such as physical sensors (elongation, acceleration or pressure) (Peters, 2010; Antunes *et al.*, 2013), chemical (Bartlett *et al.*, 2000; Zubia, & Arrue, 2001), biosensors (Varriale *et al.*, 2013) or fiber Bragg sensors (Antunes *et al.*, 2007; Cátia *et al.*, 2011).

The basic principle of this sensor is a periodic indentation (grooves) on the polymeric fiber core. The presence of the groove in the core of an optical fiber cause a disturbance on the propagation of the optical signal, thereby interacting with the environment surrounding the fiber. The transmitted optical power loss will change if the refractive index (RI) of the liquid fulfilling the grooves is different from the RI of the POF core. So, the optical signal power measured at the fiber output is dependent on the RI of the liquid around the fiber. Taking into account that the liquid refractive index doesn´t changed during the measurements, each time a groove is fulfilled, the transmitted optical power will increase. Using a POF fiber with grooves perpendicularly to the liquid surface, when the liquid rises it will sequentially fulfill each groove, and consequently increase the transmitted optical power. The amount of radiation lost to the outside depends on the dimensions of the grooves and its depth.

In this work, we present a level sensor based on POF´s that combine the optical technology properties with the lower cost of the interrogation technique, providing a practical solution to implement the physics teaching in order to acquire competencies in this area.

This level sensor was already tested on the 3rd OPTICWISE Training School on Optical Wireless Communications, in April 2014, in University of Aveiro.

Experimental system

The sensor was implemented with a large diameter core (1 mm) plastic optical fiber, with typical attenuation 0.22 dB/m, from Avago Technologies (HFBR-RUS100Z), with 10 grooves, spaced 4 cm.

The monitoring system includes an optical power source and receiver, a light emitting diode (IF-E92B 430-nm blue LED) and a photodiode (IFD91), from Industrial Fiber Optics. The data acquisition was performed with a 12 bit resolution Analog to Digital Converter (ADC) from National Instruments (USB6008). Scheme of the plastic optical fiber with grooves and the experimental setup block diagram is shown in Figure 1.

An optical fiber 2 m long was connected to the optical source and to the receiver for the sensor head preparation. The grooves were sliced on the fiber with a depth to half of the core diameter. The implemented sensor was tested by measuring the distilled water level in a cylindrical glass reservoir, with a maximum height of 40 cm. The POF was fixed to a PVC (Polyvinyl chloride) tube which remains fixed and strained along the reservoir containing the water.

Usually, level sensors can be classified into two groups, continuous and discrete. Continuous level sensors can measure the level within a specified resolution, while discrete sensors can only specify whether the level is below or above a threshold. Moreover, if the predicted costs for the discrete sensors are kept reduced, is possible to use a large array of sensors to emulate a quasi-continuous sensor. This level sensor that we present here can be classified as discrete. However, it can be deployed as a quasi-continuous solution, because is a low cost solution which can be employed with multiplexing techniques (Hopenfeld, 2006).

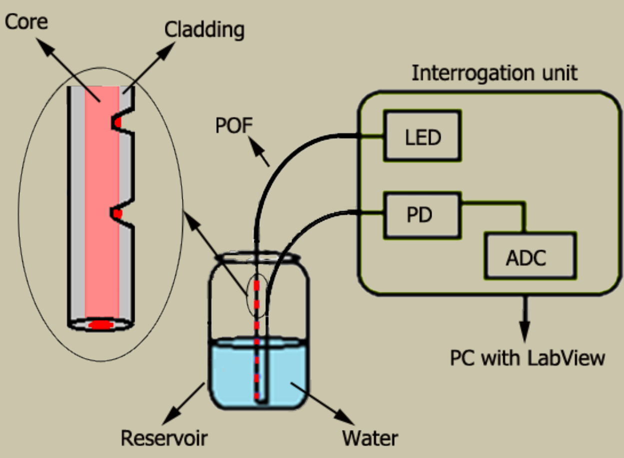

Fig. 1. Scheme of the plastic optical fiber with grooves and the experimental setup block diagram.

