



MPTL'18 – Book of Proceedings

18th Edition of the Multimedia in Physics Teaching and Learning Conference

Edited by: S. Dormido and L. de la Torre



MPTL18
Madrid 11-13 September 2013

Proceeding of the 18th Edition of the Multimedia in Physics Teaching and Learning Conference

Volume editors: Sebastián Dormido and Luis de la Torre

Volume number: 37 E

ISBN: 2-914771-90-8

Published by: European Physical Society

Managing Editor: P. Helfentein, Mulhouse

© Madrid 2014

TABLE OF CONTENTS

Foreword	9
Acknowledgements	11
Contributions	
A classroom experience with a set of interactive partial differential equations simulations	15
A new methodology to design remote laboratories with EJS and the LabVIEW connector element	21
An experimental activity to improve learning in Sciences	29
Bringing partial differential equations to life	33
Computer simulations to teach physics in secondary education. Main features for a successful learning	39
Easy Java Simulation, an innovative tool for teacher as designers of gravity-Physics computer models	45
E-experimentation in preschool science education using remote experiment environment in Trnava	53
Experimenting from a distance: optical spectrometry via the internet	59
Interactive simulations for the learning and teaching of quantum mechanics concepts	65
New Physics remote laboratories for UNEDLabs	71
Revisiting historical experiments with new technologies: tracking Huygens' footsteps	77
Sound and noise: a proposal for an interdisciplinary learning path	83
Teaching Physics using modern technology	89
Teaching sciences for primary school	95
The IWB for the construction of formal thinking: proposals for prospective primary teachers concerning motions and electrical, magnetic and optical phenomena	101
The IWB as a bridge between phenomena exploration and interpretation of electromagnetic phenomena in the construction of formal thinking	107
"The Journey of Electrical Energy": an educational animation film for promoting scientific literacy in primary and secondary school	113
The use of computers and multimedia in the Italian kindergarten, primary, and lower secondary schools in Results by EU Project SECURE research on the use of computer in Italian compulsory schools	118
Tools for learning Physics as regular applications to MID	123
Virtual laboratory in the teaching of astronomy and astrophysics in Slovakia.	129

FOREWORD

We are delighted to present the book of Proceedings of the 18th International Conference on Multimedia in Physics Teaching and Learning (MPTL). The 18th edition of this conference was hosted by the Department of Informática y Automática at UNED, in Madrid during the dates September 11-13 of 2013.

MPTL provides an innovative forum at which researchers and practitioners in Physics education present, every year, their latest research, results and ideas in this topic. MPTL also aims to be a meeting point where new ideas on the use of multimedia in Physics teaching and learning, new paradigms of virtual and remote Physics experimentation as well as continuing education and training are presented.

One pleasurable aspect of the MPTL series of the events is the relative informality of the atmosphere and the sense of working with each other to facilitate better education for all. This spirit continued in Madrid and, as hosts, we did our best to create the best environment for the event.

We are pleased to say that we have received a large number of quality papers from around the world that formed the core of our discussions and exchanges in MPTL18. From the sixty papers received, coming from participants from many different countries, twenty of the best are presented in this book of proceedings.

We expect that you will enjoy this book as much as you enjoyed your time in Spain. It has been our pleasure in welcoming you to the city of Madrid. We trust that you left the MPTL18 workshop with a wealth of new knowledge and ideas in addition to building on your professional networks and friendships. And we hope this book serves to consolidate that new knowledge.



Sebastián Dormido



Luis de la Torre

ACKNOWLEDGEMENTS

MPTL18 was only possible thanks to the work, sponsorship and interest of many people and institutions.

First of all we want to express our most deeply acknowledgement to UNED. For hosting the events (parallel sessions, plenary talks and so on), UNED provided some of its facilities in form of lecture rooms and assembly halls. This university also gave monetary support for organizing this conference.

Equally important has been the support of the European Physical Society (EPS), the main sponsor of the MPTL conferences, year by year. They also helped with the edition of this book. For all that, we wish to thank EPS.

We owe a deep gratitude to the members of the International Program Committee, the National Organizing Committee, the staff from the Centro Asociado de la UNED “Escuelas Pías”, and all other people who have contributed significantly to this conference.

Last but not least, thanks also go to the well-known three plenary speakers (Dr. István Juhos and Profs. Theodore Hodapp and François E. Cellier), as well as to all contributing authors and participants that attended MPTL18. Without you, the conference would not have been possible.



A CLASSROOM EXPERIENCE WITH A SET OF INTERACTIVE PDE SIMULATIONS

María José Cano, Francisco Esquembre, Eliseo Chacón, *University of Murcia*

Abstract

While Partial Differential Equations is a subject traditionally carried out by passive-student lessons and some hours to solve problems on the blackboard, here we show a new approach. We describe a pedagogic experience based on Interactive Engagement. We use interactive simulations that solve and visualize the solutions of the more typical equations of physics interest (Heat, Poisson and Wave equations). We use Easy Java Simulations, an authoring tool to create interactive simulations for pedagogical purposes, in connection with FreeFem++, a free finite-element based PDE solver.

1. Introduction

Easy Java Simulations, EJS for short, (EJS, 2013) is an authoring tool to help teachers and students to easily create interactive simulations of scientific phenomena in Java. It was created putting an emphasis into its versatility for teaching, making possible to design the simulation by the content of the model forgetting the building aspects.

Thanks to its connection to FreeFem++ (Hecht, 2012), a free software, developed by Frédéric Hecht from the Pierre et Marie Curie University in Paris (France), to solve Partial Differential Equations (PDEs) by finite elements, now we can create interactive simulations of a wider range of physical phenomena.

Now, EJS offers the possibility of creating self-executable jar programs with the simulations of PDE models (Cano, 2014). There, students only see the equations, their parameters, some buttons and numeric fields to change them, and the graphical solution. Any code is visible for them in order to focus their attention into the model.

In year 2013 we put into practice our connection between Easy Java Simulations and FreeFem++ designing a two hours long session for third year students of the Mathematics Degree at the University of Murcia. We wanted to improve their learning process carrying out an experience based on Interactive Engagement (McDermott, 1991).

We let them study three different models on PDEs and interact with them by changing some parameters such as the domain, boundary conditions and the equation itself. By means of guided activities, we asked them to make conclusions.

At the end of the session, we handed out a short survey to draw some conclusions.

2. Getting ready

The students had some days in advance a detailed description of the models and the activities in order to have time to read it at home. We implemented four simulations to study three basic models: Laplace operator, diffusion operator and the waves equation (Formaggia, 2011) (Johnson, 1988), (Raviart, 2004).

Once they arrived to the classroom they got all the material from the web. There were two version of the simulations. One to be executed in a not too big server we have for our project, but with allowed access only for some weeks, and another one, in local, to have the material always available.

The first simulation was explained in detail by the teacher. He showed how to explore the graphics, how to introduce new values in the text and numeric fields, how to interact with the graphics using the mouse, etc. After this introduction students became more and more independent in the following examples.

3. Laplace operator: Elastic membrane

In the first of our simulations we modeled the behavior of an elastic membrane on the domain Ω

$$\Omega = \{x^2 / a^2 + y^2 / b^2 = 1\} \quad (1)$$

that is fixed on the contour $\Gamma = \partial\Omega$ and that is under the effect of a force $f(x)dx$.

This model fits to the solution of an elliptic partial differential equation described by the Laplace operator with Dirichlet boundary conditions:

$$\begin{cases} \Delta u = f & \text{in } \Omega, \\ u = 0 & \text{in } \partial\Omega \end{cases} \quad (1)$$

We include in our simulation the possibility of changing the boundary conditions into Dirichlet-Neumann type. This physically represents a loose part of the membrane.

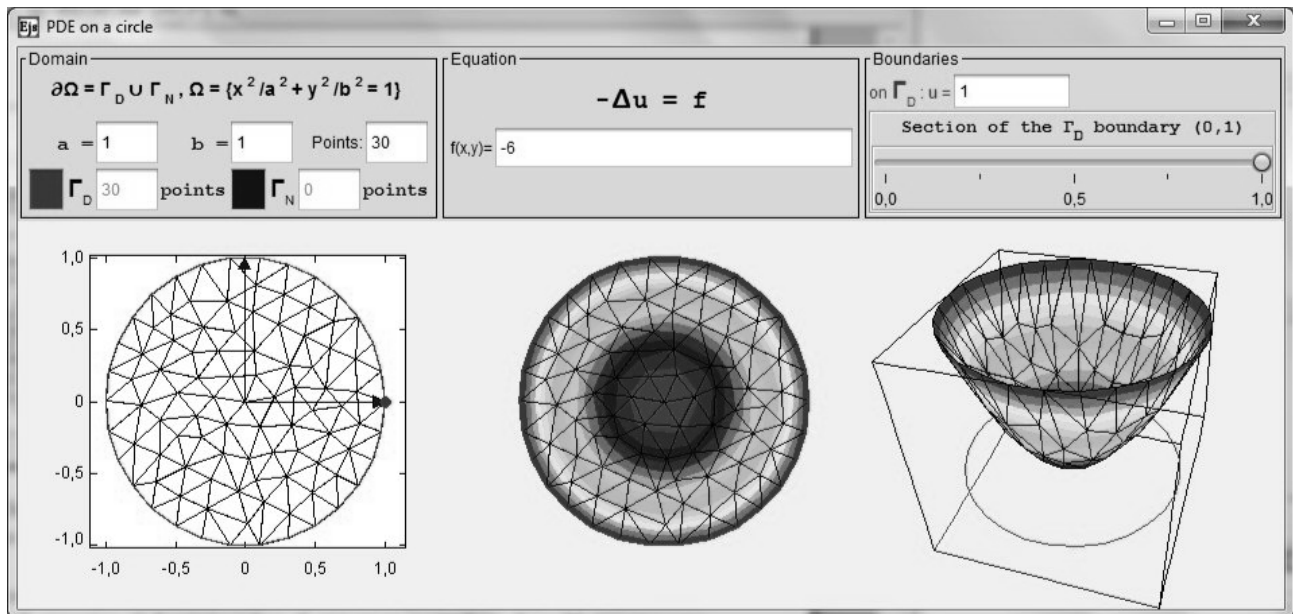


Figure 1: Elastic membrane simulation

In this section we set a list of activities. We started with some easy ones where the students are asked to associate changes in the equations with changes in the solution. For instance, they were asked to enlarge and reduce the number of points in the mesh to observe how the precision of the solution was affected, or how the values of function f changes the concavity or convexity of the solution.

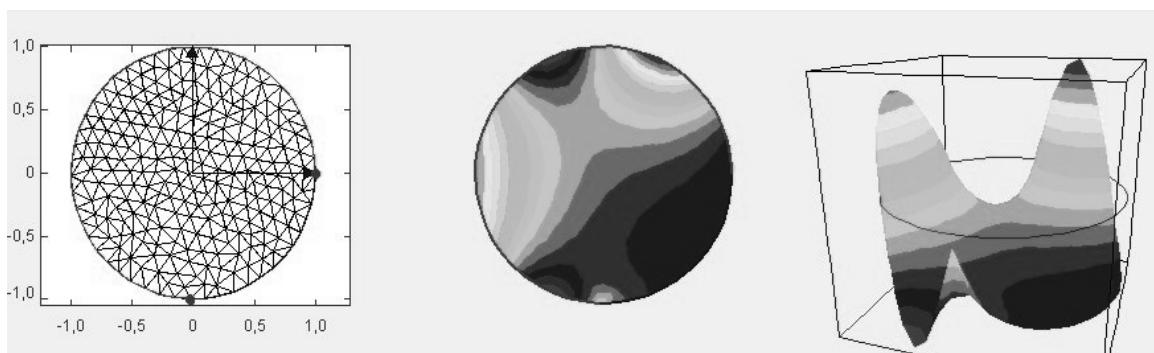


Figure 2: Example of one activity with the elastic membrane model

After this first contact with the model the students went through more complicated questions such as to solve some problems, classify them into the different types studied and analyze the solution. Or even harder, watching the graphical solution of a problem (Fig. 2), they were asked to guess the equations where this solution came from.

A second and simpler simulation was included in this part, in order to emphasize the meaning of the Dirichlet or Neumann boundary conditions, with the example of a beam.

4. Diffusion operator: Heat Equation

In this simulation (Fig. 3) we studied the behavior of a metal block with 5 holes that is exposed to a heat source for a specific time lapse on its left hand side. At the beginning the temperature of the block is 0°C degrees and the applied heat source is 100°C. On the right side of the block, heat can freely flow while the rest of the boundary is isolated.

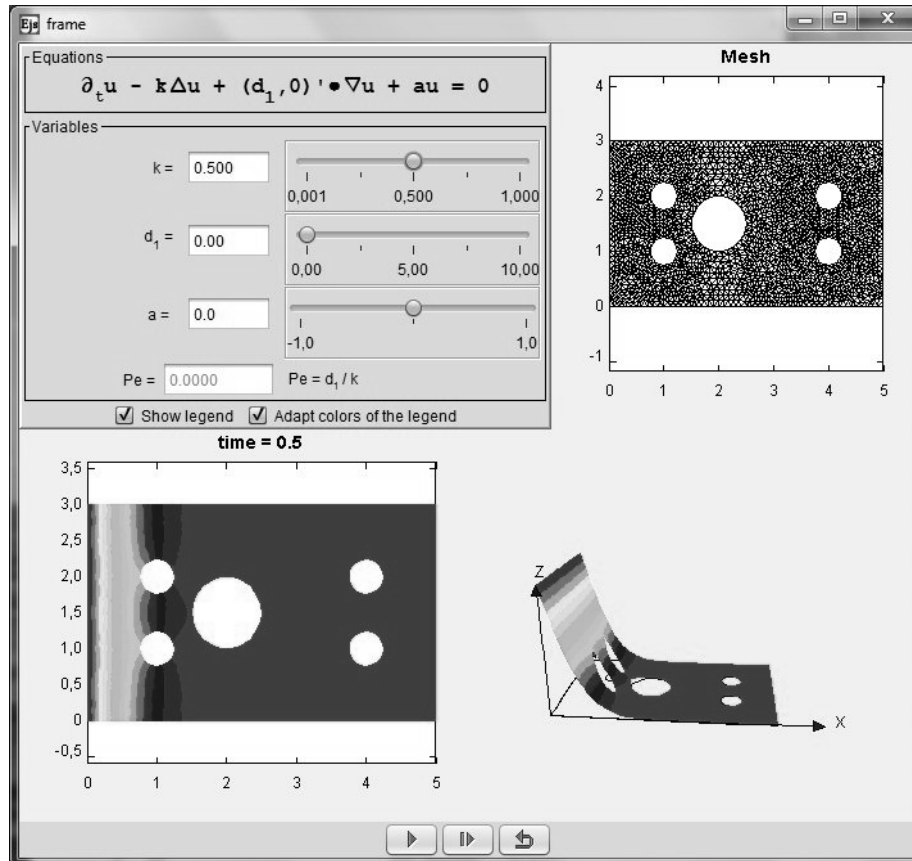


Figure 3: Heat equation simulation

The activities set now start studying the behavior of the model under the effect of diffusion, depending on k , the resistance of the environment against the diffusion.

Then the effect of transport is added and students are asked to study the instability of the system depending on the relation between k and the transport velocity d_1 ; this is the **Péclet number**.

Finally a third term is included: the effect of reaction. When the material reacts with itself creating more material or destroying what was there. Here, a is the velocity of this phenomenon, when $a < 0$ means a creation of material and when $a > 0$ destruction.

Once the three possible effects were studied, the students were asked to achieve some specific situations.

What values of a , d_1 and k are necessary to have

- a stable system in which the temperature of the 90% of the block is 0°C?
- a stable system in which the temperature of the 70% of the block is 0°C?

5. D'Alambert operator: vibrating membrane

Here (Fig. 4) we study how a membrane which is attached on its boundary, vibrates.

The initial position of the membrane is determined by the solution of the Poisson problem (being convex when f is negative and concave when positive). We provide 4 specific cases and the students were asked to introduce different expressions for the function f . They also studied the movement by changing the elasticity of the membrane.

6. Results

In order to know the student's opinion on the lab session, they were asked to answer a short survey. Only 6 out of near 20 students who took part in the session sent back their answers; it is not a fair sample but let us draw at least some ideas:

From the study of their answer we got a good impression. In general all of them gave a good mark.

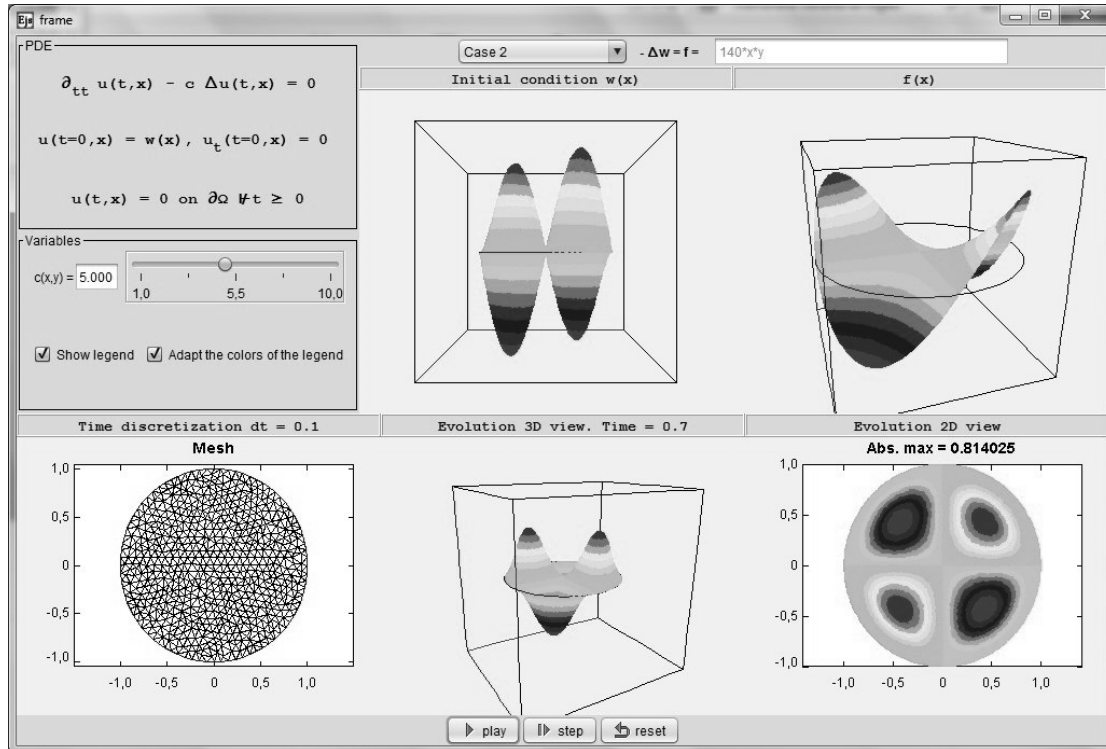


Figure 4: Vibrant membrane simulation

They were asked about:

- Session: in general, they found the simulations easy to use, and the activities easy to be answered. The worse result in this part, being also a good mark was the improvement of their comprehension of the subject.
- Visualization: they found the graphics easy to understand and they thought the graphics helped them to understand the physical phenomena represented.
- Interactivity: It was easy for them to interact with the simulations and they considered the degree of freedom wide enough.
- Knowledge acquisition: Despite they also graded positively this part, they showed some insecurity on what they really know. Some of the weaknesses were the identification of different types of boundary conditions, or the different operators and they found even difficult to associate boundary conditions to specific models.

7. Conclusions

We carried out a whole session on PDE models with a group of students who didn't use a line a code or the tricky aspects of their numerical resolution.

The finite elements methods and the variational formulation needed for the resolution were not visible at all. Even so, students were able to change several aspects of the problems, data and coefficients from the equations, getting a real time feedback.

Furthermore, they took an active part in their learning process by making predictions and associating equations with solutions. They qualified in a positive way this session as a part of their learning process.

References

- Cano M J, Esquembre F, Chacón E (2013) Bringing Partial Differential Equations to Life. MPTL18 Madrid 11-13 September. In this same publication.
- Easy Java Simulations, <http://www.um.es/fem/EjsWiki/>, accessed 2013 september.
- Formaggia L, Saleri F, Veneziani A (2011) Solving Numerical PDE's. Springer
- Hecht F (2012) New development in freefem++. *Journal of Numerical Mathematics*, 20(3-4), 251-265.
- Johnson C (1988) Numerical Solution of Partial Differential Equations by the Finite Element Method. Cambridge University Press.
- McDermott, L C (1991) What we teach and what is learned-Closing the gap. *American Association of Physics Teachers*.
- Raviart P A, Thomas J M. (2004) Introduction à l'analyse numérique des équations aux dérivées partielles (Sciences Sup). Ed. Dunod

A NEW METHODOLOGY TO DESIGN REMOTE LABORATORIES WITH EJS AND THE LABVIEW CONNECTOR ELEMENT.

Jesús Chacón, Dictino Chaos, José Sánchez, Sebastián Dormido *Department of Informática and Automática, Universidad Nacional de Educación a Distancia, 28040 Madrid, Spain.*

Hector Vargas, Gonzalo.Farias, *Pontificia Universidad Católica de Valparaíso.*

Abstract

Designing and developing web-enabled remote laboratories for pedagogical purposes is not an easy task. Often, developers (generally, educators who know the subjects they teach but lack of the technical and programming skills required to build Internet-based educational applications) end up discarding the idea of exploring these new teaching and learning experiences mainly due to the technical issues that must be mastered. To tackle this problem, authors present a novel technique that allows developers to create remote labs in a quick, didactical, and straightforward way. This framework is based on the use of two software tools: Easy Java Simulations and LabVIEW.

EJS is a modeling and authoring tool (part of the Open Source Physics project) designed to simplify the development of interactive dynamical simulations. With the features provided by this tool, an interactive simulation can be created without being an expert programmer. EJS is widely used to develop remote and virtual laboratories for physics education. LabVIEW is a graphical programming language frequently used in physics and engineering. LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. Thus, for physics educator which might not be expert programmers, but are used to the measure instruments, it is straightforward to create an interface with the laboratory hardware using LabVIEW.

The framework presented in this work exploits a new feature of Easy Java Simulations known as EJS-elements that enables Java developers to create and integrate their own authoring libraries (elements) into EJS, thus increasing its application possibilities. Particularly, the developed EJS element allows LabVIEW programs to be controlled from EJS applications through a communication network in a very easy way. This paper presents the element and the creation process of a web-enabled interactive experimentation environment for educational purposes. The development of a remote lab is illustrated with the step by step creation of the laboratory *light in isotropic media*.

1. Introduction

The integration of new pedagogical methodologies to engineering education is, nowadays, practically mandatory in most universities around the world. This statement is grounded by the number of papers published about these subjects and where the current technological advances have shown the way to follow in this field (Gillet 2005), (Casini 2003). For instance, in the European case, this has been addressed by introducing the educative community to the European Space for Higher Education (Bologna process), in which Internet plays a key role in university studies (Lareki 2010).

Regarding the aforementioned, hands-on laboratory was one of the first places where the integration of such technological advances was visible. Many engineering faculties expanded the use of these laboratories by offering students opportunities of experimentation with real systems (processes) not only by live classroom training but also remotely through the Internet. These Internet-based educational tools are currently known as *Web-based laboratories*. Web-based laboratories are divided into two categories, according to the system's nature to manipulate: virtual and remote. A *virtual laboratory* simulates a mathematical model of a physical process, whereas a *remote laboratory* provides access to a real physical process located in a remote site on the Internet (Duro 2008).

Although simulation is an appropriate way of complementing engineering education, it generally can't replace experimentation with real processes. For this reason, a full web-based laboratory should offer both training modalities. However, creating the remote version of a web-based lab is still attainable only for educators and research teams who are expert on these matters, mainly due to the amount of technical and programming issues that must be mastered (Gomes 2009).

In the literature, several different approaches oriented to developing remote laboratories can be found. In (Stefanovic 2011), authors present a remote laboratory exclusively created by using the LabVIEW platform (LABVIEW). Although LabVIEW Vis¹, can be easily made ready for Internet delivery, a LabVIEW Runtime Engine must be installed on the client side. This last step is not recommended when creating remote labs since installing software plugins sometimes can become hard for final users. For this reason, LabVIEW platform is commonly used only for creating the server side of a remote lab (other software options for the server side can be Matlab (Farias 2010) Simulink (Fábregas 2011), C++ (Costa 2010) Scicos (Magyar 2012) etc.)

On the other hand, Java applets and Flash applications have been the most popular web technologies for developing the client interface for remote labs. In (Hernandez 2008), a virtual laboratory for the analysis and study of the human respiratory system was created. In this example, an applet was developed by using Easy Java Simulations (EJS), a tool specifically created for designing and developing interactive virtual labs. Two other interesting examples of remote labs for pedagogical purposes were presented in (Morilla 2002) and (Sanchez 2004). In these articles authors present a set of web-based laboratories for teaching automatic control concepts where Java applets to access remotely the training services were used as well. Similarly, Flash applications have found some applications in virtual and remote laboratories design (Barrett 2003) and (Goffart 2007). Unlike Java, Flash has been less used by developers for designing web-based labs mainly for license payment issues.

Despite all these efforts, simple approaches to assist beginner's developers in creating remote labs are not easy to find. In this context, next lines describe the authors proposal in order to contribute in this scope.

At Spanish National Distance Education University UNED, distance education courses on automatic control for as many as 300 students each year are offered. Until few years ago, these students had to travel from all over the country to attend two-week long laboratories to complete the prescribed hands-on experiments in system identification and control courses. Fortunately, the development of Internet technologies highlighted the importance of Web-based teaching and learning in many research fields, including automatic control. Since more than 10 years, we therefore decided to use Web-based labs in our instruction so that students could minimize their need to physically attend laboratories. The acquired experience for our research team during all this time can be summarized in the following selection of papers (Vargas 2011), (Vargas 2009), (Vargas 2009b) and (Vargas 2008).

Based on the experience above described, we present our approach to create remote labs. This framework, which is an update of the work presented in (Vargas 2009), uses the software tools EJS and LabVIEW. The development exploits the new feature of Easy Java Simulations known as *EJS-elements* that enables Java developers to create and integrate their own authoring libraries (elements) into EJS, thus increasing its application possibilities. Particularly, the EJS element here presented allows to LabVIEW programs be controlled from EJS applications through a communication network simply by linking LabVIEW and EJS variables by means of a configuration wizard. The approach hides the low-level communication issues always necessary when creating remote labs, thus simplifying its creation process.

The paper is organized as follows: Section 2 provides a brief background about the design and development of web enabled control laboratories. Section 3 describes how the communication between the client and the server side is done and how to integrate the EJS Element into a simulation. Section 4 shows an example of a remote labs used for the teaching of event-based and multivariable control concepts. Finally, some conclusions about the present work and future possibilities are given in Section 5.

¹ LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters *National Instruments* <http://www.ni.com/white-paper/7001/en>.

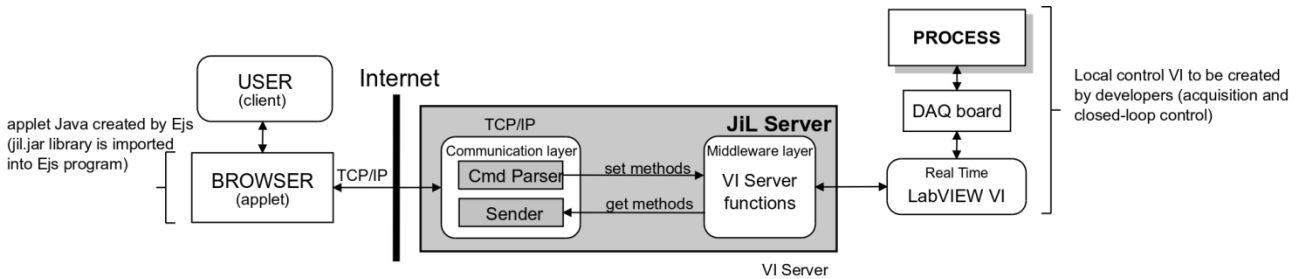


Figure 1: Architecture of the remote lab built with EJS, JiL Server and LabVIEW.

2. The Remote Lab architecture

The basic layout of a remote lab is as follows: on the one hand, the plant, whose sensors and actuators allow to interact with it, is connected to the host PC via an acquisition card (DAQ). On the other hand, the graphical user interface (GUI) that allows students the interaction with the plant, and which is an application that runs in the student PC. This solution is usually known as *client/server* architecture.

An improvement to this approach, adopted in this work, is the use of a three-tier architecture (see Fig. 1). In this solution, a middle-tier is introduced between the client and the server, acting as an intermediary that allows to eliminate or reduce the dependency of the design and implementation of both sides. Thus, the client can focus, for example, on the interface with the user, and the server on the control of the plant, while the middle-tier copes with the data exchanging issues.

Though there are different alternatives to set up the server and client PCs, what we are looking for is a solution that ideally could be applied to any case.

The *National Instrument LabVIEW platform* has been chosen to setup the server PC. It is a graphical programming tool, widely spread both in industry and academics, which allows for the rapid development of applications. One of the main advantages of LabVIEW is its great hardware support, providing *drivers* and libraries to access DAQ systems, communication protocols, etc.

The middle-tier contains the *JiL Server*, which makes public the controls and indicators of the laboratory top level VI to be accessed from the client.

Finally, the client tier is the most visible part, because it provides the GUI. The *Easy Java Simulations (EJS)* software tool is a good option because it has been designed to simplify the development of interactive simulations and graphical interfaces. EJS provides us with a mechanism to extend its capabilities, the *elements* of the model, that encapsulates Java libraries in a way that can be incorporated easily into a simulation.

Here is where the *LabVIEW Connector Element* fits, hiding the low-level details of the communication with the LabVIEW VIs via the *JiL Server*.

The framework is explained in (Vargas 2010) and can be consulted for further details. In the rest of this work, we focus on the client side, i.e. on the Java and EJS implementation.

3. Java and LabVIEW communication

The *JiL Server* software encapsulates the connection with LabVIEW by handling the client requests through TCP connections, and providing us with a protocol that allows, on the one hand, to control the execution of a LabVIEW VI and, on the other hand, to read the *indicators* and update the *controls* of the VI. This means that it does not enforce the use of a specific language at the client side. Therefore, though this section presents the implementation in Java, most of the ideas can be directly translated into other languages.

The software framework presented hereafter allows the communication of a Java applet or application with the *JiL Server* with two different levels of abstraction: a low-level protocol and a high-level protocol. Therefore, it is divided into:

- *LabVIEW Connector* that provides all the low-level functionalities, and
- *LabVIEW Connector Element* which provides the high level protocol to communicate with the *JiL Server* hiding the details to the user. It is a wrapper that allows the integration of a library into EJS

3.1. Use of the element

The high-level communication protocol allows the user to be unaware of the internals of the communication between the Java application or EJS simulation with the *JiL Server* and LabVIEW VI. This is done by means of the *UserLabviewConnector* class, which is automatically generated with the user-supplied information, i.e. the address of the *JiL Server*, the name of the remote VI and the links between the EJS variables and the LabVIEW VI controls and indicators. The configuration is done within the GUI provided by the element (Fig. 3). From a high level point of view, the functionalities that must be provided to the user to allow the interaction with a LabVIEW VI are summarized in three actions:

- Open and run a remote VI: *connect()*.
- Synchronize the EJS variables with the LabVIEW VI controls and indicators: *step()*.
- Stop and/or close the remote VI: *disconnect()*.

Thus, the synchronization of the values of the linked EJS variables and LabVIEW controls and indicators is simply done with a call to the method *step()* in the *Evolution page*.

The configuration and use of the element is illustrated with an example in the following section.

4. Example: Building a remote lab

To illustrate the use of the element, in this section a real example of a remote laboratory is described. The remote lab is based on the three-tier architecture above presented (Fig. 1).

Step 1: Design. Snell's law (or the law of refraction) along with the law of reflection constitute axioms already stated by Sir Isaac Newton and they are both part of the fundamental laws in optics. Particularly, Snell's law describes the relationship between the angles of incidence (θ_i) and refraction (θ_r), when light (or other waves) passes through a boundary between two different isotropic media (air and water, for instance). This relationship is given by the indices of refraction of the two media (n_1 and n_2) in such way that the ratio of the sines of these angles is a constant, n , mathematically:

$$n_1 \sin(\theta_i) = n_2 \sin(\theta_r) \Rightarrow \frac{\sin(\theta_i)}{\sin(\theta_r)} = \frac{n_2}{n_1} \equiv n \quad (1)$$

When $n_2 > n_1$, $\theta_r < \theta_i$ so the light comes closer to the perpendicular line to the boundary. On the contrary, when the light passes from a more refracting media to a less refracting one ($n_2 < n_1$), it gets away from the perpendicular line. As later described, the didactical setup allows the study of the relationship between the angle of refraction and the angle of incidence for both cases: $n_2 > n_1$ and $n_2 < n_1$. In this second case it is possible to check that there is a certain value of the angle of incidence for which the angle of refraction reaches 90° . This angle is known as limit angle, since for greater values of the angle of incidence the refraction phenomena disappears and the boundary between the two media behaves like a mirror. This is known as the total reflection effect.

The setup. The didactical setup for Snell's law real experiment (Fig. 2) was built using aluminium pieces, a transparent plastic container, a webcam, a laser pointer, and a stepper motor. The aluminium pieces make up the basic structure of the didactical setup which holds the plastic receptacle (containing water, for example), the motor, and the green laser pointer. An aluminium disc that rotates around its central axis supports the laser pointer. The stepper motor controls the rotation of the disc and so, the position of the laser pointer in relation with the plastic container and the angle in which its light incidences over the water (θ_i).

The experiment. The student is supposed to obtain the measure of the refraction angle for different values of the incident angle. So the procedure is to choose an angle, move the arrow to make it coincide with the refracted ray, and press the button "take a measure". The measures are stored and presented to the student in different ways: a table with the numerical data, a plot of the sinus of the incident angle vs. the sinus of the refracted angle, and a plot of the incident angle vs. the refracted angle, which can be used as an approximation to the ratio of the sinus when the measured angle is small. When the student has taken a reasonable number of measures, then it can go to the plot and obtain the refraction index. This is done with the button --, which computes a

linear regression of the measures. Computing the value within the angle vs. angle plot for small angles yields a value approximately correct. However, as the angles grow up the approximation is worst. This can also be illustrated by including or excluding points from the computation of the linear regression.

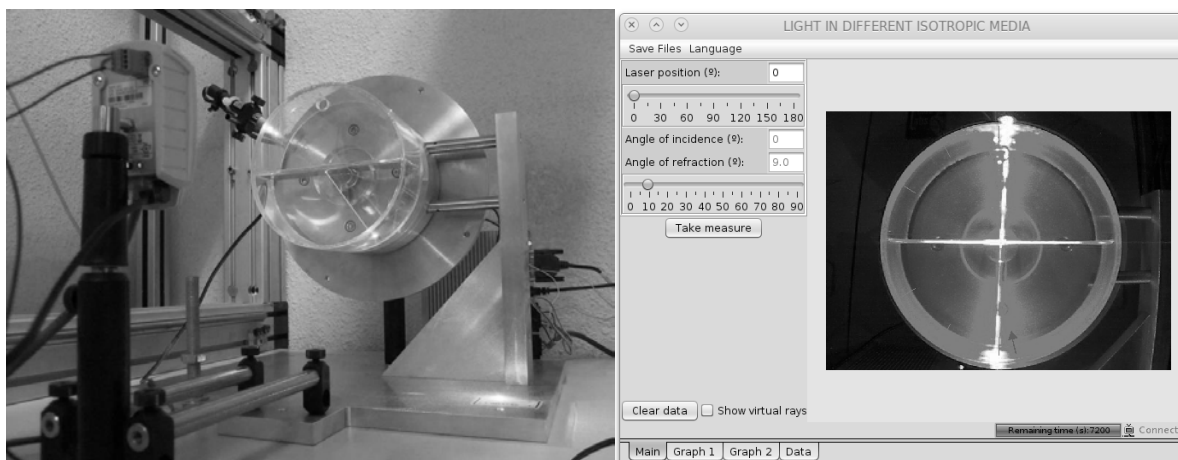


Figure 2: The physical plant is shown on the left and the student interface in EJS is shown on the right.

Step 2: Adding the Element. The *Labview Connector Element* must be incorporated to the current simulation to add the ability to connect with Labview. This must be done in order to have them available for the model. Each element can be instantiated one or more times, if it is needed to connect with different servers, but usually only one instance is necessary. The name assigned to the element in this step is used to access the element in the code (see Fig. 3).

Step 3: Setting up the Connection. The *LabVIEW Connector Element* must be configured prior to use it in the code. The basic configuration required is the *url* where the server can be located, the relative path of the *VI* and the variables that will be exchanged with the server. This can be done with the configuration dialog provided by the element (Fig. 3), which allow to create links between the *EJS model variables* and the *VI controls and indicators*.

Step 4: Initialization Code. The method *labview.connect()* must be invoked to open the connection with the server. Usually this is done either into an *Initialization*, to start the connection automatically, or triggered by a button of the user interface.

Step 5: Evolution Code. At this step, the communication with the server is usually done periodically, to obtain the new values from the sensors readings, and to send the updates in the control action or other parameters. These two things can be done with a call to the method *labview.step()* in an *Evolution Page*.

Step 6: User Interface. The user interface is shown in Fig. 2. From this window it is possible to control the execution of the remote lab and interact with the plant.

5. Conclusion

The main contribution of this work is an architecture for rapid development of remote labs. The architecture is based on the use of LabVIEW, the *JiL Server*, and EJS, and allows educators who are not expert programmers to address the development of a remote lab with a minimized learning curve, due to the intuitivity of the graphical tools in the framework.

A significant effort has been dedicated to improve the ease of use, encapsulating all the low-level issues presented at the client side into the *EJS Model Element* mechanism. An *Element* is a wrapper that allows us to easily incorporate Java libraries into EJS simulations, providing with a graphical user interface to help the developer with the configuration and use of the library.

The *LabVIEW Connector Element* allows to configure a connection with a LabVIEW VI, to link EJS variables with the controls and indicators of the VI, and to control the execution of the VI. An important feature of the element is that reduces the possibility of introducing errors in the code, thus reducing the time and effort needed for the development phase.

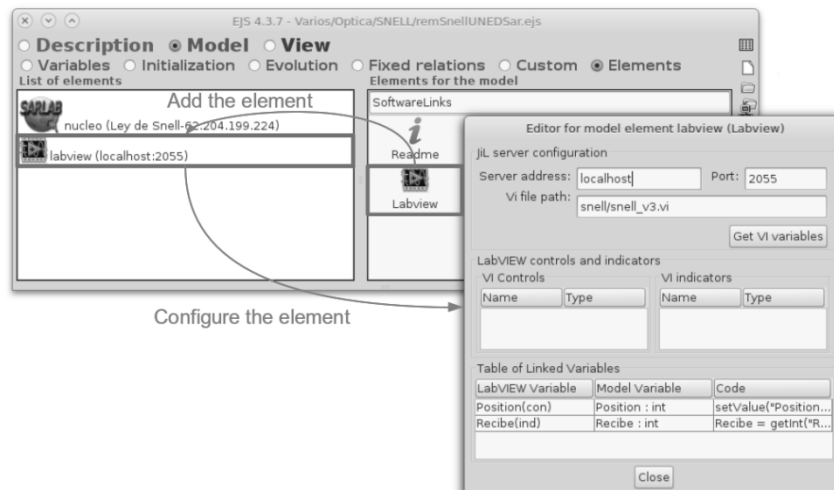


Figure 3: At the right of the Model Elements Page, the elements available in the libraries appear as an icon with the name of the element. New instances of the elements are created by dragging and dropping the element icons to the left panel.

References

- Gillet D, Nguyen A.V and Rekić Y (2005) Collaborative web-based experimentation in flexible engineering education, *IEEE Transactions on Education*, vol. 48, pp. 696-704.
- Casini M, Prattichizzo D and Vicino A (2003) The Automatic Control Telelab: A User-Friendly Interface for Distance Learning, *IEEE Transactions on Education*, vol. 46, no. 2, pp. 252-257.
- Lareki A, Martínez J and Amenabar N (2010) Towards an efficient training of university faculty on ICTs, *Computers & Education*, vol. 54, no. 2, pp. 491-497.
- Duro N, Dormido R, Vargas H, Dormido-Canto S, Sánchez J, Farias G and Dormido S (2008) An Integrated Virtual and Remote Control Lab: The Three-Tank System As a Case Study, *Computing in Science and Engineering*, vol. 10, no. 4, pp. 50-59.
- Gomes L and Bogosyan S (2009) Current Trends in Remote Laboratories, *IEEE Transactions on Industrial Electronics*, vol. 56, no. 12, pp.4744-4756.
- Stefanovic M, Cvijetkovic V, Matijevic M and Simic V (2011) A LabVIEWbased remote laboratory experiments for control engineering education, *Computer Applications in Engineering Education*, vol.19, issue. 3, pp.538-54.
- LabVIEW, home page at <http://www.ni.com/labview>, accessed 2013 september.
- Farias G, De Keyser R, Dormido S and Esquembre F (2010) Developing networked control labs: a Matlab and Easy Java Simulations approach. *IEEE Transactions on Industrial Electronics*, vol. 57, no.10, pp. 3266-3275.
- Fábregas E, Farias G, Dormido-Canto S, Dormido S and Esquembre F (2011) Developing a remote laboratory for engineering education, *Computers & Education*, vol. 57, pp. 1686-1697.
- Costa R, Valles M, Jimenez L.M, Díaz-Guerra L, Valera A and Puerto R (2010) Integración de dispositivos físicos de un laboratorio remoto de control mediante diferentes plataformas: LabVIEW, Matlab y C/C++, *Revista Iberoamericana de Automática e Informática Industrial RIAI*, vol. 7, no. 1, pp. 23-34.
- Magyar Z, Zakova K (2012) SciLab Based Remote Control of Experiments, In *Advances in Control Education*, vol. 9, no. 1, pp. 206-211.
- Hernandez A.M, Maanas M.A and Costa-Castello R(2008) Learning Respiratory System Function in BME Studies by Means of a Virtual Laboratory: RespiLab," *IEEE Transactions on Education*, vol.51, no.1, pp.24-34.
- EJS, home page at <http://www.um.es/fem/EjsWiki>, accessed 2013 september.
- Sánchez J, Dormido S, Pastor R and Morilla F (2004) A Java/Matlab-Based Environment for Remote Control System Laboratories: illustrated With an Inverted Pendulum, *IEEE Transactions on Education*, vol. 47, no. 3, pp. 321-329.
- Sánchez J, Morilla F, Dormido S, Aranda J and Ruipérez P (2002) Virtual and Remote Control Labs Using Java: A Qualitative Approach, *IEEE Control System Magazine*, vol. 22, no. 2, pp. 8-20.
- Barrett R, Cona J, Hyde P, Ketcham B, Kinney B, Schakelman J (2003) Virtual Microscope. University of Delaware, <http://www.udel.edu/biology/ketcham/microscope/>.

- Goffart J (2007). Design of a web-based remote lab for a brewery process. Master thesis, HAMK University of Applied Sciences, Finland.
- Vargas H, Sánchez J, C.A. Jara, Candelas F.A, Torres F and Dormido S (2011) A Network of Automatic Control Web-Based Laboratories, IEEE Transactions on Learning Technologies, vol. 4, no. 3, pp. 197-208.
- Vargas H, Sánchez J, Salzmänn Ch, Esquembre F, Gillet D and Dormido S (2009) Web-enabled Remote Scientific Environments, Computing in Science and Engineering, vol. 11, no. 3, pp. 34-46.
- Vargas H, Salzmänn Ch, Gillet D and Dormido S (2009b) Remote Experimentation Mashup,, Proc. 8th IFAC Symposium on Advances in Control Education (ACE09), Kumamoto, Japan.
- Vargas, Sánchez J, Duro N, Dormido R, Dormido-Canto S, Farias G, Dormido S, Salzmänn Ch and Gillet D (2008) A Systematic Two-Layer Approach to Develop Web-Based Experimentation Environments for Control Engineering Education," Intelligent Automation and Soft Computing, vol. 14, no. 4, pp. 505-524.
- Vargas H (2010) An Integral Web-based Environment for Control Engineering Education. PhD Thesis Dptm. Informática y Automática, UNED. Madrid, Spain.