Experimental results

It is observed that as water is added in the reservoir the transmitted signal optical power increases and the optical losses decreases. The sensitivity of the sensor, in this case by linear fit to the data of Figure 2 a) and b), is 13.5±0.05 mV per each groove and 0.253±0.005 dB/groove, respectively. The resolution of the sensor is related to the distance between the produced grooves. Nevertheless, it can be improved if we decrease the distance between grooves. The measuring range of the proposed sensor depends on several factors, such as the length of the POF (due to the optical attenuation) and the number and depth of the grooves, the optical power emitted by the LED and the minimum detectable optical power of the photodetector.

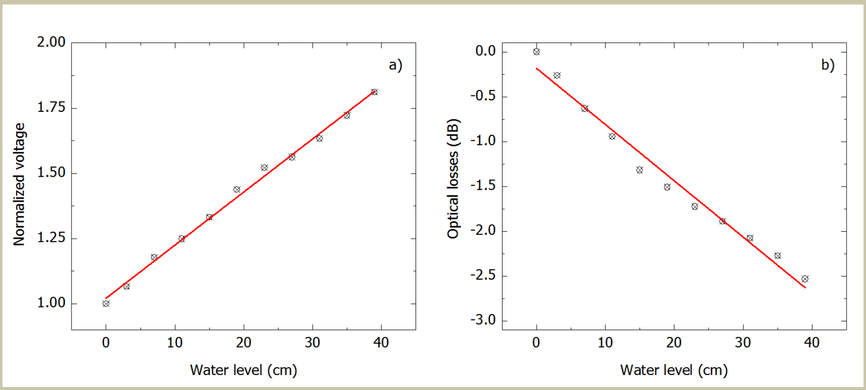

Fig. 22 a) Normalized voltage with the water level variation. b) Optical losses with water level variation. The dots represent the experimental data and the lines represents the linear fit (correlation factor > 0.9952 for a) and correlation factor > 0.9799 for b)).

Discussion and Conclusion

This paper reports a short project designed and carried out for laboratory work of graduate and post graduate disciplines with the main focus on integrating physical and engineering competences. A polymeric optical fiber intensity based level sensor was presented. A sensitivity of 13.5±0.05 mV/groove was estimated for the tested version. The number of grooves and the distance between them define the sensing resolution. Moreover, the sensor sensitivity and resolution can be adapted for different applications.

Some possible applications of this sensor are in the monitoring of groundwater tablet levels, soil moisture monitoring and levels of precipitation in meteorological stations. This level sensor may prove to be a viable alternative/solution to existing electronic sensors, due to the production lower cost.

This short project has received a positive feedback from the students. In their opinion this project is a simple and interactive way to acquire competencies in POF based sensors and related technology.

Acknowledgements

The authors acknowledge the support by FCT (Portugal), through the PEst/C/CTM/LA 25/2013 Research project. Paulo Antunes acknowledges the financial support from FCT through the Postdoctoral fellowship SFRH/BPD/76735/2011.

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TRIZ METHODOLOGY FOR ANALYSIS AND SYNTHESIS OF INNOVATION

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Abstract

TRIZ methodology developed since 1946 by G.A. Altshuller is continued in Russia, USA, UK, Czech Republic, France, Germany, Japan, and in other countries by Altshuller followers. TRIZ is a powerful methodology for systematic as well as creative problem solving in a wide range of technology. It can mean a qualitative change in learning, education, and in technical creativity necessary at the start of all processing and product innovations in practice.

TRIZ methodology consists of single steps of the systematic analysis of the problem situation and of recommended approaches (principles) leading to synthesis – to innovated solution. TRIZ has been created step by step as a result of patent studies and generalization of successful solution procedures. It was found out that strong solutions of higher innovation degrees and invention levels can be reached through a relatively small number of objectively applied repeatable procedures which can be studied and acquired towards the solution. Understanding of these approaches at the educational process improves both the acquirement of the known technological solutions and the effectiveness of the searching new solutions of the technological problems in practice.