AN EXPERIMENTAL ACTIVITY TO IMPROVE SCIENCE LEARNING

Angela Milazzo, Marco Schioppa, *Department of Physics University of Calabria (Italy)*

Eleonora Bilotta, Filomena Lento, Pietro Pantano, *Department of Psychology, University of Calabria (Italy)*

Abstract

Students often have problems in learning scientific disciplines, in particular Physics; the Extreme Energy Event project was born to provide an innovative way to deal with this issue. Its main objective is attracting young students to science, by making them work in a real astroparticle physics experiment.

This paper reports on the activities related to the EEE project in Calabria (Italy), focusing in particular on how students learn the basic concepts related to cosmic rays physics through their direct involvement in the project experimental activities. In Calabria two schools are currently involved: the High School "G.B. Scorza" in Cosenza and the High School "E. Fermi" in Catanzaro Lido.

1. Introduction

The EEE Project [1,2] was conceived in 2003 by professor Antonino Zichichi, and is presently carried out by a collaboration of several research institutes, including Centro Fermi, INFN, CERN and MIUR (the Italian Ministry of Education, University and Research). It is an experiment for the detection of Extensive Air Showers which exploits the Multigap Resistive Plate Chamber (MRPCs) technology [4].

Essentially it makes use of the standard technique, consisting in detecting the muon component arriving to the ground of the extensive air showers generated by the energetic primaries when they enter the atmosphere. Due to the very high energy of the primaries, the corresponding showers are characterized by section areas of several km².

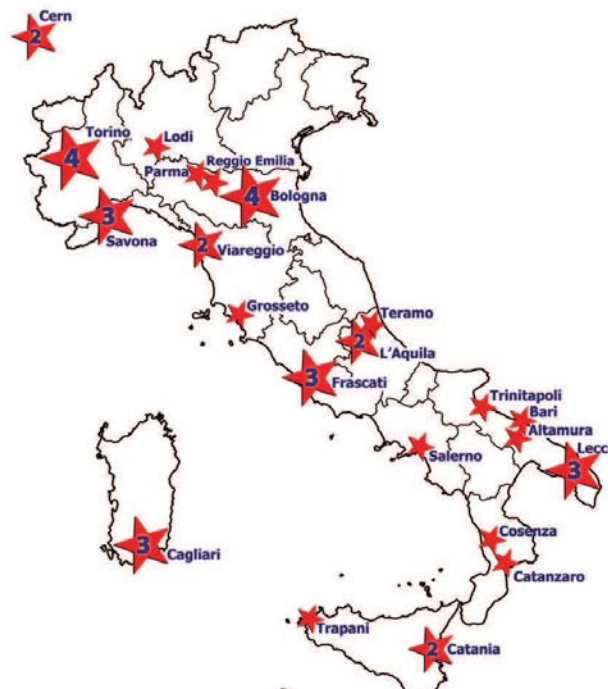


Fig.1 Schema of the array of EEE project. The numbers inside the stars indicate the presence of more than one EEE site in the same town. The total number of EEE sites is 40.

The innovative aspect lies in the fact that the detection sites are mostly hosted in Italian high schools scattered all over the national territory (plus CERN). Each site hosts a muon tracking

telescope made of three MRPCs each, very similar, conceptually, to the chambers developed for the Time-Of-Flight system of the ALICE experiment at LHC [3,4]. The present network of the EEE Project is shown in fig. 1; as of today, it consists of 40 telescopes located at various high schools (and at two INFN sections, and CERN) distributed all across the Italian territory, with clusters of 2, 3 or 4 telescopes concentrated in some cities, and additional sites located more distant to increase the total surface coverage.

Beyond its interesting scientific goals, the peculiarity of the EEE project lies in the fact that most of the activities related to the experiment have been —and still are— carried out by Italian high-school students and teachers, working in close contact with the scientists and technicians of the Universities, INFN and Centro Fermi. From the point of view of scientific communication and outreach activities, this is a very important added value to the Project.

In fact, the EEE detectors have been built at CERN by the teachers and students of the project, and the EEE sites presently located in Italian high schools are operated by people from these schools. The commissioning of the system was performed by mixed teams under the supervision of experts and researchers from scientific institutions. This joins in the very same activity the important didactic aspect deriving from taking direct part to a real scientific experiment, with the interest of performing a research in an advanced field of investigation [6].

The detection of an Extensive Air Shower (EAS, in the following) is operatively achieved by measuring the coincidences in time among events recorded at different sites of the EEE network. Therefore, the detectors used must combine a good tracking performance with an excellent time resolution, must be reliable on a long-term time line, easy to use and, possibly, cheap. All characteristics which are well met by the Multigap Resistive Plate chambers [5].

In addition to EAS of extreme energy, the EEE network will study also other interesting phenomena. For instance, a systematic study of the single muon flux and its variations, correlated with the relevant environmental parameters (local or astrophysical), is currently being carried on.

2. The muon detector

An extensive description of the EEE Project telescopes has been already reported in several publications; for instance see, last in order of time, ref. [7]. Here just the most important info will be reported, for the sake of self-consistency.

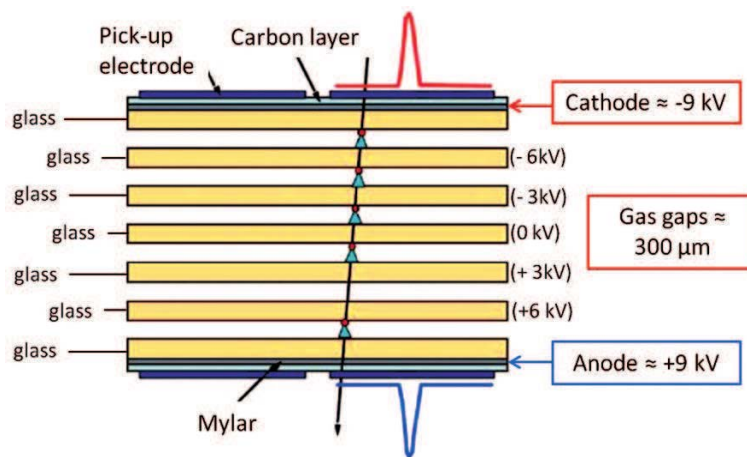


Fig.2 Layout of an MRPC

Each EEE Project telescope is composed by three Multigap Resistive Plate Chambers (MRPCs), characterized by an active area of about 2 m². The MRPCs used, shown in fig. 2, have six gaps obtained by a stack of glass plate spaced 300 μm each by means of commercial fishing line, and characterized by a volume resistivity of about 10¹³ Ωcm. The outer glass plates are coated with graphite painting, in order to be able to apply the high voltage and obtain the desired electric field in the gas gaps; when an ionizing particle passes through the gas, it creates a certain number of

primary ion-electrons pairs, which are amplified in the usual avalanche process and finally induce a signal on the external readout strips. The gas filling the gaps is a mixture of $C_2H_2F_4/SF_6$ 98/2, while each MRPC is equipped with 24 copper strips 160 cm long, having a pitch of 3.2 cm.

The particle impact point is reconstructed by the hit strip in one direction, and by the signal arrival time difference at the strip ends in the other direction. At the operating voltage of 18 kV, the measured MRPC efficiency is typically 95% and the time resolution is of the order of 100 ps, so that strip dimension, and time differences provide a spatial resolution of about 1 cm in both coordinates. The signals coming from the front-end cards are collected and processed when a triple coincidence of the MRPCs generates the trigger for the data acquisition. The absolute time of each event, necessary to spot coincidences between events recorded at different sites, is obtained by means of a Hytec GPS VME module.

3. Outreach activities

An important part of the EEE Project lies in its possibility to be a very effective method to communicate the meaning of the scientific research to a wide selected audience, summarized in its motto: “Bring Science to the heart of the young”. This was one of the reasons why it was decided to locate the EEE telescopes in high schools and to have students help “hands on” in the assembling, testing and monitoring of the detectors and in data taking and analysis.

The schools include both Licei (Italian secondary schools) specializing in classical or scientific studies and Istituti Tecnici (technical schools). After some introductory lessons by the school teachers on cosmic-ray physics and MRPC detectors, roughly few students for school were selected to go to CERN —with 1 or 2 teachers— for a one-week stay to assemble the chambers, under the guidance of CERN and INFN researchers. This proved to be a very fruitful and exciting period for the students, usually at their very first visit to a big laboratory, during which they learn how to work in a team and live —even if only for a short time— the researcher life. At the end of the week they are taken to visit some of the LHC experiments, where they can see detectors very similar to the ones they just built and which are actually used in real experiments.

Once the chambers arrive at the schools, the students take part in the first tests: search of possible gas leaks, check the cable connections and perform, after explanation and with the help of the INFN people, the preliminary measurements of chamber efficiency.

Later on, during the data taking stage, the students are taught how to monitor the telescopes and they provide the daily checks which are mandatory to keep the system running. As some good data are available, the students learn how to treat and analyze them, using the very same analysis tool used in professional scientific research. Moreover, since younger students work in close contact with more experienced ones, the acquired skills are transmitted in the most natural way.

Almost all the schools, moreover, set up their own EEE Project web page, with links to Centro Fermi, CERN and INFN, where they store all the relevant info on about how the project develops at the different sites. Page

4. Work at the schools in Calabria

The work in the schools at Cosenza and Catanzaro was divided in three phases.

The first phase consisted in introductory seminars, for teachers and students, about cosmic rays physics, showing in particular the use of tools to detect and measure ionizing particles and methods to measure the properties of Cosmic Rays (CR). All this was performed using multimedia support, such as videos, photos and applets to simulate VME electronics

The second phase was the assembling of the telescopes in the school laboratories, made by the students under their teachers supervision. During this phase students have built up the gas system and the high voltage systems, routed the cables, assembled the readout electronics and installed and the data acquisition programs.

The third phase consisted in the participation of the students to group discussions, filming of video clips, presentations and talks. A web page and a Facebook page devoted to the EEE project and all related activities were set-up. Furthermore, an electronic book (e-log) was implemented, similar

to a board diary, where each student can describe the activities executed in order to share the experience acquired to the whole group of participants.

All students have taken part to all the activities proposed with enthusiasm and curiosity. At the end of these activities a test was proposed to the students in order to verify the improvement on scientific subjects understanding. The first results from this test have shown that this kind of activity increases the potential of every student, and does not penalize anybody, since it involves all the three learning processes: visual, auditory and kinesthetic.

Visual students learn by images, graphics, and by reading and writing; auditory students by listening and group discussions; and kinesthetic ones by practical approach, laboratory activities and so on.

Usually in the schools the visual and auditory students are advantaged, while kinesthetic ones are slightly penalized for various reasons, such as a poor instrumentations in the schools, missing laboratories and so on; for these reasons they generally do not excel at school, because they are considered distract or not interested to the activities in the class.

On the contrary, in the framework of the EEE project, the experimental activities are intrinsic and they do not depend on the economical possibility of the school to instrument expensive laboratories, so that the improvement on learning scientific disciplines is the same for all types of students, and kinesthetic students can show their potentiality as well as the other students. Results from our preliminary test show, in fact, that the best results are also from that part of students that can be considered kinesthetic.

5. Conclusions

The Extreme Energy Events Project experiment involved a very relevant effort in terms of organization during the assembly and commissioning phases, chamber transportation, and, in general, coordination among the different components —scientists, technicians, students and teachers— of the Project.

From the hardware point of view, the detectors composing the telescopes have perfectly met the requirements of the experiment, in terms, for instance, of efficiency, spatial and time resolution. Many telescopes now have been taking data since several years without almost any interruption, which demonstrate the high reliability of this detector and of the associated system at the sites.

From the educational point of view the results obtained in this initial phase of EEE project in the schools of Calabria are very promising. As more and more experience will be acquired also on this aspect of the project, didactic methods will also be improved, and even better results will be reached.

References

Centro Fermi web site: www.centrofermi.it/eee.html.

EEE Collaboration (R. Antolini et al.), 29th ICRC Proc., Pune 8, 279 (2005).

ALICE Collaboration, Addendum to TOF Technical Design Report, CERN/LHCC, 2002-016.

A. Akindinov et al., Nucl. Instrum. Methods Phys. Res. A 661, S98 (2012).

EEE Collaboration (M. Abbrescia et al.), Nucl. Instrum. Methods Phys. Res. A 539, 263 (2008).

EEE Collaboration (M. Abbrescia et al.), Nucl. Instrum. Methods Phys. Res. A 588, 211 (2008)

EEE Collaboration (M. Abbrescia et al.), JINST 7, P11011 (2012).

BRINGING PARTIAL DIFFERENTIAL EQUATIONS TO LIFE

María José Cano, Francisco Esquembre, Eliseo Chacón, *University of Murcia*

Abstract

Interactivity is of paramount importance when teaching difficult physical problems such as those modeled by Partial Differential Equations (PDEs). We show how we created interactive simulations for some of these models without much programming effort but high quality computing and visualization. In our simulations, students can interactively change parameters, boundary conditions, even the equations themselves, and get immediate feedback of these changes through the visualization of the newly computed solution. We connect a high level PDE solver, FreeFem++, with Java and Easy Java Simulations.

1. Introduction

Usually, teaching on Partial Differential Equations (PDEs) is based on very theoretical lectures, where students are taught to solve the equations by analytical methods. This approach, makes sometimes difficult to associate the equations to the physical model and, therefore, intuition is not properly motivated.

Some of the pedagogical challenges we face are: firstly, the solutions of PDEs are function, and the derivation into more than one variable makes the solution hard to be mentally visualized; and secondly, the more sophisticated aspects of the resolution of PDEs are out of the curriculum of an initial course on PDEs.

Visualization of the solutions, using images or animations, can help students to understand more easily the key concepts of the system under study. Also the interaction with them is a key point in their understanding because interactivity allows them to make changes and predictions and get an immediate feedback of how they affect the model.

The implementation of software for this kind of material by means of programming languages and standard libraries demands a considerable programming effort from students and teachers, besides, the need of some out-of-curriculum topics.

In this paper we show how we have implemented a tool to create interactive simulations on PDE models in an easy way. For this aim we have used FreeFem++ (Hecht, 2012), a C++ based, high level language for experts to solve PDEs that works with the variational formulation and with the finite element method. We have connected this language to the Java programming language that brings many facilities to implement interactivity, and we have encapsulated the FreeFem++ output into java objects. Then we have created the visualization elements to graphically show this objects inside the OSP (OSP, 2013) visualization library, an open-source library created for physics education.

Finally, we have included our work into Easy Java Simulations (EJS) (EJS, 2013), a modeling and authoring tool to create interactive simulations for pedagogical purposes in an easy way. It was performed putting an emphasis into its versatility for teaching and it is designed for those who are more interested in the content of the simulations than in the coding aspects.

2. An interactive simulation on PDEs

Fig.1 shows the initial appearance of one of the simulation generated by Easy Java Simulations.

In this simulation we see the solution of a Dirichlet problem defined over a circular domain. The graphics show the domain and its discretization into triangles (mesh) and the solution on 2D and 3D views.

On the top-left panel we can make some changes over the domain such as the length of the horizontal and vertical radii (a and b) and the number of points on which the border is going to be divided to produce the mesh. Parameters a and b can also be modified by sliding the two blue arrows on the image with the mouse pointer.

On the second panel we can redefine function $f(x,y)$ and introduce any analytical expression on x and y .

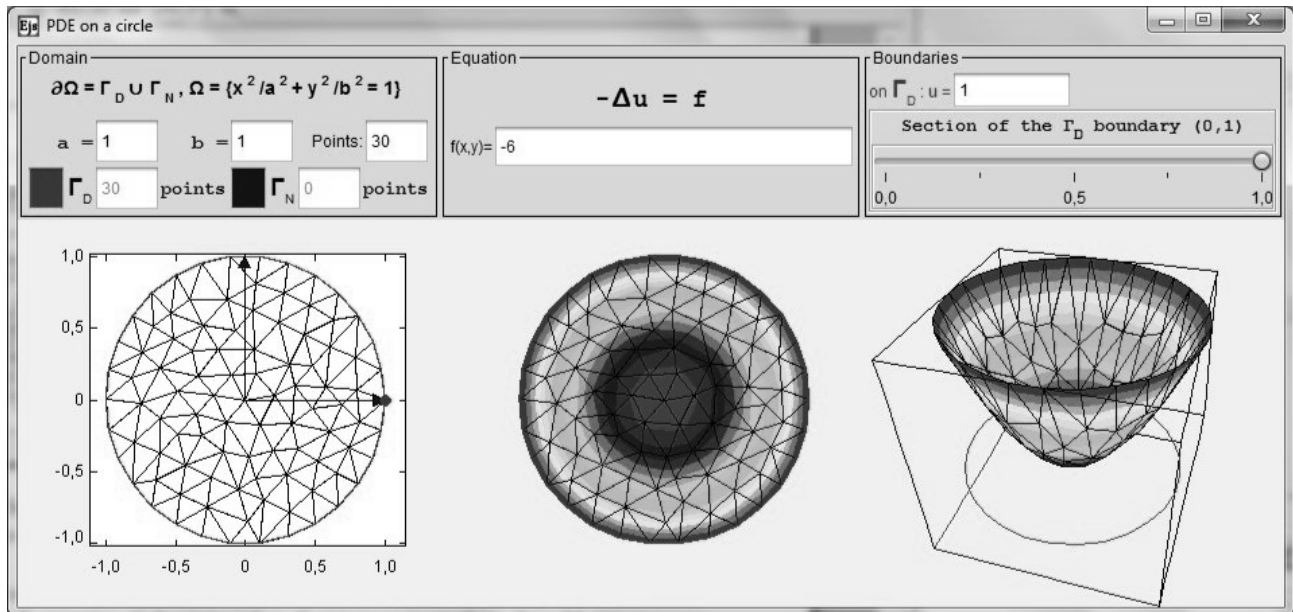


Figure 5: Initial appearance of a PDE interactive simulation.

Finally in the third panel we can modify, using the slider, the length of the section of the boundary where a Neumann type of boundary condition is going to be imposed. This section will be drawn in blue color. As a consequence, we might have the Laplace operator with mixed (Dirichlet and Neumann) boundary conditions or with pure Dirichlet data.

When any change is made into the model, the solution is recalculated by FreeFem++ and shown in our visualization.

In this example, even undergraduate students of Mathematics, Physics and Engineering, who are not yet familiar with programming and who have not knowledge on variational formulation and finite elements can study the behavior of the model. They do not need to write a line of code and they can focus in making predictions and to get an immediate feedback of how changes affect to the model.

3. A few lines on FreeFem++

FreeFem++ is a free C++ based language, developed and maintained by F. Hecht from the Jacques-Louis Lions Laboratory of the Pierre et Marie Curie University, which allows to define domains and to implement and resolve problems on Partial Differential Equations using finite elements methods. It has a well maintained web page, with updated documentation and many user provided examples (FreeFem++, 2013).

A plain text file (script) is used by FreeFem++ to set the domain and the problem. Defining a simple domain and its discretization into triangles (mesh) is quite simple. The shape of the domain is described by the parametric equations of its boundary and the triangulation of the domain is generated inwards from a partition laid on this boundary. For instance, the mesh on a circle centered in (0.1, 0.3) and radius 0.5, with 30 points along the circumference is going to be defined as follows:

```
border C(t=0,2*pi){x = 0.1 + 0.5*cos(t); y = 0.3 + 0.5*sin(t);}
mesh Th = buildmesh(C(30));
```

To obtain a plot of this mesh is enough to add to the script the sentence `plot(Th);`

Next, assume that Th is a triangulation that discretizes the domain Ω . On this domain, we define a simple problem described by the Laplace operator with homogeneous Dirichlet boundary conditions:

$$\begin{cases} \Delta u = f & \text{in } \Omega, \\ u = 0 & \text{in } \partial\Omega \end{cases} \quad (1)$$

The variational formulation (Allaire, 2007) of (1) is required to solve the problem by finite elements.

The script code in the FreeFem++ language is:

```
fespace Vh(Th,P1); //P1-elements or another type of finite elements
Vh u,v;
func f=sin(x)*cos(y); // example of function f
problem laplace(u,v) =
    int2d(Th)(dx(u)*dx(v)+dy(u)*dy(v)) // bilinear part
    +int2d(Th)(-f*v)// right hand side
    +on(1, u=0);//Dirichlet cond. on the bound (label 1)
laplace; //solve the pde
plot(u); //plot the solution
```

Finally, is worth to mention that there are two distributions of FreeFem++. In addition to the default distribution there exists FreeFem++-cs (client-server) (Le Hyaric, 2013). It can be installed in another machine (a computer or a supercomputer) allowing the remote access.

4. Building a simulation on PDEs with Easy Java Simulation.

In order to show how a simple simulation is created in EJS we are going to explore the previous one. Opening this simulation in EJS we see how the simulation is divided into three main panels: Description, Model and View.

The Description panel is an HTML editor to write some information about the model. It can also be used to describe some class activities.

The Model panel is where the connection is done, it is the more interesting part. EJS connects to other libraries by the subpanel Elements, Fig. 2. Here we can create a FreeFem element and edit its properties.

In the properties menu, Fig. 3, we find several fields to set the server information and the script. If the server direction field is kept empty EJS will call the FreeFem++ installed in the same computer where EJS is being executed. By contrast, if a server direction is written, a search for the FreeFem++ installed in the other computer will be done. Here you can add a username and password for security issues.

Finally, in the text panel, the script is written using the Freefem++ language as we described in Section 3.

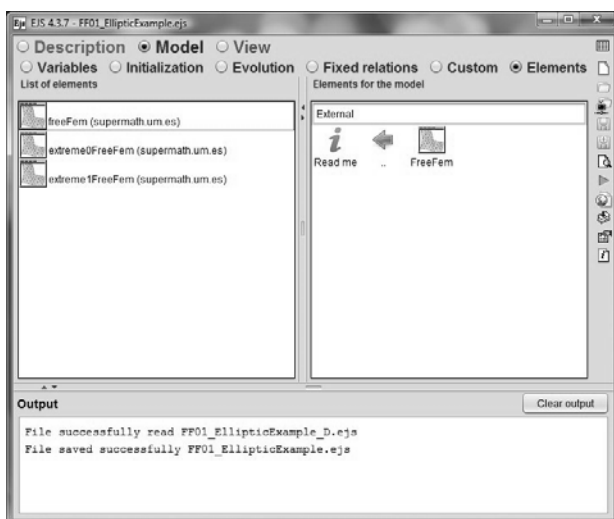


Figure 6: Elements in the Model panel of EJS

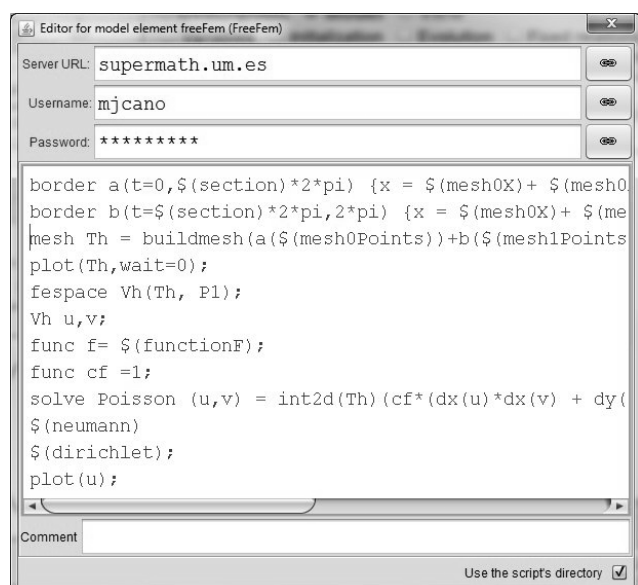


Figure 7: FreeFem element menu.

By a dollar symbol before a variable we indicate that it is not a variable of the FreeFem++ script but it is an EJS variable. As a consequence, its value has to be read if the solution is recalculated. This is the way we achieve interaction. In the example, we create the mesh, and we set the number of points in the simulation. Finally we define and solve the equations of the problem with the Neumann and Dirichlet conditions. The solution is sent to java.

Once the FreeFem element is created, we can ask it to run the script using the runScript function via the order:

```
freeFem.runScript();
```

This code can be used from any part of the simulation, for instance in the initialization or the evolution. Its execution sends back a ScriptOutput object which contains a group of Java objects, with the information to plot meshes and solutions.

Finally, in the View panel, Fig. 4, we just need to drag and drop the icons to add the visualization elements to the view tree. Each element has a menu where you can edit its properties. In this menu is possible to select the Java object to plot from the script execution output, but also, to introduce the information of cells and values of the solution using the text fields.

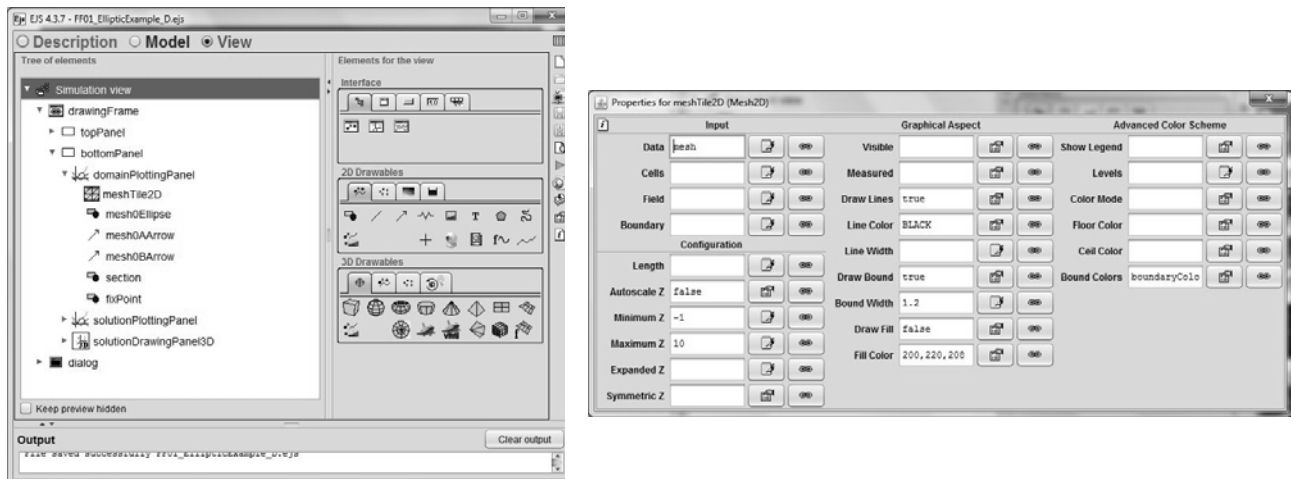


Figure 8: View panel from EJS (left) and view element menu (right).

Some of the features we can modify for the element view are: the range of color to represent the different values, setting a floor and ceiling colors or using the autoscale mode, whether to show the mesh over the solution, whether to show or not, the lines of the bound, the colors and the width used to draw them, etc.

6. Conclusions

The cooperation between EJS and FreeFem++ makes possible the creation of interactive simulations on PDE problems. We firmly believe this is going to help both, students and teachers, in the learning process of these equations.

These simulations are easily built by teachers and advanced students thanks to its modular organization and the view elements included.

Undergraduate students can use the simulations as independent programs without programming requirements. They will be able to study and analyze the models and, more important, to make changes on the parameters involved with a real time feedback.

References

Allaire G (2007) Numerical Analysis and Optimization: An Introduction to Mathematical Modelling and Numerical Simulation. OUP Oxford.

Easy Java Simulations, <http://www.um.es/fem/EjsWiki/>, accessed 2013 september.

FreeFem++, <http://www.freefem.org/ff++/index.htm> accessed 2013 september.

Hecht F (2012) New development in freefem++. *Journal of Numerical Mathematics*, 20(3-4), 251-265.

Le Hyaric A (2013) FreeFem++-cs: an integrated environment for [FreeFem++](#),

<http://www.ann.jussieu.fr/~lehyaric/ffcs/>, accessed 2013 september.

Open Source Physics, <http://www.opensourcephysics.org/>, accessed 2013 september.

COMPUTER SIMULATIONS TO TEACH PHYSICS IN SECONDARY EDUCATION. MAIN FEATURES FOR A SUCCESSFUL LEARNING.

Daniel Aguirre Molina, *Colegio Pedro Poveda*

Antonio Quesada Armenteros, Marta Romero Ariza, *Universidad de Jaén*

Abstract

Simulations are a good tool to learn science. But not every use of simulation is productive. Lack of good criteria for using simulations and virtual labs in secondary education drives to inefficient practices that provoke the ICT use of teachers at class is decreasing, as no good results are encountered. Then, it's necessary to establish what features must simulations and virtual labs have in order to generate good results, from the point of view of acquisition of scientific knowledge.

These features are based on the framework of the TCPAK, and take into account a good design not only of the simulation itself, but also of the environment and didactic sequence where the simulation is applied.

1. Introduction

While ICT is becoming prevalent in schools, and children are increasingly growing up with ICT, teachers' use of ICT for teaching and learning continue to be a concern for educators (Jimoyiannis, 2010). Integrating ICT into classroom teaching and learning continue to be a challenging tasks for many teachers (Chen, 2010).

If we analysis one the last survey of ICT in Education made at European level (EUN, 2013), we can observe that almost all teachers at all grades have used ICT to prepare lessons and more than four out of five have used ICT in class in the past year, an increase since 2006. However, the percentages of teachers using ICT in more than 25% of lessons has not increased since 2006. We can see besides in some countries the use of ICT for educational purposes is being lower.

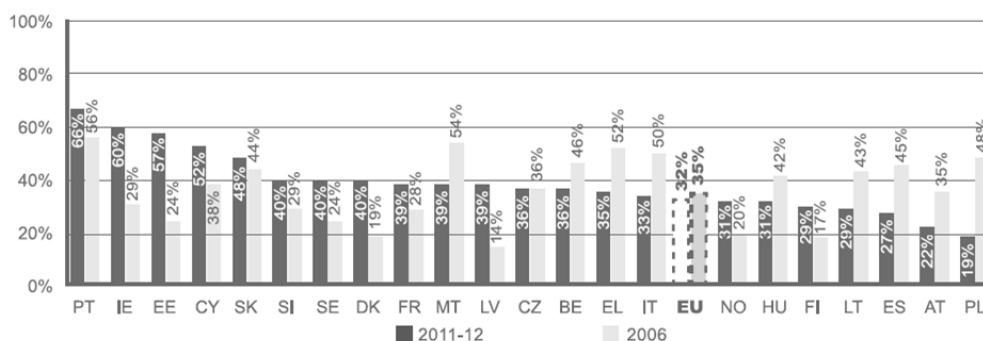


Figure 1. Teachers' use of ICT in more than 25% of lessons (grade 8, EU and country level, 2006 and 2011-12)

The **low use of digital resources and tools** is a concern. Digital textbooks and multimedia tools are the resources most frequently used. However, only 30% of students use them once a week or almost every day, but more than 50% of students at all grades never or almost never use such resources.

On the other hand, the most of the use is to continue with the traditional ways of teaching: Presentation to support theoretical lessons, asking for information...but only a minority highlights its use to support innovative methodologies.

Thomas (2001) spoke about the way ICT must be introduce at schools in the science teaching, and the problem was not techniques. He proposed that pedagogy should be strongly informed by appropriate theoretical orientations, the importance of models in science should be acknowledged in pedagogy and in software development, developing students' metacognition during instruction involving computers should be focused upon, and teachers' and students' beliefs and epistemologies should be recognized as key factors in educational change involving computer

implementation and use.

Voogt et al. (2013) argued the importance of learner-centered instruction to enhance student learning. They projected pedagogical approaches that are consistent with the expectations and values of the knowledge society and showed how these might differ from those consistent with the expectations and values of the industrial society. According to them, the pedagogical approaches that are expected to be important in the knowledge society should include, among others, providing variety in learning activities, offering opportunities for students to learn at their own pace, encouraging collaborative work, focusing on problem solving, and involving students in the assessment of their learning. This implies that not only is there a need for 21st century skills but also that these skills ask for learner-centred approaches to education, which might be referred to as 21st century learning.

About teachers, they proposed develop and use models for teacher learning on technology use in schools and classrooms at the pre and in-service levels. Policy needs to be developed on levels of knowledge responsibility and capacity of teachers in ICT integration. Further research and development of models such as the TPACK (Technological Pedagogical Content Knowledge) model is indicated in relation to the development of collaborative models for teacher learning on ICT integration, at the pre- and in-service levels.

The adoption of technology by teachers is conceived as a process that develops through different stages: from being aware and informed about the possibilities of ICT in education, to a more routine utilization of ICT in classroom practice, and finally to creative uses of technology for teaching and learning (Voogt et al., 2013).

In addition, although many teachers possess basic ICT competencies, many of them lack competencies related to the pedagogical use of ICT.

Based on the need to be able to integrate technology skills with pedagogical skills in order to successfully integrate ICT in educational practice, Koehler and Mishra (2009) elaborated the TPACK model. TPACK stands for technological pedagogical content knowledge and is related to Shulmans' notion of pedagogical content knowledge (PCK) (Shulman 1987). PCK represents the unique expertise teachers have. By blending pedagogical and discipline based knowledge, teachers are able to teach complex concepts. Through adding technology to PCK, teachers should become aware that in today's teaching, technology has an indispensable role, because it can add to the pedagogy as well as to the content of many subjects. The TPACK model seems to be a powerful model to further understand the knowledge teachers need to integrate ICT in their teaching.

From this, several models have emerged, like the proposed by Jimoyiannis (2010) called TPASK, changing "content" by "science", where he develops concrete skills to Science teaching.

2. Simulations and virtual labs.

The New Media Consortium, a globally-focused not-for-profit consortium, established the Horizon Project in 2002 to identify and describe emerging technologies that seemed likely to have a significant impact on a variety of sectors around the world (Spector, 2013). Potential impacts on teaching, learning and creative inquiry have been a focus from the very first *Horizon Report*. The *Horizon Report* includes sections on key trends, critical challenges and technologies to watch. The report identifies six technologies to watch in three time-to-adoption contexts: one year or less, two to three years, and four to five years.

In the last report (NMC, 2013), the New Media Consortium speak about the presence of virtual and remote laboratories in four or five years' time. The reasons this report highlight are:

- Because virtual laboratories do not involve real equipment or chemicals, students can feel more comfortable making mistakes and running experiments as often as they like.
- Educators can play back videos of the experiments students have run online, pinpoint areas of improvement, and acknowledge students who have excelled.
- Virtual and remote laboratories increase access to science tools, allowing learners from all over the world to use them via wireless or cellular networks; laboratory work is no longer limited to spaces on physical campuses"

These conclusions agree with the actual research, as De Jong (2013) affirms:

“An important affordance of virtual laboratories is that reality can be adapted. Designers of virtual experiments can simplify learning by highlighting salient information and removing confusing details, or they can modify model characteristics, such as the time scale, that make the interpretation of certain phenomena easier. Students can conduct experiments about unobservable phenomena, such as chemical reactions, thermodynamics, or electricity.

In virtual laboratories, students can also directly link unobservable processes to symbolic equations and observable phenomena, which encourages them to make abstractions over different representations.”

On the other hand, De Jong, give a step more, proposing that real laboratories, in the future, will have an important motivational scope, as if we abuse the use of virtual labs, probably our students will get saturated and unmotivated towards the study of sciences.

From the teacher point of view, simulations have also advantages (Rutten et al., 2012), like the saving of time, allowing them to devote more time to the students instead of to the set-up and supervision of experimental equipment; the ease with which experimental variables can be manipulated, allowing for stating and testing hypotheses; and provision of ways to support understanding with varying representations, such as diagrams and graphs

However, research indicates that, overall, students have substantial problems with all of the inquiry processes listed above. Students have difficulty choosing the right variables to work with, they find it difficult to state testable hypotheses, and they do not necessarily draw the correct conclusions from experiments.

They may have difficulty linking experimental data and hypotheses, because their pre-existing ideas tend to persist even when they are confronted with data that contradict those ideas.

Students also struggle with basic experimental processes (Chen, 2010). They find it difficult to translate theoretical variables from their hypothesis into manipulable and observable variables in the experiment; they design ineffective experiments, for example, by varying too many variables at one time; they may use an “engineering approach,” where they try to achieve a certain state in the simulation instead of trying to test a hypothesis; they fail to make predictions; and they make mistakes when interpreting data. Students also tend to do only short-term planning and do not adequately monitor what they have done (de Jong, 2006).

By this, the scaffolding it is necessary to improve their performance in simulation-based learning (Rutten et al., 2012).

Research in inquiry learning currently focuses on finding scaffolds or cognitive tools that help to alleviate these problems and produce effective and efficient learning situations.

Examples of cognitive tools are assignments (exercises that set the simulation in the appropriate state); explanations and background information; monitoring tools (to help students keep track of their experiments); predefined hypotheses; experimentation hints (such as “vary one thing at a time” or “try extreme values”); process coordinators (which guide the students through the complete inquiry cycle); and planning tools.

At this point, we can pose the question: what are the main features to get a successful didactic process?

One thing is clear; now we can affirm the use of simulations to science teaching improve the acquisition of knowledge, in general, but not always.

Scalise et al. (2011) analyses 79 articles about simulations and virtual labs focus on secondary education and from them, only 3 (3,8%) speak about no improvement of knowledge, 20 (25,3%) offer mixed results (some groups gained and others no), 14 (17,7%) showed gain under correct conditions and 42 (53,2%) improvement. Then, we can conclude that 96,2% of the studies report an improvement of the results.

The features for this improvement of the results are:

Almost 40 of the studies cited as key aspects of the “scientific inquiry” as influential in learning gains. These aspects include that students are helped to develop research questions, designing experiments, performing simulation projects and collect and analyze simulation data.

The next factor of success comes from aspects of scientific representations and visualizations that can be obtained through the simulations. (36 articles reported this factor). In these cases, offering views was especially helpful in understanding the dynamic processes where the simulation showed

changes over time.

The next major factor is related to aspects of the software or hardware, following the collaboration in the scientific process, followed by providing answers to students individually and the fact that student understanding was evaluating.

Scalise et al. (2011) detail that the main features for a good use of simulations on secondary education, where we highlight the next ones:

Focal points:

-Do cue students to extract relevant information from the interface. Be aware that visual “focal points”, such as movement and color contrast, will draw student attention. Use them intentionally for substantive features of learning.

-Consider a rich range of modalities for presentation in the interface for instance include visual and auditory resources but also consider haptics, kinetics and other kinds of new media information, if appropriate.

Cognitive load:

-Start with basic attention to standard interface usability characteristics. Note that for science simulations in particular, the interface should allow representations and text to be integrated where appropriate.

-Do not overload working memory. Be aware that for low prior knowledge students, even having controls separate from animation, as in a standard navigation menu approach, can overload working memory.

Scaffolds:

-Employ effective scaffolds to promote learning, including teaching and encouraging students to use help functions. Basic approaches to scaffolding can include “hover” labels that appear when moused over, and clickable links to provide information.

-Effective scaffolds also include “cognitive tools” such as monitoring tools to monitor experiments, experimentation hints, and planning tools. Be sure to use “fading” to reduce interface scaffolding as student progress in their understanding.

Sense-making:

-Simple graphics with less detail can be more effective than realistic representations. Additional detail and realism can be added as students sense-making ability improves.

-Don't use graphics that interact and inter-relate for non-meaningful reasons. Do emphasize critical variables visually. Note integrating text or explanations with associated animations often showed increased learning gains. More research is needed to effectively scaffold students between multiple representations, and to use representations effectively to complement, constrain and construct understanding.

Differentiating Instruction:

-Allowing users to stop, start and replay visualizations as needed can allow reinspection and aid learning.

-Allowing close-ups, alternative perspectives and control of speed can facilitate perception and comprehension.

Relevance:

-Simulations should be connected with real world target applications, and students should also explore these off-line and hands-on.

-User interactivity with the simulations in many modes can increase engagement. Make sure appropriately rich media is used, to well represent the relevant target.

Interpretation:

-Explicitly ask students to interpret, compare and control displays.

-Use abstraction carefully. Visualizations simplified through abstractions can require high reasoning capability and absorb cognitive resources. When abstraction used, equations and formulas should be explicitly connected with conceptual displays. Students should practice translating meaning.

Scientifically Oriented Questions:

-Active inquiry includes identifying the study problem and writing hypotheses, so don't pose questions simple as a “given”. Avoid “cookbook” science but have a clear purpose, ensure

students know what it is, and include assessments with measures of knowledge.

-Learner support through the computer interface for the inquiry process is important, including in hypothesis development, design, and predictions. Scaffolds are needed for successful prompting of questions from students.

Design and Conduct Investigations:

-Make sure students recognize experimental outcomes as clues to scientific phenomena. Link quantitative data with conceptual displays. Include learner decision-making beyond software control, and sufficient procedural info.

-Avoid random trial-and-error and include frameworks for decision-making. Ways to collect/display data to examine relationships, heuristics for systematic variable control, scientific models to describe phenomena.

Formulate/Evaluate Explanations:

-Scaffolds are necessary to relate observations/conclusions to plausible explanations. Systematization in confirmation of hypothesis is necessary to avoid wrong conclusions.

Some students recognize original hypothesis are wrong but cannot explain unexpected behavior. Grappling with cases fosters explanations. Instructor-student conversations diagnose issues.

Internet conferencing and role play foster discussions. Collaboration and “co-laboratories” effective when each students brings own data/reflections, to converge on more descriptive language.

Communicate & Justify Findings:

-Epistemological beliefs can lead students and teachers to think truth is received from an authority figure rather than explored based on evidence. Justification helped students “think like scientists”.

-Self-reflection and comparing work samples helped students. Discussing findings and using graph and visual organizers were simple, effective communication approaches.

References

- Chen, S. (2010). The view of scientific inquiry conveyed by simulation-based virtual laboratories. *Computers & Education* 55 (2010) 1123–1130
- de Jong, T. (2006). Technological Advances in Inquiry Learning. *Science*, vol. 312
- de Jong, T., Linn, M., Zacharia, Z. (2013). “Physical and Virtual Laboratories in Science and Engineering Education”, *Science* 340, 305.
- EUN (2013). <http://essie.eun.org/> Accessed 2014, February
- Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development . *Computers & Education* 55 (2010) 1259–1269
- Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education*, 9(1), 60-70.
- NMC (2013), <http://www.nmc.org/publications/2013-horizon-report-k12>. Accessed 2014, February
- Rutten, N., van Joolingen, W. R., van der Veen, J.T., (2012). The learning effects of computer simulations in science education. *Computers & Education*, 58 (2012) 136–153
- Scalise, K., Timms, M., Moorjani, A., Clark, L., Holtermann, K., Irvin, P.S., (2011). Student Learning in Science Simulations: Design Features That Promote Learning Gains. *Journal of Research in Science Teaching*, vol. 48, no. 9, pp. 1050–1078.
- Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-22.
- Spector, J. M. (2013). Emerging Educational Technologies and Research Directions. *Educational Technology & Society*, 16 (2), 21–30.
- Thomas, G. P. (2001). Toward Effective Computer Use in High School Science Education: Where to from Here? *Education and Information Technologies* 6:1, 29-41.
- Voogt, J., Knezek, G., Cox, M., Knezek, D., ten Brummelhuis, A. (2013). Under which conditions does ICT have a positive effect on teaching and learning? *A Call to Action Journal of Computer Assisted Learning*, Vol. 29(1), 4-14

EASY JAVA SIMULATION, INNOVATIVE TOOL FOR TEACHERS AS DESIGNERS OF GRAVITY-PHYSICS COMPUTER MODELS

Loo Kang WEE, *Ministry of Education, Educational Technology Division, Singapore*

Giam Hwee GOH, *Ministry of Education, Yishun Junior College, Singapore*

Ee-Peow LIM, *Ministry of Education, Anderson Junior College, Singapore*

This paper is on the customization of computer models using the Easy Java Simulation Authoring Toolkit for the Singapore syllabus, based on real data, supported with literature-reviewed pedagogical features. These four new computer models serve to support the enactment of evidence-based classroom science learning that is. The authors suggest that with strong teacher guidance, these computer models can be effective tools for science learning. Students also enjoy learning because of the increased level of interactivity when exploring the modeled science with enhanced visualization as compared with the traditional pen and paper problem solving.