The **TRIZ methodology** is supported by unique software tool - **Goldfire® Innovator**. It helps engineers to formulate problems effectively thanks to deep analyses of the existing problem or situation, and to search in many databases filled with potentially relevant ideas and solutions. From the point of view of physics teaching, the **Goldfire® Innovator** overcomes usual lack in the educational process – the insufficient interconnection between theory and practice. It gives an excellent

possibility to show students technical applications of physical laws, and helps in this way to the understanding of physical theories. At the same time, it demonstrates that significant technical innovations can be solved only with theoretical background.

Goldfire Innovator is trade mark of IHS, Boston, USA.

Keywords: TRIZ methodology; Goldfire Innovator.

Summary

Theory of Inventive Problem Solving (TRIZ) is a relevant tool not only for managers, engineers, and scientists on the way of searching the optimal solution of various technological tasks but it is very useful pedagogical tool for teachers at technical high schools and technical universities, too. A brief description of analytical and solving instruments of innovative TRIZ methodology and its software support Goldfire Innovator is presented.

Introduction

Innovation of production is the condition of long-term competitiveness. There is a lot of ways of object innovation. The researcher should have not only subject knowledge in the field of study but also methodical knowledge how to proceed by problem definition, information collection, problem solving, and verification of the founded solution. The preparation to the systematic problem solving belongs to the fundamentals of engineering education. Engineering graduates provided with the methodology of systematic and creative thinking can adapt more easily and rapidly to the variable demands of the practice. There are many methods offered to the support of technical creative work, and many new emerge. For effective support of innovation practice the methods that are usable for solving of specific practical problems are most important. The methodology of creation and solving of innovation problems (TRIZ) and its software support help the innovator with recommendation and information by analysis of the technical object, with the formulation of the problem to be solved, with the synthesis in the process of searching of problem solving variants, and with the verification of the founded solution. We introduce shortly specific methodical and software tools.

TRIZ Methodology

TRIZ methodology has developed since 1946 on the base of results of study of great amount of patented technical solutions. In the last few years this methodology has been studied and used by establishment of outstanding schools and companies in the USA, Japan, Russia, South Korea, Germany, Great Britain, France, Italy, Sweden, Czech Republic and Slovakia. The methodology leads the solvers from vague problem situation to the problem description, through comprehensive analysis of the object and the formulation of innovative task, to the conceptual recommendations of solution variants, and finally to the verification of founded solution. The methodology uses two complementary methods: analytical Functional Costs Analysis (FCA) of the object, and research method Algorithm for Solving Invention Problems (ARIZ). Nowadays, the TRIZ methodology is supported by unique software tool – Goldfire Innovator.

Functional Costs Analysis (FCA)

FCA helps to find answers to questions "WHAT" and "WHY" should be innovated in the object. It helps the user:

- To study the object step by step by means of analysis of components, connections, functions, parameters;
- To define key elements according to their functional, problem and costs importance;
- To choose proper innovative tasks in agreement with development trends;
- To formulate correctly numerous innovative tasks: "what" and "why" should be improved in the object.

It is known that proper innovative tasks and correctly derived assignments are more than one half of the solution. The worst losses arise when teams of specialist develop good solutions on the base of wrongly formulated problem.

Algorithm for Solving Invention Problems (ARIZ)

ARIZ helps the user to find answers to many questions "HOW" could and should be solved innovative tasks in agreement with experiences of generation of inventors. These experiences are concentrated in methodical-research process of algorithmic type. Research tools offered in ARIZ help the user:

- To find in tasks technical contradictions and hidden physical contradictions that represent the kernel of the problem;
- To generalize the model of the conflict pair of material elements in time and place;
- To formulate precisely the problematic technical function in the solved problem;
- To find innovative solutions of contradictions by means of relevant recommendations (obtained by study of patent technical solutions) and relevant applications of these recommendations in various parts of technique;
- To confront and revised founded solution ideas with objective tendencies of technical progress.

For solution of technical contradictions in the problem ARIZ recommends heuristic principals, for solution of physical contradictions in a technical contradiction it recommends separating progress, for solution of conflict pairs of material elements in time and place it recommends solution patterns, and finally for other solution of a technical function in the problem it recommends theoretically suitable phenomena and effects from the database of phenomena and effects that are known and described in natural sciences. To all recommendations relevant information (patent technical applications of these recommendations) are offered for study and inspiration. Tendencies of technique development serve as confrontation of the object state with development laws valid in technique. The user can think about recommendations how to solve his task; he can draw relevant information (application of these recommendations) to extend his knowledge potential, and so increase the probability to find a new and progressive technical solution of his problem.