Pilot research suggests that students' enactment of investigative learning like scientists is now possible where gravity-physics 'comes alive' and students' learning is enriched.

Download simulations:

https://dl.dropboxusercontent.com/u/44365627/lookangEJSworkspace/export/ejs_model_GField_and_Potential_1D_v8wee.jar

https://dl.dropboxusercontent.com/u/44365627/lookangEJSworkspace/export/ejs_model_GFieldandPotential1Dv7EarthMoon.jar

https://dl.dropboxusercontent.com/u/44365627/lookangEJSworkspace/export/ejs_model_KeplerSystem3rdLaw09.jar

https://dl.dropboxusercontent.com/u/44365627/lookangEJSS/export/ejs_model_EarthAndSatelite.jar

1. Innovativeness of EJS

We have used the Easy Java Simulation (EJS) (Christian, Esquembre, & Barbato, 2011; Esquembre, 2012; Hwang & Esquembre, 2003) Authoring Toolkit and found it to be an innovative and versatile (generate java scripts models that runs on almost any mobile devices has a library of models free for anyone to change; allows for collaborative exploration sessions in Moodle, compliment remote laboratory usage; interfaces with sensors augmented reality and others) tool as it allows ordinary teachers to network with the Open Source Physics community. We present 4 computer models that the authors have customized to the Singapore syllabus for students' interactive learning. The authors have gained valuable experiences that sensitize us to effective teaching and learning with computers models such as augmenting with real equipment, where possible.

2. Rationale for use of computer models

We chose computer models as we believe physics is best learnt by inquiry through hands-on exploration. Many of our students fail to visualize the gravitational effects of planetary masses such as those causing the motions of satellites. We also saw word problem solving pedagogy to give students very little physical meaning.

3. The 5E Lesson design framework

The 5E lesson design framework is commonly used in the public schools and can be used to aid the inquiry-based lessons with computer models. By making use of practical situations for example the 15th February 2013 Chelyabinsk meteorite hitting Russia, students are more inclined to be *Engaged* in applying inquiry-based learning. Worksheets that detail the steps necessary to plan, experiment and measure to collect data encourage students to *Explore* the subject. *Explanation* of concepts can be done through student collaboration to share their evidence-based discussions. By questioning the students, the teacher is able to inspire *Elaboration* of content from students. Student presentations on the topic can *Evaluate* the given problem.

4. Computer models

Our computer models are available for download via the links and we welcome anyone to

further customize them for their own teaching and learning needs, licensed Creative Commons Attribution. The simulations are updated to the latest EJS 5.0 beta version after feedbacks from students and teachers.

4.1. Gravity Mass Model

Point Charge Electric Field in 1D Model by Andrew (Duffy, 2009), Professor of Physics, Boston University, USA served as the template for our Gravity Mass Model (Duffy & Wee, 2010a). The gravity mass model (Figure 1) is suited for the inquiry of gravitational field strength and potential of a 2 mass (M1 and M2) system with a test mass m, in the x-direction dimension. Invisible concepts of field strength and potential are modeled, allowing students to experience near 'impossible' isolated gravitational effects of small masses.

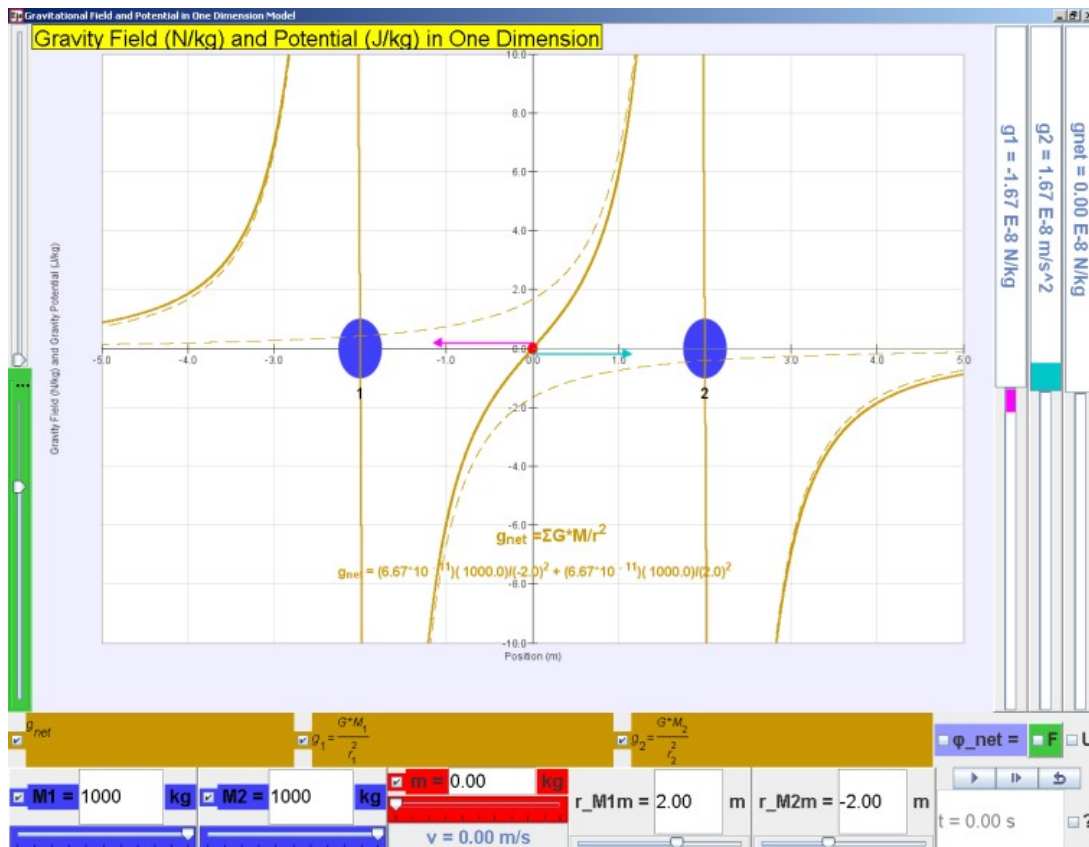


Figure 1. Gravity Mass Model(Duffy & Wee, 2010a) suitable for investigative inquiry learning through data collection, customized with syllabus learning objectives such as gravitational strength g , gravitational potential ϕ when one or both masses $M1$ and $M2$ are present with a test mass m . Superimpose are the mathematical representations, vector presentation of g , based on current Newtonian model of gravity.

4.2. Earth Moon Model

The earth moon model (Figure 2) is suited for the inquiry of gravitational field strength and potential of the earth and moon system with a test mass m , in the x -direction. Concepts such as zero net force position and escape velocity of earth can be experienced and explored. These simulations provide simple means of doing practically impossible 'experiments' such as going to the Moon. We found the concepts of zero net force position and escape velocity to be especially useful in our classrooms with students. This is adapted from Duffy's (2009) work in Point Charge Electric Field in 1D Model which we customized to suit the gravitational concepts.

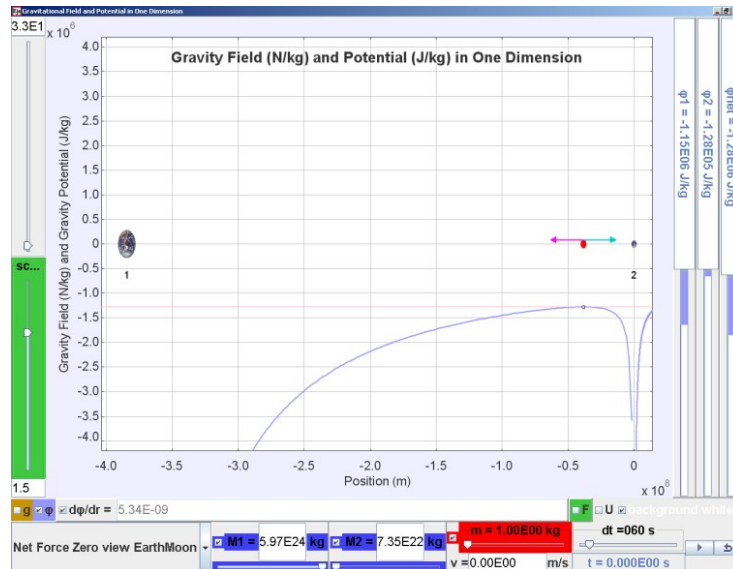


Figure 2. Earth Moon Model (Duffy & Wee, 2010b) suitable for investigative inquiry learning, further customized to allow the experiencing of an Advanced Level examination question June 87 /II/8. Data are based on real values where students can play and experience physics otherwise difficult to related to paper based question.

4.3. Geostationary Satellite Model

Earth and moon model by Francisco (Esquembre, 2010), Professor of Mathematics, University of Murcia, Spain, serves as the template for our geostationary satellite model (Figure 3). The geostationary satellite model (Wee & Esquembre, 2010) is suited for visualization of the three common orbits as well as some non-geostationary orbits. We even included incorrect physics such as a geostationary satellite above a point on the northern hemisphere of Earth. This is used to challenge thinking about what is 'wrong' with this orbit. A free body diagram showing the equal and opposite forces acting separately on the Earth and satellite helps students use what they learnt about Newton's Third Law in this context (Wee & Goh, 2013).

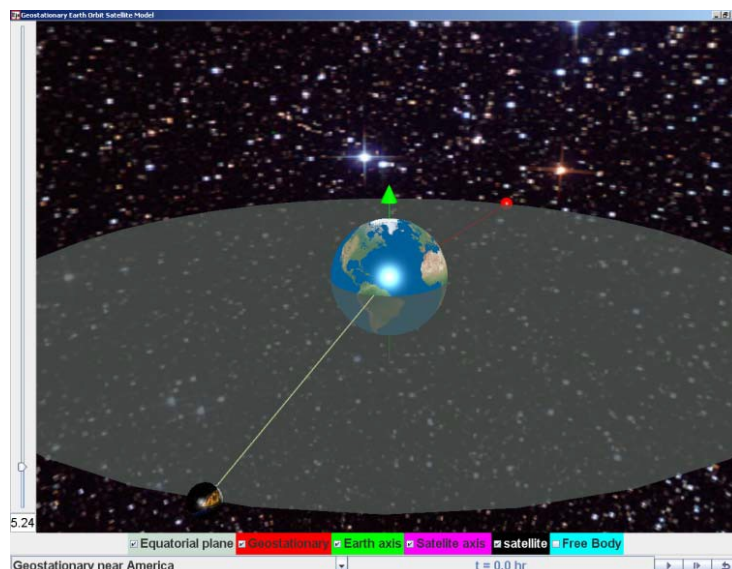


Figure 3. Geostationary Satellite around Earth Model (Wee & Esquembre, 2010) suitable for inquiry learning through menu selection. The geostationary checkbox option, 3D visualization, customized with Singapore (red) and America (satellite) as a location position for satellite fixed about a position above the earth with 24 hours period, same rotation sense on the equator plane.

4.4. Kepler's System Model

The Kepler's Solar System Model (Timberlake, 2010), Professor of Physics, Berry College, USA serves as the template for our Kepler's System Model (Figure 4) (Timberlake & Wee, 2011). In addition to inquiry features-ideas in this paper by the same first author, (Wee, Goh, & Chew, 2013) we add the ability to use the EJS to collect and display the data instead of relying on pen and paper to record. This further supports our claim that EJS is an innovative tool for teacher professional development as the authors are able to customize and align the students' learning activity with the simulation tool. This would not be possible if the authors were to take existing simulations that cannot be customized.

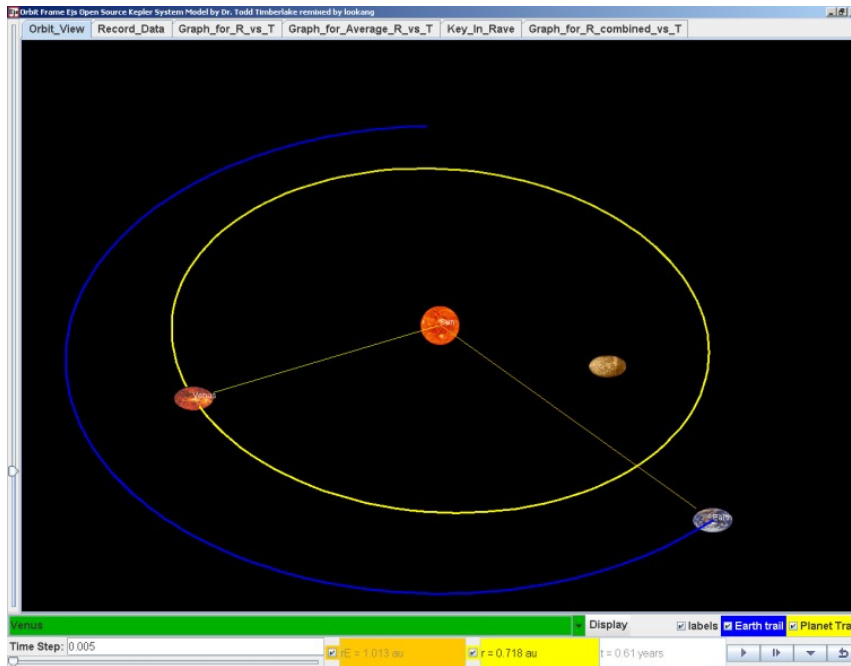


Figure 4. Kepler's System Model (Timberlake & Wee, 2011) with actual astronomical data built into the simulation, with realistic 3D visualization, (radius of planets such as Earth, r_E and another planet for comparison r , and time t for determination of period of motion, T) data for inquiry learning and to situate understanding.

#	T / years	R / A.U.	Raverage / A.U.
0	0.245	0.387	0.000
1	0.615	0.723	0.000
2	1.000	1.000	0.000
3	1.880	1.524	0.000
4	11.888	5.203	0.000
5	29.500	9.537	0.000
6	84.200	19.190	0.000
7	164.000	30.060	0.000
8	248.400	39.480	0.000

• data collect inside EJS instead of pen paper

$T = Ar^n$
 $\ln T = \ln(Ar^n)$

Planet	r / year	r / 10^6 km	$\ln T$	$\ln r$
Mercury	0.24	67.3	-1.43	18.0
Venus	0.62	109	-0.47	18.5
Mars	1.88	210	0.63	19.2
Jupiter	11.87	799	2.47	20.5
Saturn	29.45	1469	3.38	21.1

$r_E = 0.999 au$

Figure 5. Kepler's System Model (Timberlake & Wee, 2011) with tabs to Record Data showing (top) the data collectable by students after several runs of the model and (bottom) sample pen paper recording of the data

We have not tried out these newly developed features-ideas (Figure 5) for supporting learning but we speculate that students would approach the tasks now more like scientists, using computers to do routine work and seeing trends and patterns. EJS is also an effective tool for the authors because we are able to make EJS plot all the data points (Figure 6), with two possible data analysis to study trends of $T^2 = 0.999R^3$ (Figure 7) and $\lg T = 1.4981\lg R$ (Figure 8).

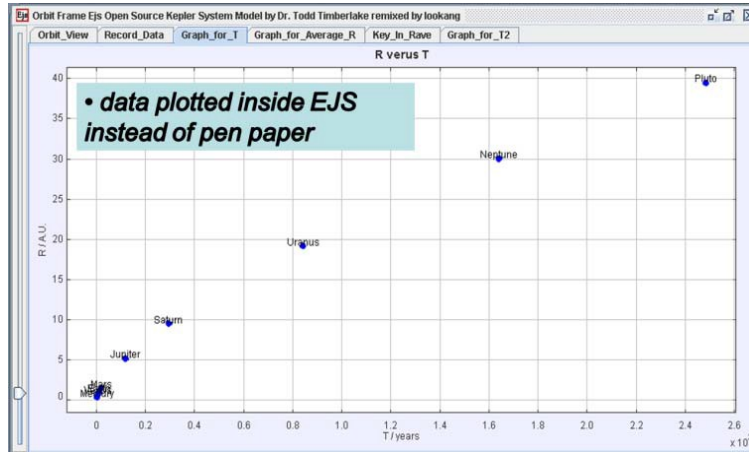


Figure 6. Kepler's System Model (Timberlake & Wee, 2011) with tabs to show Graph for period T.

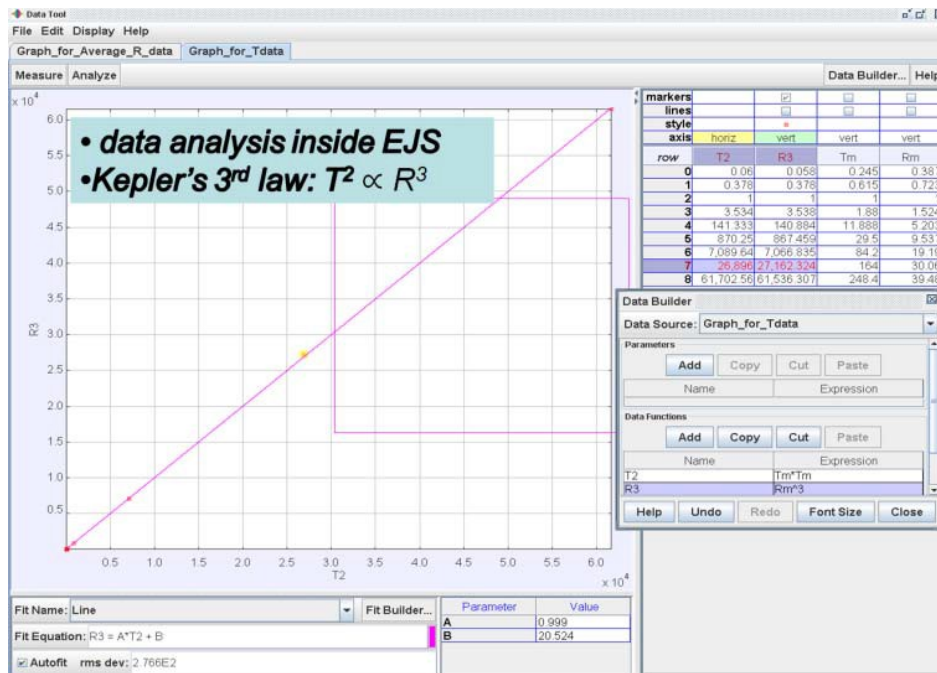


Figure 7. Kepler's System Model (Timberlake & Wee, 2011) with data analysis tool for best fit line for $T^2 = R^3$ with coefficients $A = 0.999$ suggesting to $T^2 \propto R^3$.

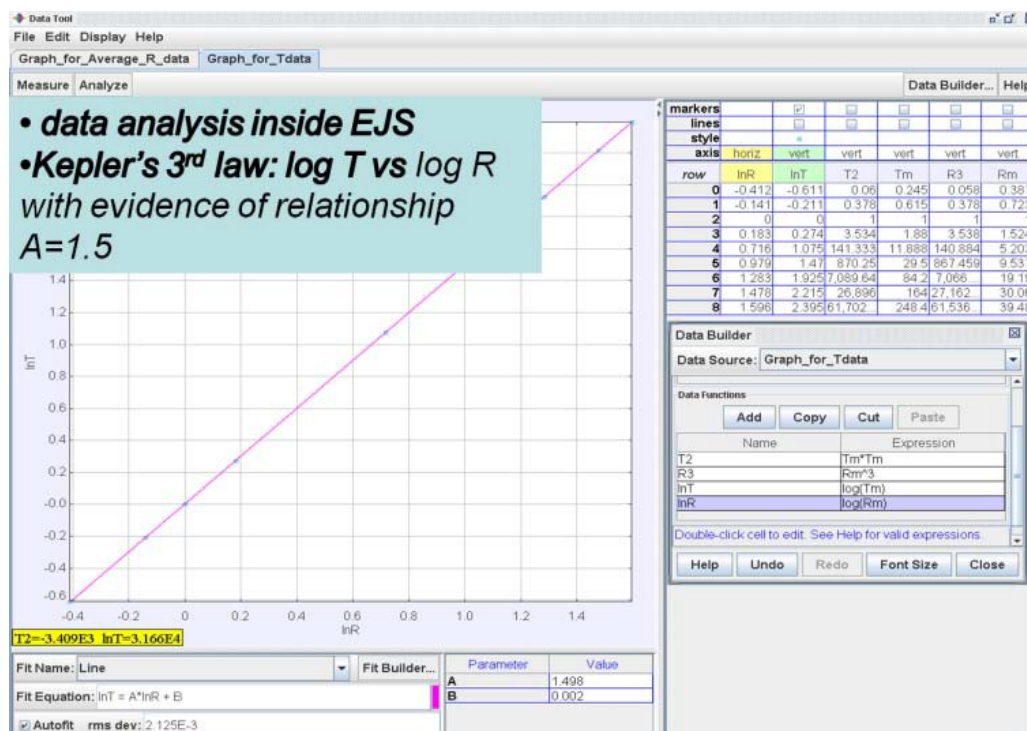


Figure 8. Kepler's System Model (Timberlake & Wee, 2011) with data analysis tool for best fit line for $\lg T$ and $\lg R$ with coefficients $A = 1.498$ suggesting $\lg T = 1.498 \lg R$.

We have briefly discussed the customized these four computer models for interactive engagement learning by standing on the shoulders of OSP giants. This is an innovative approach that deepens teacher's professional development in computer models design at practically zero dollars.

5. Conclusion

The authors have presented four gravity computer models that we have co-designed with teachers and students inputs, based on the earlier models-templates from the Open Source Physics (OSP) community. We argued for the use of EJS to design simulations as an innovative method for teacher professional development, and we advocate this professional learning for teachers who wish to customized simulations and eventually move on to teach students physics by coding-modeling in EJS.

The authors' school based research computer models, add credibility to this innovative approach of teachers' professional development through designing-customizing computer models that serves as effective inquiry tool that increases interactive engagement and visualization.

Feedback from the students has been positive, as triangulated from the survey responses, interviews with students and discussions with teachers.

The free EJS computer models can be downloaded from <http://weelookang.blogspot.sg/2013/04/mptl18-easy-java-simulation-innovative.html>, ComPadre Open Source Physics (Wee, 2012) and NTNU Virtual Physics Laboratory (Timberlake & Wee, 2011; Wee, Duffy, & Hwang, 2012a, 2012b; Wee & Esquembre, 2010) digital libraries. We hope more teachers around the world will further customize them for more intelligent (Juuti & Lavonen, 2006) guided inquiry in their own classes.

Acknowledgement

We wish to acknowledge the passionate contributions of Francisco Esquembre, Fu-Kwun Hwang and Wolfgang Christian for their ideas and insights in the co-creation of interactive simulation and curriculum materials.

This conference paper is made possible; thanks to the MOE-AST overseas training fund and eduLab project NRF2011-EDU001-EL001 Java Simulation Design for Teaching and Learning, awarded by the National Research Foundation, Singapore in collaboration with National Institute of Education, Singapore and the Ministry of Education (MOE), Singapore. Lastly, we also thank MOE for the recognition of our research and development on the computer models as a significant innovation with the 2012 MOE Innery (HQ) GOLD Award.

References

- Christian, Wolfgang, Esquembre, Francisco, & Barbato, Lyle. (2011). Open Source Physics. *Science*, 334(6059), 1077-1078. doi: 10.1126/science.1196984
- Duffy, Andrew. (2009). Point Charge Electric Field in 1D Model. From <http://www.compadre.org/Repository/document/ServeFile.cfm?ID=9411&DocID=1574>
- Duffy, Andrew, & Wee, Loo Kang. (2010a). Ejs Open Source Gravitational Field & Potential of 2 Mass Java Applet. from <http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=1921.0>
- Duffy, Andrew, & Wee, Loo Kang. (2010b). Ejs Open Source Gravitational Field & Potential of Earth and Moon Java Applet. from <http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=1924.0>
- Esquembre, Francisco. (2010). Ejs Open Source Earth and Moon Model. 1.0. From <http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=1830.0>
- Esquembre, Francisco. (2012). Easy Java Simulations. Retrieved 13 September, 2012, from <http://www.um.es/fem/EjsWiki/pmwiki.php>
- Hwang, F. K., & Esquembre, F. (2003). Easy java simulations: An interactive science learning tool. *Interactive Multimedia Electronic Journal of Computer - Enhanced Learning*, 5.
- Juuti, K., & Lavonen, J. (2006). Design-Based Research in Science Education: One Step Towards Methodology.
- Timberlake, Todd. (2010). Kepler System Model. 1.0. from <http://www.compadre.org/Repository/document/ServeFile.cfm?ID=9757&DocID=1451>
- Timberlake, Todd, & Wee, Loo Kang. (2011). Ejs Open Source Kepler 3rd Law System Model Java Applet. 1.0. from <http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=2225.0>
- Wee, Loo Kang. (2012). Geostationary Earth Orbit Satellite Model. from <http://www.compadre.org/Repository/document/ServeFile.cfm?ID=11775&DocID=2634> & <http://www.compadre.org/osp/document/ServeFile.cfm?ID=11775&DocID=2634&Attachment=1> (public download)
- Wee, Loo Kang, Duffy, Andrew, & Hwang, Fu-Kwun. (2012a). Ejs Open Source Gravitational Field & Potential of 2 Mass Java Applet. from <http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=1921.0>
- Wee, Loo Kang, Duffy, Andrew, & Hwang, Fu-Kwun. (2012b). Ejs Open Source Gravitational Field & Potential of Earth and Moon Java Applet. from <http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=1924.0>
- Wee, Loo Kang, & Esquembre, Francisco. (2010). Ejs Open Source Geostationary Satellite around Earth Java Applet. requires Java 3D and Runtime. From https://sites.google.com/site/lookang/edulabgravityearthandsatelliteyc/ejs_EarthAndSatelite.jar attredirects=0&d=1 & <http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=1877.0> (requires Registration to download)
- Wee, Loo Kang, & Goh, Giam Hwee. (2013). A geostationary Earth orbit satellite model using Easy Java Simulation. *Physics Education*, 48(1), 72.
- Wee, Loo Kang, Goh, Giam Hwee, & Chew, Charles. (2013). *Enabling Gravity Physics by Inquiry using Easy Java Simulation*. Paper presented at the 5th Redesign Pedagogy, Singapore. <http://arxiv.org/ftp/arxiv/papers/1303/1303.0079.pdf>

E-EXPERIMENTATION IN PRESCHOOL SCIENCE EDUCATION USING REMOTE EXPERIMENT ENVIRONMENT IN TRNAVA

Miroslava Ožvoldová, Adriana Čemešová, Trnava University in Trnava, Slovakia

Abstract

In this paper we have tried to answer the question: "Is it a real possibility to use Integrated e-Learning with the support of simple remote and virtual experiments in preschool education?" In our experiment we focused on the science oriented simple experimentation and its impact on the children's key competencies in the preschool education. The didactic materials used in this experiment were compiled into five thematic units. In our discussion we will examine solely the unit "Environment". The gained results confirmed our hypothesis of the importance of the combination of all forms of experiments on the development of children's key competencies in the science oriented preschool education.

1. Introduction

An experimentation is an integral part of learning and acquisition of knowledge, skills and experience for their real world life. The experimentation, in its simplest form takes place from the early age of the child together within his /her areal observations. The first observation is followed by the first games at home then experimentation at school and guided activities. Later, as students, they meet with demonstrations and laboratory experiments during classes at the school. None of the natural sciences and technically oriented teacher doubts about the importance of the experiment in science education in general. However, it is surprising that from the start of the new school reform in 2008, the allocated space for the science education in a Slovak school is lesser and consecutively the school experimentation is disappearing. This situation is resulting into continuous decline of the scientific literacy of pupils and students in the past years. How to deal with the ensued situation? There are several possibilities to choose from. The one of them is to start to deliver children scientific approach to knowledge since early childhood in the preschool age. In our research we focused to deliver corresponding information through the Internet and information-communication technologies (ICT) making use of the general positive approach of the youngest generation toward those techniques. The new generation feels easy to handle those new ICT, frequently mastered at time consuming entertainment such as computer games gives a potential tool for a new and effective and meaningful way of learning.

The presented article brings the experience gained with the activities supporting the acquisition of the science experience by the use of the both: real and remote experimentation carried across the Internet.

2. E - experiment

At the beginning let us specify some terminology, generally may be not obvious. What we mean by the word e-experiment? The prefix "e" is usually linked to the word electronic, however, in our work the e-experiment is rather linked within computer aided experiment realm. The e-experiments may be classified into two groups - real and virtual. The real computer aided experiment (RCE) is performed on a real physical interface located in a laboratory with a real data acquisition supported by a computer. Generally, we are speaking about. type of hands on laboratory connected computer aided experiment system, when the experimenter and physical equipment are on the same place, If the real physical equipment is located in a laboratory and the experimenter is at an arbitrary place (any place inside or outside of any building) with the Internet connection he/she may control the experimental physical equipment remotely across the Internet using the server – client connection. We speak about remote real experiment (RE), or *real remote e-laboratory*. Similarly, if the experimentator is connected via the Internet to an interactive simulation, we are speaking about virtual e-experiment (VE) and *virtual remote e-laboratory* Both types of mentioned e-laboratories have gradually found its place in the educational process at all levels of education, but still dominantly utilized at the university level (Azad A.K. (2011), Zubia, J.G. 2011, Kostelníková (2013). We are going to discuss utilization of e-experiments in the Slovak preschool education as a novelty that was introduced for the first time into educational process in the academic year

2011/2012 (Čemešová, A. (2012), Paláková, (2013). We have experimented on the development of children's key competencies in preschool age by means of the combination of all above mentioned forms of the e-experiments together with simple experiments (SE), using simple tools in the rooms or school yards.

3. Science e-experimentation in preschool education

Our motivation for the experimental work in the direction of INTe-L – new strategy of education, which will be explained in this paper later, came from the recent paper of Wieman (2005) supporting and calling for the change in the educational methodology. Since we had experience with e-lab using at a university and higher secondary level, we asked ourselves the question: Is it possible to use e-experiments at the lower primary and pre-primary level of education? Our question was answered after our pedagogical quasiexperiment.

In the pilot project, we aimed to set out the proposals and its realization to support children's interest and enthusiasm into scientifically tuned activities using e-experiments. Furthermore the experiment was oriented on the acquisition of preschool children's science concepts of the real world experience. In this chapter we introduce briefly the INTe-L strategy and one of the implemented units – named "Environment".

3.1. Integrated e-Learning and inquiry based science education

The Integrated e-Learning (INTe-L) as proposed by Schauer et al, (2009) is a new strategy of the cognition of real world in physics teaching via utilization of all above mentioned forms of the experiments. The keystone of this strategy is to acquire knowledge via active e-experimentation activities. The aim of INTe-L is the fact, that the natural science's can only be taught via scientific methods of work, through direct observation and direct experience. It is based on the method sciences use for the cognition of real world around us, with the huge utilisation of the latest ICT. The strategy aims to gain the knowledge and to shape the ideas of the children and students of a given concept or phenomenon guided by the lessons learned by experience rather than as an information memorized as an axioms of physical laws governing our surrounding world. Even though the children knowledge referring to physical laws may not exist yet, we wanted to examine the possibilities of science-tuned activities and effect on development of children's key competencies. If we wanted to put our work with children in the category of research-tuned concepts, we have to talk about structured inquiry - where children have to deal within the given problem following the instructions alongside with a teacher's assistance.

The teacher is desirable in the first phase to formulate very precisely and clearly the basic questions, suitable for children and studied thematic unit. The questions must be designed towards the natural curiosity of children, regarding the happenings around them. If the experiment is properly prepared, the questions are followed by the transformation leading from the curiosity into the action. This transformation displays the beginning of the activity which may be called "children's science research".

When a child is playing and unknowingly acquire experience there is a merging activity of previously and newly acquired information. The child creates his/her new ideas and pre-concepts. The final phase of the "Schola ludus", as it was called by J. A. Comenius, is completed by discussions with others children and teacher, who acts as a research mediator. Children among themselves share their new knowledge, beginning with the formulation of science reasoning and perhaps the first perception of their environmental surroundings. All even eager want to express what they have learned to others. Thus, active play for every child becomes more relevant. The child is trying to defend his/her findings and compare them with the findings of other children. After that the phase of children's questions come - reflection. According to reflection, we see, via active experimenting, if we encourage children to the new ideas. So we check whether we have prompted them to form a basis for logical reasoning, to the formation and development of the foundations of natural science, mathematics, pre-reading and cultural literacy of preschool children.

3.2. INTe-L unit Environment in preschool education

In the beginning of our survey, we have set thematic units, which are suitable for preprimary children education. We have focused on the current events and situations from their real life environment. So far we have designed units: Environment - Whether, Light, Take Aim and Throw, Mass and Weight, Strength and Movement. For each individual unit corresponding all three types of experiments (SE, RE, VE) were chosen and we have prepared didactical materials. Although we focused on RE, we have considered appropriate to give children the issue of the implementation of a simple experiment. Later we have accessed to the remote real and virtual experimentation. This sequence supports the development of key skills: manual dexterity and computer skills. Children learned very quickly and there has always been one of them, or more, so skilful that the experimentation in the interactive whiteboard environment was realized without any problems.

The following section will introduce the unit Environment and its individual experiments, as we conducted with children forwardly and later in groups.

- Measuring Air Temperature - simple experiment (Tools: mercury and digital thermometer).

The motivation, which preceded realization of the experimentation, was conducted through the interviews with children. It deals with what they know about the daily weather, the meteorological stations or weather forecast, ... Furthermore, we showed them pictures of the Earth from satellite images.

The level of the children knowledge of the surveyed themes were complementary guided by the questions: "How could we find out what the weather will be tomorrow, so we know how to dress appropriately? How can we find out when it will be the hottest day-time interval? What we need to measure? Where did we learn about the weather forecast? Who predicts the weather? What does the weather forecast for humans? ... All our activities have led to the three partial goals (PG). The first: "To identify with a thermometer, when the day temperature and the intensity of solar radiation is the highest during the investigation . The experimentation has been head towards educational objective: 1) To understand the time relationship during a day: the meaningful use of the concepts: morning, afternoon, evening, yesterday, tomorrow, today; 2) To measure the temperature with a thermometer and determine with the help of an adult indoor and outdoor temperature; 3) To record the temperature into the weather calendar; 4) To understand a simple graph. The introductory part was followed by the experimentation, as already mentioned, was carried under the supervision and help of the teacher due to auxiliary and safety reasons.

- Measuring Air Temperature - remote experiment

For the temperature measurements we have used the RE, freely available at <http://kf.truni.sk/remotelab1.sk>, which allows the monitoring of the selected physical parameters: temperature, pressure, sunshine through the Internet. As an introduction we had a conversation with the children about what we have found on the Internet and about the meteorological stations. The interactive whiteboard was connected to the Internet, where the pictures of Earth from satellite were obtained. We have also visited the first Slovak e-laboratory, where the temperature and the intensity of the sunshine in Trnava can be measured (<http://kf.truni.sk/remotelab>). Later, the Google map was used to compare the location of two cities: Trnava and Beluša, where experiment was realized (Figure 1).

The main aim of the second activity was the children understanding of the air temperature record in the form of a graph through a remote e-laboratory, presented across the Internet in the IT environment. The proposed activities were carried out by devices: IT, laptop and Internet, with individual learning objectives: 1) To know how to use a web browser to obtain the necessary information (Mozilla Firefox, Google); 2) To know the Slovak flag; 3) To know how to properly use the icons on the real remote experiment; 4) To understand the recording of the air temperature and combine it with that intensity of sunlight; 5) To understand that the temperature in Slovakia differs from the location, to make comparison of the the temperature in Trnava and Beluša; 6) To focus on a map, using IT; 7) To operate IT by finger; 8) To

delineate the characteristics of a chart weather (sunny, cloudy).

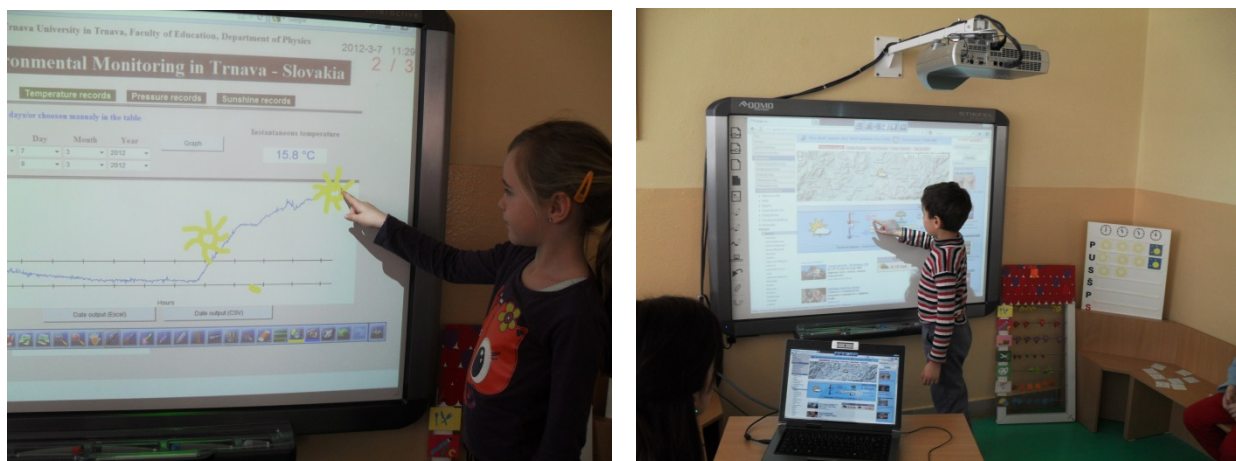


Figure 1: Whether monitoring across the remote access in Trnava <http://remotelab1.truni.sk> (left), in Beluša (right)

- Measurement of the temperature - virtual experiment

For a given activity - air temperature measurement and the chosen target group of children at the time of the first experiment, any simulation was not used. In the next year we incorporated into the project the simulation (<http://phet.colorado.edu/en/simulation/balloons-and-buoyancy>). Laying out the next aim of PG3 was to bring children's notions referring to the atmosphere as gaseous substances surrounding us. This observations supports the following educational activities: 1) The notion of the air around us, as a large set of moving small, eye invisible particles; 2) The virtual experiment leading to the connection between hotter environment, presented by a higher temperature on the thermometer and particle movement acceleration.

4. Discussion and conclusion

In this paper we have presented the one from the five realized scientifically tuned children activities in kindergarten with support of INTe-L strategy with the simple, as well as remote experiments through the Internet. The education design, promote the development of scientific competence of child labour, which in the future will form the basis of scientific thought and developing their science process skills.

Our aim was to construct knowledge of the children, connect their experience with a new knowledge through active learning and an action as the real environment, as well as in virtual environments through IT. The result is a qualitative change in children's notion development. The experiments related to the world of nature around us were confirmed together with the expectations that the children examined within a series of experiments and a real happening in the real world.

The result of the realized children's scientifically tuned activities may be summarized by acquired following children competencies: motoric, social, cognitive, personal (interpersonal), teaching responsibilities, information and communication competencies. The number of the individual competencies is presented in the diagrams on the Fig. 2.

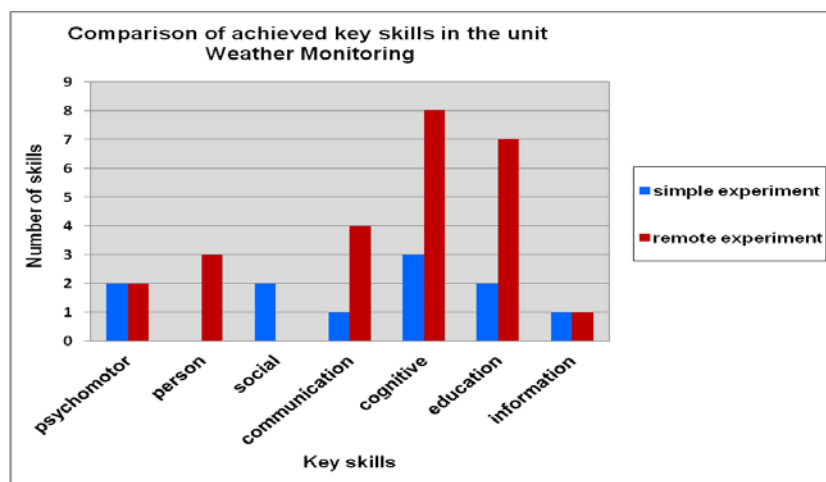


Figure 2: Number of achieved skills developed in the unit Environment –Weather Monitoring

Based on our findings we can conclude that implementation of proposed science-tuned activities in the form of direct and indirect observation should be encouraged and use to motivate pupils from a very early age. They are capable of a joy and seamlessly perform experiments in an interactive whiteboard or in kindergarten yard. The fact that children could be seen very happy in the environment, they learned to observe, to infer, to form conclusions and to convince us with their answers to the questions asked in the interview. The interview was conducted after four weeks of experiments are conducted. We found it interesting and we think it is important to mention that the quasi-experiment was appealing not only for children but also for the actual teacher and her colleagues. Gained results confirmed that the INTe-L is a suitable strategy for the science-tuned education by means of inquiry based science tuned activities also in preschool education.

Acknowledgements

The authors would like to thank to the Grant Agency of the Ministry of Education of the Slovak Republic – KEGA 020TTU-4/2013 "Accreditation of personalized ICT natural sciences teacher's education centre" and 011TTU-4/2012 "Energy as a Category in Science Education via remote experiments and Integrated e-Learning".

References

- Zubía J, G. and Alves G. R. (2011) Using Remote Labs in Education, Two little Ducks in Remote Experimentation, University of Deusto, Bilbao, Spain, 2011, ISBN 978-84-9830-398-8
- Azad A. K. M, Auer M E and Harward J W (2011) Internet Accessible Remote Laboratories: Scalable E-Learning Tools for Engineering and Science Disciplines. In: IGI Global, USA. 2011, 1 vyd.. 1. pp. 676, SBN 13: 9781613501863, ISBN10: 1613501862.
- Lowé D, Newcombe P, Stumpers B (2013) Evaluation of the Use of Remote Laboratories for Secondary School Science Education, Research in Science Education, V 43 (3), Springer Journals, June
- Kostelníková, M. and Ožvoldová, M. (2013) Inquiry in physics classes by means of remote experiments *Procedia - social and behavioral sciences*, 89(1), pp. 133-138.
- Čemešová, A.: The use of interactive whiteboard in preschool education, Diploma Thesis, Faculty of Pedagogy, Trnava University in Trnava, Slovakia, p. 81, 2012 (in Slovak)
- Paláková Z.(2013) Interactive white board utilization in preschool education, Diploma Thesis, Faculty of Pedagogy, Trnava University in Trnava, Slovakia, p. 80 (in Slovak)
- Wieman C. and Perkin, K. (2005) Transforming Physics Education, *Physics Today*, Vol. 58 Nov. 2005, pp. 26-41.
- Schauer, F., Ožvoldová M., Lustig, F.: Integrated e-Learning - New Strategy of Cognition of Real World in Teaching Physics, in: INNOVATIONS 2009, World Innovations in Engineering Education and Research iNEER, Special Volume 2009, chapter 11, pp. 119-135, ISBN 978-0-9741252-9-9, Arlington, USA

EXPERIMENTING FROM A DISTANCE: OPTICAL SPECTROMETRY VIA THE INTERNET

Lars-Jochen Thoms, Raimund Girwidz, *LMU Munich, GERMANY*

Abstract

Since Bohr found the relationship between optical spectra and the structure of atoms, spectroscopy is an important method in Physics. Furthermore, also in elementary optics and for the understanding of color perception the analysis of spectra is a fundamental component. Every student should have the opportunity to study optical emission spectra. Because spectrometers are expensive and an accurate calibration is necessary to achieve spectra of high quality, we developed a remotely controlled laboratory. Students can carry out real experiments via the internet. They can choose from six standard light bulbs like tungsten incandescent light bulbs, halogen incandescent lamps, cold white and warm white compact fluorescent lamps, light-emitting diode lamps or special bulbs. The light from one bulb is collected with a cosine-corrected fiber optic irradiance probe and analyzed with a commercial spectrometer. The probe can be positioned in front of the bulb in a field of 1×1.5 square meters. This allows further experiments like analyzing the decrease of spectral intensity with the squared radius or the spatial spectral radiant emittance. With compact fluorescent lamps, differences can be noticed between the light coming from the gas discharge and light coming from the fluorescent layer. Technical details and the experimental potential are explained.