Goldfire Innovator

IHS Goldfire® Innovator is a unique software tool that supports the TRIZ methodology. This software extends abilities of developers, designers, and engineers to search systematic and verify new technical solutions. It supports researchers both in developing of new products and in removal of imperfections

or in design of modified properties of existing products and processes. Goldfire Innovator includes:

- Tried and tested methodologies and disciplines for innovation process control;
- Precise data retrieval and capacity for knowledge control;
- Critical content of 15 millions world patents;
- Database of more than 9 thousands physical and technical effects;
- Access to more than 2 thousands cross-disciplinary scientific www portals.

Goldfire Innovator consists of the following:

1. TechOptimizer

This part of SW allows the user to:

- Structure the conceptual design stages of any innovation or new product or process;
- Model systems or processes in terms of parameterized functions, apply sophisticated Value Engineering algorithms to perform a detailed value diagnostic of the model, and then formulate key problem statements (Fig. 1);
- Methodologically explore multiple design scenarios to reveal optimized systems that exceed original functionality, cost less, and have fewer problems.

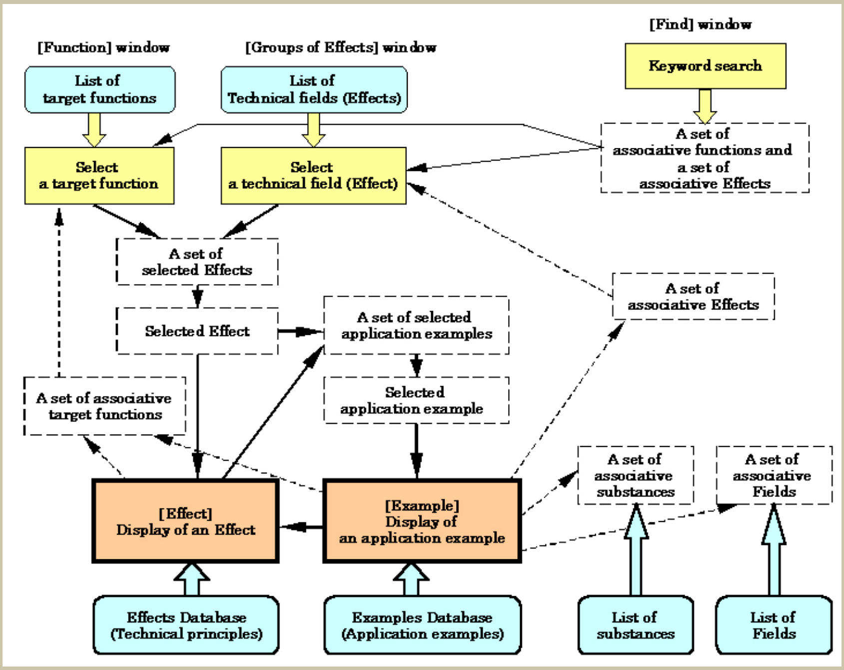

Fig. 1. Schema of Value Engineering algorithms

2. Knowledge Base

Of technological solutions Searchable Knowledge Bases are created using the natural language indexing technology. Unstructured electronic documents are processed into an index of "meaning fingerprints" for sentences and phrases, which define a clear pattern that can be matched by a computer during searches (Fig. 2). Furthermore, it allows users to build personal Knowledge Bases, transforming documents on their hard discs, networked drives, personal emails, and selected Internet sites into precision knowledge retrieval systems.