1. Introduction

Since Bohr found the relationship between optical spectra and the structure of atoms, spectroscopy is an important method in Physics. Furthermore, also in elementary optics and for the understanding of color perception the analysis of spectra is a fundamental component. Every student should have the opportunity to study optical emission spectra. Since spectrometers are expensive and an accurate calibration is necessary to achieve quantitative spectra, we developed a remotely controlled laboratory.

1.1. Experimenting from a distance

Many national science education standards define competencies in science and engineering that all students should be able to demonstrate at subsequent stages in their K-12 learning experience (e.g., National Research Council, 2013). Experimenting is an essential part of physics and physics education. However, if expensive, complex, or challenging experimental set-ups are not available or practicable in school, remotely controlled laboratories can offer new, additional possibilities, that enable experimental experience, develop experimental competencies, and furthermore assist discovery learning. For many reasons, physical experiments should be feasible in distance learning.

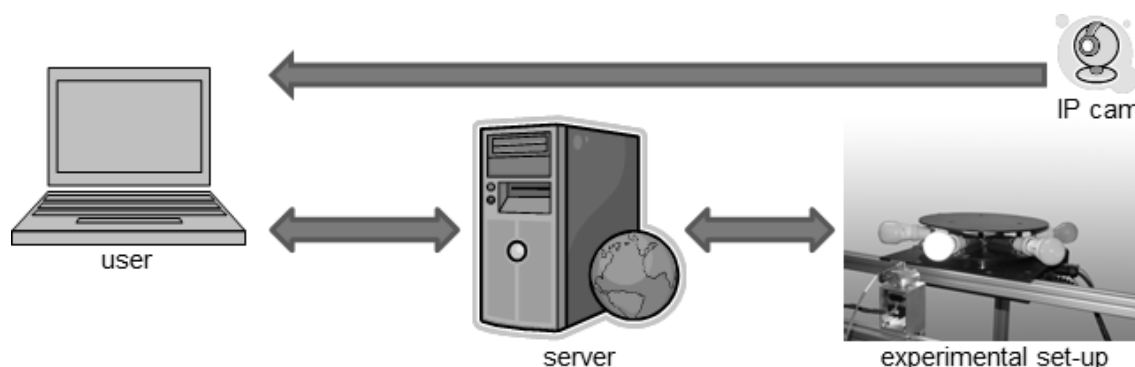


Figure 1: Schematic set-up of a remotely controlled laboratory (RCL) as implementation for an experiment on optical spectrometry. One or more users may connect to a server. One user can control the experimental set-up, watch the scene with an IP cam, and capture spectral data. In addition, other users may follow the process and measure the spectral data, too.

2. Physical aspects

The developed experiment on optical spectrometry allows the assessment of customary lamps with E 27 lamp sockets. For that purpose, the irradiation at a certain position is collected with an optical fiber and analyzed with a USB compact spectrometer. Currently, we use an *Ocean Optics USB650 Red Tide Spectrometer*. It projects the received light through a 25 μm entrance slit on a linear silicon CCD array with 650 active pixels offering approximately 2,0 nm optical resolution full width at half maximum. Radiation within a wavelength range of 350-1000 nm is recorded with 12-bit A/D resolution. With this, "intensities" are measured within a range of 0-4096 arbitrary units.

2.1. Considering the characteristics of the detector system

Unfortunately, the following aspect often is not sufficiently discussed.

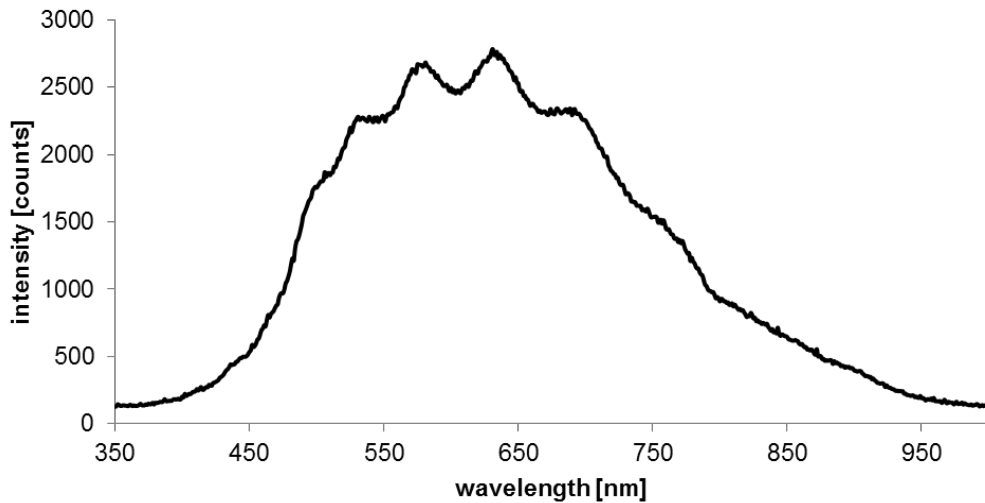


Figure 2: Measured spectrum of a tungsten halogen lamp.

Figure 2 shows the measured spectrum of a usual customary tungsten halogen lamp. For learning purposes, this graph requires special considerations. Students may identify this spectrum as blackbody radiation, on the one hand due to the form of the curve, and on the other hand based on their knowledge that thermic radiators like tungsten lamps may be regarded as blackbody radiators. Actually, a tungsten lamp radiates only a small part (about 4%) of its radiation in the visual part of the spectrum.

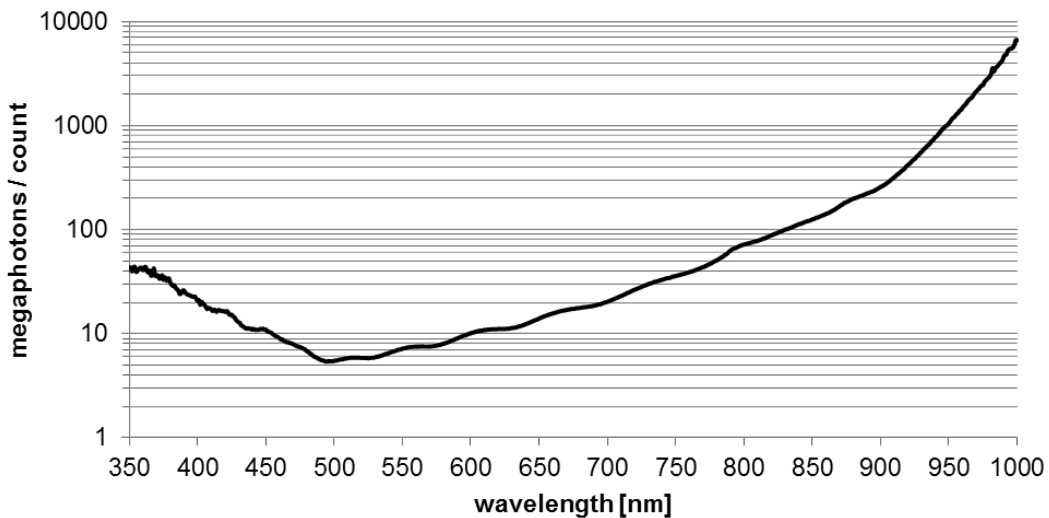


Figure 3: Spectral sensitivity of the detector system.

The important point to keep in mind is that the spectral sensitivity of the detector system is extremely dependent on the irradiated wavelength. Figure 4 shows the measured spectral sensitivity with a logarithmic scaling. Attention should be paid to the fact that there is a factor 1000 in the spectral sensitivity between 500 nm and 1000 nm. Without accurate calibration, neither two measured “intensities” at different wavelengths may be compared nor can any statements be made about the spectral power distribution of the radiation examined.

2.2. Calibration

For the calibration of the radiometric system used, the distributor of the spectrometers’ manufacturer kindly provided us with a radiometric calibration standard. In this case, it is a calibrated tungsten halogen light source with a well-known spectral power distribution. This calibration standard provides absolute spectral irradiance in $\mu\text{W}/\text{cm}^2/\text{nm}$ at the fiber port. The source can be calibrated specifically for a bare fiber or a fiber with attached cosine corrector.

2.3. Measurement of spectral irradiance

Irradiance is the power of electromagnetic radiation per unit area incident on a surface, such as the fiber’s cross-section at its tip. Nevertheless, with a bare fiber it is not possible to measure the true irradiance because the coupling of light into the fiber is highly dependent on the incidence angle. Instead, the irradiance should be proportional to the cosine of the incident angle. Furthermore, a probe is needed with a 180-degree field of view. The spectrometers’ manufacturer provides a so-called cosine corrector: a window made from opaline glass mountable on the tip of the optical fiber creating a dependency on the incidence angle that is nearly proportional to the cosine.

For spectrometry, it is common to consider each wavelength or frequency in a spectrum separately. Figure 4 clearly reveals how important it is to use appropriate optics, calibration and to take into account the detector characteristics.

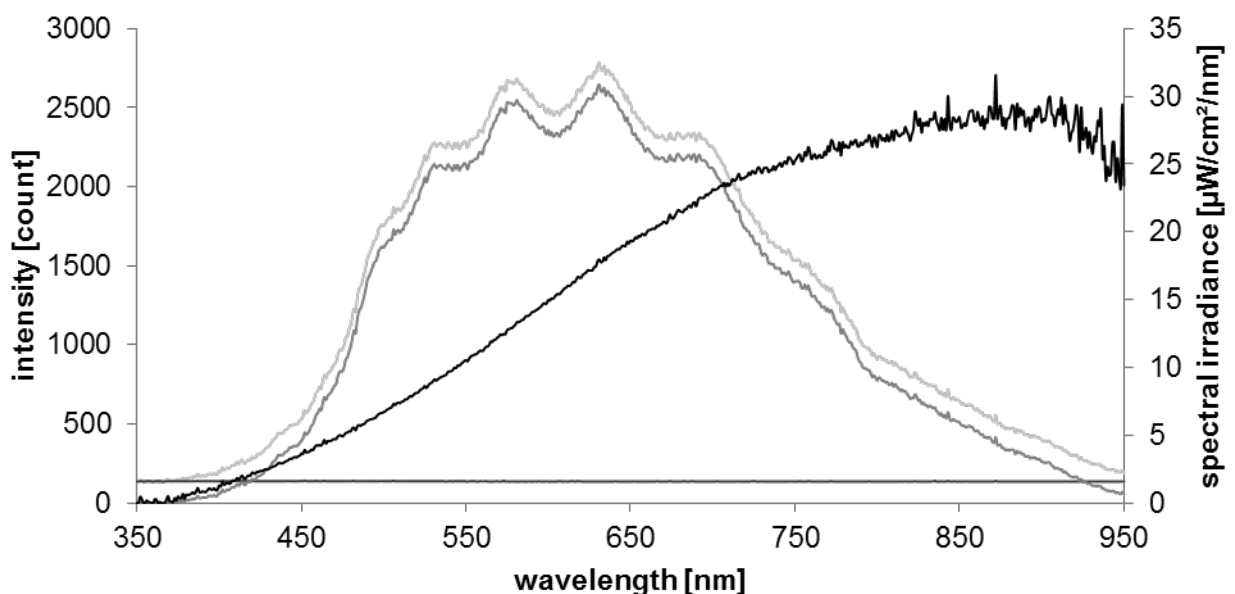


Figure 4: From apparent spectrum to true spectral irradiance. Recorded intensity spectrum (light gray), dark-noise spectrum (dark gray), intensity spectrum (mid gray), and spectral irradiance (black).

3. Technical aspects

On the RCL spectrometer server, the acquisition of spectra is done by a windows service. The same program than computes the spectral irradiance. The acquired and the computed data will than be send to a client and there be displayed. A special challenge was to make mobile devices like smartphones and tablets able to display the spectra and to control the experiment. Therefore, the client program is build for HTML5 web browsers, nowadays available on any device.

In German schools, network restrictions are very high and we have to consider firewalls. Therefore, we use a commercial WebSocket service (pusher.com) to deliver spectral data and control data. Before a user may control the experiment authentication is necessary. This is done by a PHP script running on a usual web server that also provides the website for the experiment. An IP cam watches the experimental set-up and sends the captured video stream directly to the client where the video stream is displayed in the browser. The advantage of using the WebSocket service is that no static IP is needed for the RCL server. Only the IP cam needs direct Internet access.

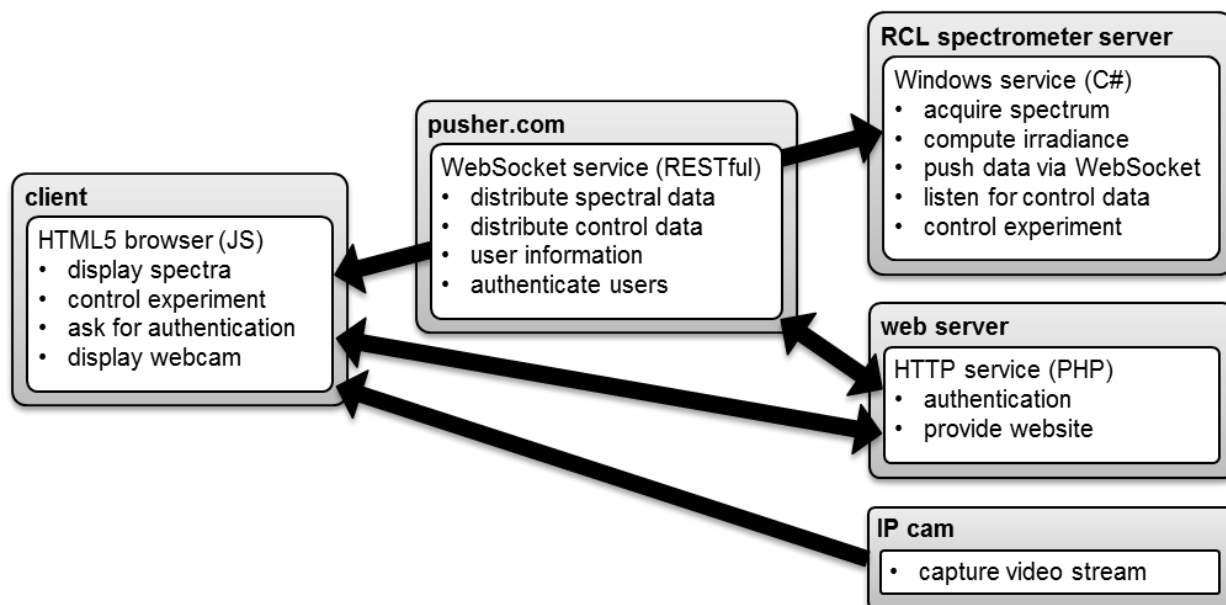


Figure 5: Schematic software set-up of the spectrometer remote lab implementation.

Several parameters of the experimental set-up may be changed by the user. For example, the acquisition parameters for the spectrometer may be set, like the integration time, the boxcar width (averaging over neighboring pixels), or the samples to average (averaging over two or more sequentially recorded spectra). Furthermore, users can choose from six standard light bulbs mounted on a carousel like tungsten incandescent light bulbs, halogen incandescent lamps, cold white and warm white compact fluorescent lamps, light-emitting diode lamps or special bulbs. The cosine-corrected probe may be moved and positioned in front of the bulb in a field of 1 x 1.5 square meters. The probe may be rotated too.

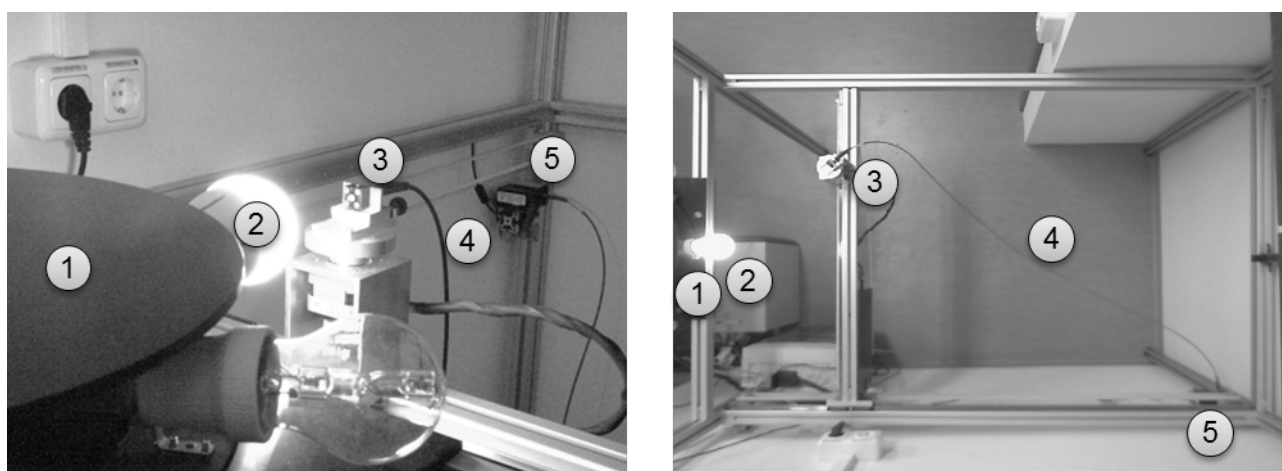


Figure 6: Experimental set-up of the spectrometer remote lab implementation (a) in detail and (b) from above: (1) carousel, (2) light source, (3) cosine-corrected probe, (4) optical fiber, (5) spectrometer.

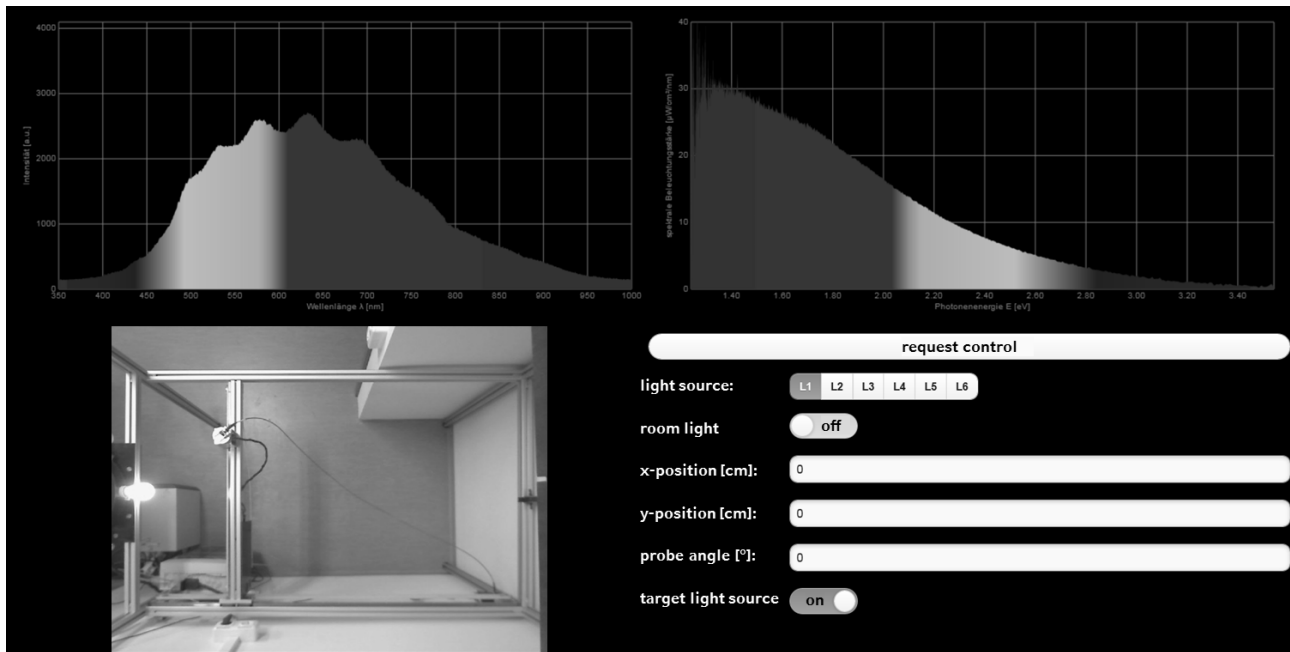


Figure 7: User interface.

4. Educational aspects

Many different objectives may be followed by students. They may compare spectra from different lamps and thus rate the usability of the light sources for a certain purpose. Students may assess color temperature and color fault. They may compare the radiated light with the color sensitivity of the human eye. Students may distinguish between physical and physiological quantities. They can analyze the energy efficiency of usual lamps.

The free positioning of the probe allows further experiments like analyzing the decrease of spectral irradiance with the squared radius or the spatial spectral radiant emittance. With compact fluorescent lamps, differences can be noticed between the light coming from the gas discharge and light coming from the fluorescent layer.