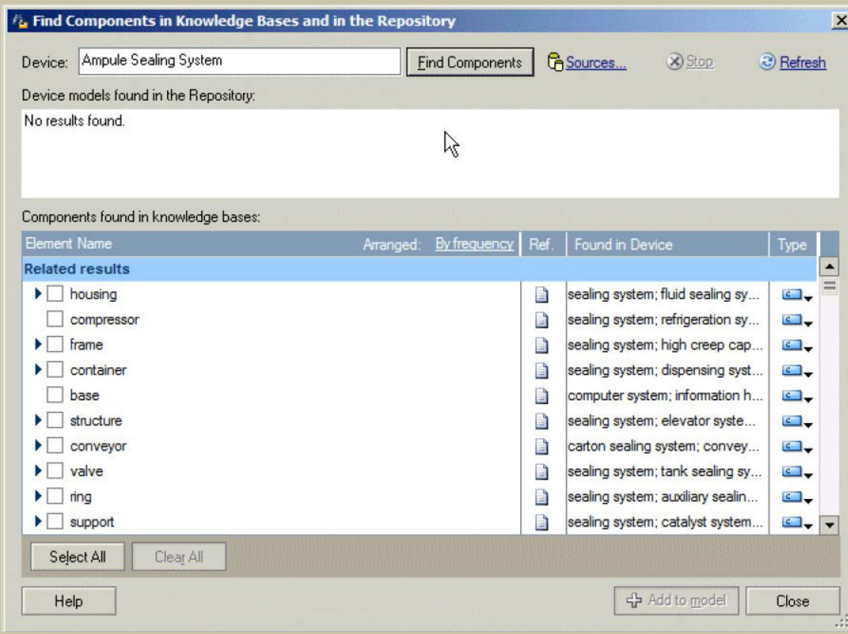

Fig. 2. Example of searching in Knowledge Base

3. Scientific Effects Database

This database contains animated descriptions of unique fundamental processes and their industry applications to assist engineers with both day-to-day and complex problem solving (Fig. 3). By drawing upon this extensive cross-disciplinary content, researchers quickly identify methods for performing specific design functions (Fig. 4). In addition, users can quickly create unique chains of processes that produce the desired output and utilize existing resources.

4. Solutions Search of Worldwide Patent Databases

The software provides a portal for access to a constantly updated database of patents worldwide. Researchers can harness the full value of patent documents as sources of innovative solutions and competitive intelligence. The patents are worldwide and constantly updated to ensure complete and timely information. The software has a natural language interface; this allows the users to formulate queries as free-form text to retrieve direct answers to their questions. Semantic processor finds and offers to the user only "knowledge" contained in documents and with the form of user's created database that contains ordered representatives of information kernels of all processed sentences from all read documents. The user has not to read great amount of documents founded by the key words technology; he only search problems and their solvers ordered in the user's database that was created by semantic processor after "reading" all sentences in documents founded on Internet. The searching effectiveness of relevant information and knowledge is considerable.

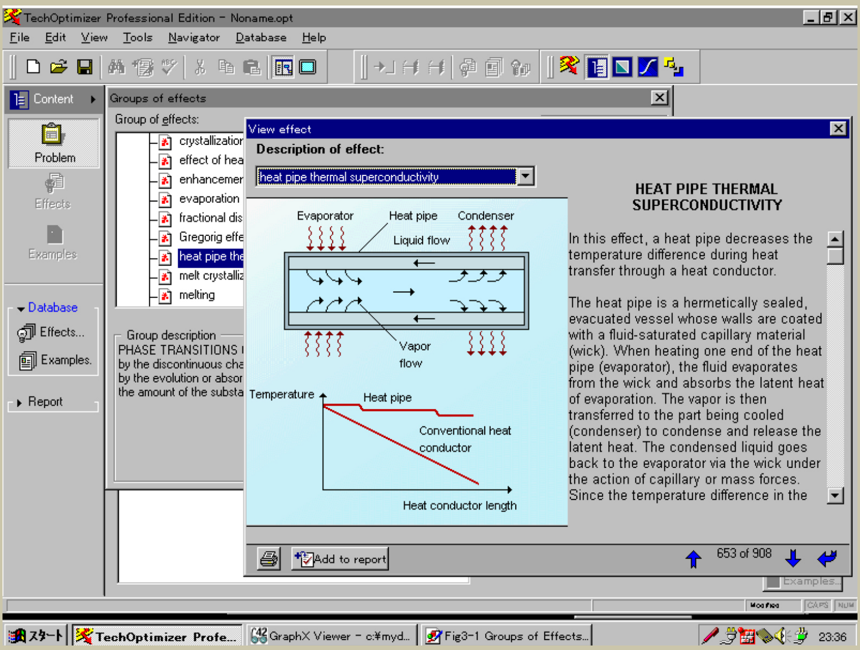

Fig. 3. Example of animated physical effect (Thermal Superconductivity) and its industrial application (Heat Pipe)

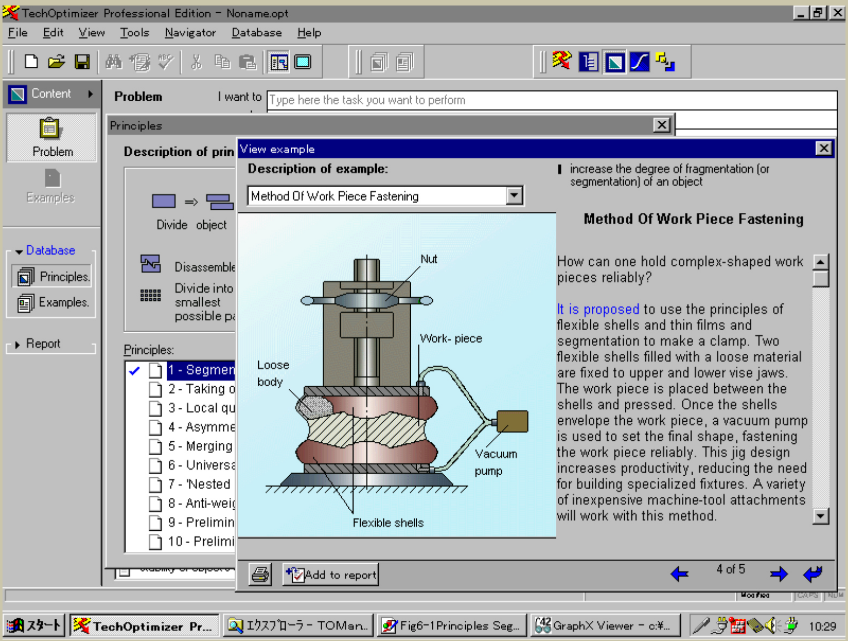

Fig. 4. Example of performing specific design function – Segmentation of an object

TRIZ methodology and Goldfire Innovator in education at FEEC BUT

At the Faculty of Electrical Engineering and Communication of Brno University of Technology the TRIZ methodology and its software support Goldfire Innovator are systematic taught in optional master course "Project Management of Innovation". Course graduates are able to analyse the object, synthesize the innovative solution, and search relevant information and knowledge for problem solving. They also elaborate their own innovation project.

Scientific effects database of Goldfire Innovator can be used also in basic course of physics. It gives an excellent possibility to show students technical applications of basic physical laws, and helps in this way to the understanding of physical theories. At the same time, it demonstrates that no technical innovations are possible without theoretical background.

Conclusions

The brief description of the methodology of creation and solving of innovation problems (TRIZ) and its software support Goldfire Innovator has been presented. The methodology and the software tool are cross-disciplinary means of attractive technical education, methodical tools of systematic approach to the problem in the analysis period, tools of search for creative solution in the synthesis period, and the effective research tools of process and products innovations in practice.

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Challenges and solutions

Plugins and apps for effective teaching

SEFI

SEFI, the Société Européenne pour la Formation des Ingénieurs, is an international organization whose role is to foster the development of engineering education.
Its 400 members, including 200 from tertiary education institutions, hail from 42 countries.
Its mission is to support and promote European engineering education by linking institutions and educators, providing services to its members, serving as an international forum, and representing the European engineering education community.

PHYSICS WORKING GROUP

The SEFI Physics and Engineering Education Working Group (PWG) aims to promote discussion of the didactics of physics teaching and the role and importance of physics in engineering education. With this aim PWG organizes conferences, workshops, and seminars on a regular basis. We promote the exchange of views and networking between physics teachers at universities and colleges in different countries and with different backgrounds and experience.

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