5. Conclusion

The presented remote-lab experiment on optical spectrometry is highly educative and instructive for an introduction to atomic physics.

Acknowledgements

The authors want to thank *Nanotec Electronic GmbH & Co KG*, Feldkirchen, Germany for supporting us with experimental hardware like stepper motors, stepper motor drivers, and power supplies. We also want to thank *Acal BFi Germany GmbH*, Gröbenzell, Germany for loaning us a radiometric calibration standard. At least, we want to thank *Pusher Ltd.*, London, United Kingdom for offering us the unlimited use of their WebSocket service free of charge.

References

National Research Council. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

INTERACTIVE SIMULATIONS FOR THE LEARNING AND TEACHING OF QUANTUM MECHANICS CONCEPTS

Antje Kohnle, *School of Physics and Astronomy, University of St Andrews, United Kingdom*

Abstract

Since 2009, we have been developing and evaluating interactive simulations with accompanying activities for the learning and teaching of quantum mechanics concepts at university level. The QuVis simulations build on education research and our lecturing experience, and aim to specifically target student areas of difficulty in quantum mechanics. Simulations are available on a wide range of topics from introductory to advanced level quantum mechanics.

This article gives an overview of the three collections of QuVis simulations developed so far. These include simulations for physics students, simulations for physical chemistry students studying introductory quantum mechanics and simulations to support a new introductory quantum mechanics curriculum based on two-level systems. Evaluation with students plays a decisive role in optimizing the educational effectiveness of the simulations and activities. We describe methods used to refine and further develop the resources. We give examples of revisions based on outcomes of individual student observation sessions.

1. Introduction

Interactive simulations can help students to engage with and explore physics topics through high levels of interactivity, prompt feedback and multiple representations of physics concepts (Podolefsky 2010). They can give students visual representations of abstract concepts and microscopic processes that cannot be directly observed. Well-designed interactive simulations promote engaged exploration, where students actively explore and make sense of the phenomena shown led by their own questioning. Careful design of simulations in terms of affordances (actions that are available) and constraints (features that restrict actions) can make simulations effective through implicit scaffolding of students' exploration. Due to its often abstract ideas far removed from everyday experience and counterintuitive results, interactive simulations can be particularly useful to help students learn quantum mechanics. Research-based simulations for the learning and teaching of quantum mechanics have been developed and shown to enhance student understanding (see e.g. Goldberg 1967, Schroeder 1993, Steinberg 1996, Zollman 2002, Belloni 2006, Singh 2008, McKagan 2008, Zhu 2012).

The Quantum Mechanics Visualization Project QuVis (www.st-andrews.ac.uk/physics/quvis) consists of research-based interactive simulations and accompanying activities for the learning and teaching of quantum mechanics concepts at university level (Kohnle 2012). Simulations make use of previous work on developing educationally effective simulations and research on student difficulties with quantum mechanics, and are informed by our lecturing experience. They aim to specifically target student misconceptions and areas of difficulty in quantum mechanics. Many simulations cover topics not found elsewhere. As described in section 2, one collection of QuVis simulations aims to make topics typically covered at the advanced level accessible to a first course in quantum physics. These simulations are embedded in a full online course including texts and problems.

Each simulation includes two views, the "Controls" view with the interactive elements and the "Step-by-step Explanation" view that explains key points with animated highlighting and includes step controls. Through the text explanations, simulations aim to be self-contained instructional tools. Simulations have been coded in Adobe Flash, with Mathematica used for graphics where needed. The majority of simulations include an accompanying activity. Depending on simulation context, activities aim to help students build mental models of quantum mechanics concepts, use the simulations to collect and interpret data, and to make

connections between multiple representations. They promote guided exploration and sense-making and provide scaffolding to progress from simpler to more complex situations. Simulations and activities are freely available from the QuVis website and can be played or downloaded from this site. Full solutions to activities are available to instructors.

In what follows, we give an overview of the simulations and describe features that make them effective for learning (section 2). Section 3 describes the methods used for refinement of simulations and activities and gives examples of outcomes based on individual student observation sessions. Section 4 outlines future plans.

2. Overview of the simulations

The QuVis website includes three collections of resources: simulations for physics students, simulations for physical chemistry students studying introductory quantum mechanics and simulations to support a new introductory quantum mechanics curriculum based on two-level systems.

2.1. Simulations for physics students

This collection of simulations covers a wide range of topics, with currently 50 simulations available. The majority of simulations are aimed at the intermediate level, covering topics such as wave packets, energy eigenstates and superposition states in one-dimensional potentials, measurement and wave function collapse, one-dimensional scattering, expansion in eigenstates, time-independent perturbation theory and spin and angular momentum. A smaller number of simulations are aimed at the introductory level (such as the probabilistic analysis of classical systems) and the more advanced level (such as the density matrix, spin clusters and spin chains).

2.2. Simulations for physical chemistry students

Chemistry students may have less mathematical background than physics students, so visualization may play an even more important role in helping these students learn quantum mechanics concepts. In order to extend the resources to be more useful to chemistry students studying introductory physical chemistry, we modified existing simulations by removing or adding functionality and tailoring explanations, developed new simulations and developed accompanying problems sets aimed at chemistry students. Topics of the simulations link to Atkins' "Physical Chemistry" textbook, with most simulations developed so far focussing on basic quantum theory. Simulation topics include one-dimensional potentials, the Heisenberg Uncertainty Principle, multi-particle wave functions, the hydrogen atom, many-electron atoms, angular momentum and valence-bond theory. There are currently 18 simulations available in this collection.

2.3. Simulations for a new introductory quantum mechanics curriculum

Recent developments include a collection of 17 simulations with accompanying activities as part of the Institute of Physics (IOP) Quantum Physics resources available at quantumphysics.iop.org and on the QuVis website (Kohnle 2014). The IOP resources consist of learning and teaching materials (texts, simulations and activities) for a novel approach to a first course in university quantum mechanics starting from two-level systems. This approach immediately immerses students in inherently quantum mechanical aspects by focusing on experiments that have no classical explanation. It allows from the start a discussion of interpretative aspects of quantum mechanics and quantum information theory. The resources are freely available (but

require registration) with multiple paths through the material. Texts have been written by researchers in quantum information theory and foundations of quantum mechanics. The simulations cover the topics of linear algebra, fundamental quantum mechanics concepts, single photon interference, the Bloch sphere representation, entanglement, local hidden variables and quantum information.

Fig. 1 shows a screenshot of the *Superposition states and mixed states* simulation from this collection. This simulation allows students to use a Stern-Gerlach apparatus that can be oriented along two orthogonal axes to investigate whether they can experimentally distinguish mixed states and superposition states. Students can choose different input spin states, which include a superposition state, a corresponding mixed state and two unknown input states (see the “Input particles” panel in Fig. 1). The simulation shows the individual input spin states and spin measurement outcomes, and the experimentally determined and theoretical outcome probabilities mathematically and graphically.

Simulations aim to help students make connections between multiple representations by using physical, mathematical and graphical representations, with consistent representations across different simulations. In the *Superposition states and mixed states* simulation, flashes are used to help students make connections between the measurement outcome on the screen and the outcomes shown in the “Number of measurements” panel. Colour is used to help students differentiate between the two measurement outcomes. Colour is also used to link the number of measurement outcomes to their respective observed and theoretical detection probabilities as shown mathematically and graphically (the three right-hand panels in Fig. 1).

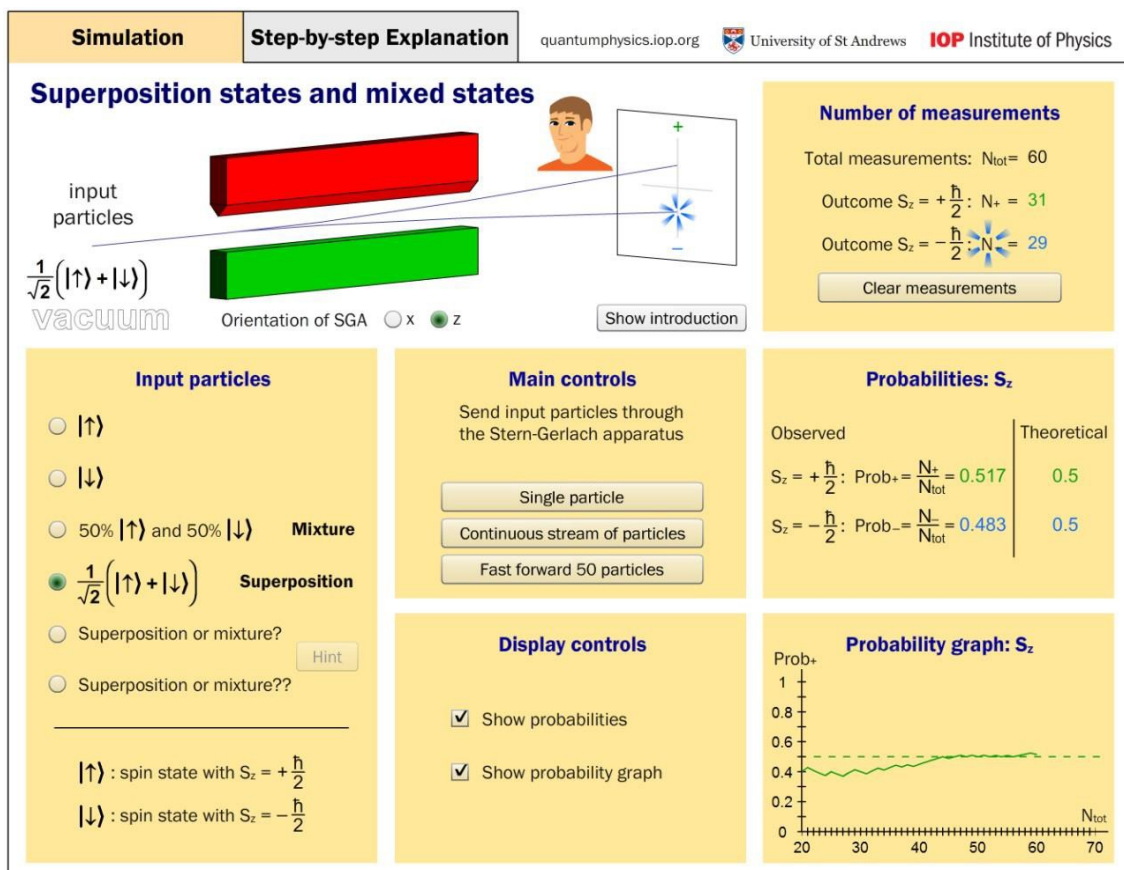


Figure 1: A screenshot of the “Superposition states and mixed states” simulation. This simulation allows students to investigate whether they can experimentally distinguish mixed states from superposition states.

Several simulations aim to help students develop quantum models and transition students away from classical perspectives by using comparisons between classical and quantum systems. The activity to the *Superposition states and mixed states* simulation asks students whether they encounter similar mixtures of objects in their everyday experience, and helps students make sense of the difference between quantum superposition and classical mixtures.

Simulations provide an intuitive interface that uses interactive controls such as sliders, buttons and tick boxes that are familiar to students. Controls and depictions of experimental apparatus have a similar look-and-feel across all simulations. Layout makes use of the fact that controls are typically explored top to bottom and left to right. The initial configuration is kept simple and includes an introductory text to encourage exploration and avoid overwhelming students. To reduce complexity and focus on fundamental ideas, simulations depict idealized and simplified situations. Some of the simulations aim to help students develop mental models by making the invisible visible, such as depicting single photons. As shown in Fig. 1, some of the simulations allow students to collect data to see how quantum-mechanical quantities are determined experimentally. These simulations can help students understand inherent statistical fluctuations by showing how the experimental quantities approach the theoretically predicted values in the limit of a large number of measurements. For the simulations where students collect data, a “Clear measurements” button allows students to reset the simulation.

3. Evaluation and refinement

Feedback from students at the appropriate level is vital to ensure simulations and activities are effective for learning. We have used the following evaluation methods to iteratively refine the simulations:

- End-of-course student surveys on attitudes towards and use of the simulations
- Surveys focusing on individual simulations asking about clarity, ease-of-use and aspects found confusing, completed by students directly after working with a simulation
- A conceptual diagnostic survey to assess learning gains of topics for which students had used simulations
- In-class observations of students working with simulations
- Individual observation sessions with student volunteers using screencapture and audiorecording
- Assessing learning gains using pre- and post-tests
- A small number of comparative studies

In what follows, we give three examples of revisions based on outcomes of individual student observation sessions (42 hours in total with 19 student volunteers) of the IOP Quantum Physics simulations (see also Kohnle 2013). In these sessions, students first interacted freely with a simulation and then worked on the activity for that simulation. Students were asked to “think aloud”, e.g. to describe what they were seeing and making sense of and what they were finding confusing. Data were analyzed for common difficulties with content, interface and activity. This led to revisions of simulations and activities, included in all resources wherever appropriate.

For the *Superposition states and mixed states* simulation (Fig. 1), we found that students initially had difficulty understanding the mixed state. We revised the simulation so that the state of each input particle is shown in the graphics window. Thus, for the mixed state, the simulation now shows a random sequence of spin-up and spin-down input states. This allows students to make connections between the input state and the measurement outcome seen as a flash on the screen. For the superposition state, the simulation now shows a sequence of identical input states. We found that this revision helped students make sense of the difference between mixed states and superposition states.

Previous studies on developing educationally effective simulations show that including small puzzles or challenges in simulations can encourage prolonged engagement and inquiry (Adams 2008, Podolefsky 2010). To be productive, challenges need to be aligned with the learning goals of the simulation. We have incorporated small challenges into several simulations, e.g. the two unknown input states shown in Fig. 1. In the observation sessions,

students often tell us that they particularly enjoy these challenges. Our studies show the importance of scaffolding the challenges in terms of students having other examples in the simulation for comparison, and in some cases providing a Hint button that brings up additional help but does not contain the solution. Activities also scaffold the challenges; the activity to the *Superposition states and mixed states* simulation first asks students to focus on the known input states and only later asks them to apply what they have learned to tackle the challenges.

The personalization principle is an important aspect of designing effective e-learning resources. This includes personalized language and on-screen characters (Clark 2011). Initially, the introductory text and text explanations were impersonal and did not include learning goals. One student commented in an observation session “I think the introduction [introductory text] made sense by itself. But I don’t really think it relates to what you are doing very well. In the introduction it talks about what observer A could see...” Thus, we revised the text of all simulations to be more personal to students using formulations such as “You can send particles through the experiment...”. Many simulations now explicitly state the learning goal in the introductory text. For the *Superposition states and mixed states* simulation, the introductory text states “Your goal is to determine whether or not you can experimentally distinguish mixed states from superposition states.” We also added images of observers into the simulations where applicable, as shown in Fig. 1.

4. Conclusions and future steps

We have given an overview of the QuVis simulations and described features that make them effective for learning. We have stressed the key importance of student feedback in ensuring resources are effective for learning, and described methods used to iteratively refine simulations and activities.

We are currently developing HTML5 versions of the simulations suitable for touchscreens, and are carrying out observation sessions to optimize interface design for devices with smaller screens. We are conducting further evaluation studies using simulations in courses with students at multiple institutions, and assessing learning gains through a combination of pre- and post-testing, survey questions and some comparative studies. We will optimize and further develop simulations and activities based on this evaluation.

We plan further work on how best to visualize photon superposition and entangled photon pairs, with the aim of devising visualizations that help students develop productive mental models. We plan further development of more open activities that encourage exploration and discussion, and activities that are inherently collaborative in nature. We plan the development of simulations that incorporate game-like features to enhance motivation. We also plan simulations on further topics, with a particular focus on quantum information theory.

Acknowledgements

We thank all colleagues at St Andrews and other institutions that have been involved in evaluation studies. We gratefully acknowledge all of the students who participated in studies to optimize the simulations and activities. We thank the undergraduate students at St Andrews who have coded the simulations, and the students that have been involved in evaluation work as part of their final year project dissertations. We thank the UK Institute of Physics, the UK Higher Education Academy and the University of St Andrews for funding the QuVis project.

References

- Podolsky N S, Perkins K K and Adams W K (2010) Factors promoting engaged exploration with computer simulations, *Phys. Rev. ST Phys. Educ. Res.* 6 (2), 020117-1 to 11
- Goldberg A, Schey H M, and Schwartz J L (1967) Computer-Generated Motion Pictures of One-Dimensional Quantum-Mechanical Transmission and Reflection Phenomena, *Am. J. Phys.* 35 (3), 177-186
- Schroeder D and Moore T (1993) A computer-simulated Stern-Gerlach laboratory, *Am. J. Phys.* 61 (9), 798-805
- Steinberg R N, Oberem G E, and McDermott L C (1996) Development of a computer-based tutorial on

- the photoelectric effect, *Am. J. Phys.* 64 (11), 1370-1379
- Zollman D, Rebello S and Hogg K (2002) Quantum physics for everyone: Hands-on activities integrated with technology, *Am. J. Phys.* 70 (3), 252-259
- Belloni M, Christian W and Cox A J (2006) *Physlet Quantum Physics: An Interactive Introduction*, Pearson
Prentice Hall, Upper Saddle River, NJ
- Singh C (2008) Interactive learning tutorials on quantum mechanics, *Am. J. Phys.* 76 (4), 400-405
- McKagan S B, Perkins K K, Dubson M, Malley C, Reid S, LeMaster R and Wieman C E (2008) Developing and Researching PhET simulations for Teaching Quantum Mechanics, *Am. J. Phys.* 76 (4&5), 406-417
- Zhu G and Singh C (2012) Improving students' understanding of quantum measurement. II. Development of research-based learning tools, *Phys. Rev. ST Phys. Educ. Res.* 8 (1), 010118-1 to 13
- Kohnle A, Cassettari D, Edwards T J, Ferguson C, Gillies A D, Hooley C A, Korolkova N, Llama J and Sinclair B D (2012), A new multimedia resource for teaching quantum mechanics concepts, *Am. J. Phys.* 80 (2), 148-153
- Kohnle A, Bozhinova I, Browne D, Everitt M, Fomins A, Kok P, Kulaitis G, Prokopas M, Raine D and Swinbank E (2014), A new introductory quantum mechanics curriculum, *Eur. J. Phys.* 35 (1), 015001-1 to 9
- Kohnle A, Baily C, Hooley C, and Torrance B (2013), Optimization of Simulations and Activities for a New Introductory Quantum Mechanics Curriculum, in 2013 PERC Proceedings, Engelhardt P V, Churukian A D and Jones D L ed., Portland, 209-212
- Adams W K, Reid S, LeMaster R, McKagan S B, Perkins K K, Dubson M and Wieman C E (2008) A Study of Educational Simulations Part II - Interface Design, *Journal of Interactive Learning Research* 19 (4), 551- 577
- Clark R C and Mayer R E (2011) *E-Learning and the science of instruction*, John Wiley, San Francisco

NEW PHYSICS REMOTE LABORATORIES FOR UNEDLABS

Manuel Yuste, Carmen Carreras, Juan Pedro Sánchez, Jaime Arturo de la Torre, Alberto de la Torre, Luis de la Torre, Rubén Heradio, Ignacio Zúñiga and Sebastián Dormido, UNED

Abstract

UNEDLabs is network of virtual and remote laboratories for Physics and Control Engineering disciplines. Since the Control Engineering part has been operative for quite a long time now, UNEDLabs offer many VRLs related to this subject. However, the Physics part is still recent and therefore, not so many VRLs are available at UNEDLabs.

This work presents three new experiments that are going to be added to UNEDLabs in the near future as VRLs: the photoelectric effect, the diffraction of light and the vibrating strings.

1. Introduction

UNEDLabs (de la Torre *et al.* 2012; Dormido *et al.* 2012) is the combination of the AutomatL@bs (Vargas *et al.* 2011) and the FiL@bs (de la Torre *et al.* 2011) projects. The first one was a network of virtual and remote laboratories (VRLs) in Automatic Control. The second one was its counterpart for Physics. However, UNEDLabs is not just a mere sum of these two different projects but an evolution of both for the old Content Management System (called eMersion) was replaced by an up to date Learning Management System (Moodle) that facilitates and enhances the deployment, management, access and use of the VRLs.

This network of VRLs keeps growing every year and this work presents three new VRLs being developed to be included into UNEDLabs as soon as they are completely ready and finished.

2. The photoelectric effect

The purpose of this experiment, in the first place, is to experimentally check the photoelectric effect and, in second place, to determine Planck's constant's value.

The photoelectric effect is the emission of electrons from a metal surface by the action of light. The radiation must be sufficiently energetic because electrons should use one part of the absorbed photon energy to leave the metal; the rest of the absorbed energy is employed as kinetic energy. The electrons with the weakest links and not suffering internal losses emerge from the metal with the maximum kinetic energy, therefore:

$$K_{\max} = hv - W_0 \quad (1)$$

where ν is the radiation frequency, h is the Planck constant, $h\nu$ is the energy associated with each photon and W_0 is the extraction work, characteristic of each metal.

In order to make this experiment remotely accessible a specific assembly was designed taking a commercial device from Leybold Didactic as a starting point (see Fig. 1a). This commercial device has an optical bench with a mercury lamp, a convergent lens, a disc with a collection of interferential filters with different wavelengths and a photoelectric cell. A power supply for the mercury lamp, the amplifier circuit that allows measuring the voltage generated by the photoelectric cell (and stored within a capacitor), a second power supply for the amplifier circuit and a voltmeter complement the whole device.

The modifications done to the previous experimental setup for allowing the remote manipulation of this experiment are (see Fig. 1b): 1) substituting the original disc with the collection of filters with a motorized disc using a stepper motor, 2) connecting a small USB module for acquiring data in a digital way (although the original analogic voltmeter is preserved and used to give a visual measure through a webcam), 3) installing a webcam that offers a view of the whole assembly, and 4) programming the control and monitoring of the instruments as well as the user interface of the remote lab application. An Arduino board is used for controlling the stepper motor in point 1 and for reading the voltages in point 2. Fig. 2a shows the final experimental setup for this remote laboratory.

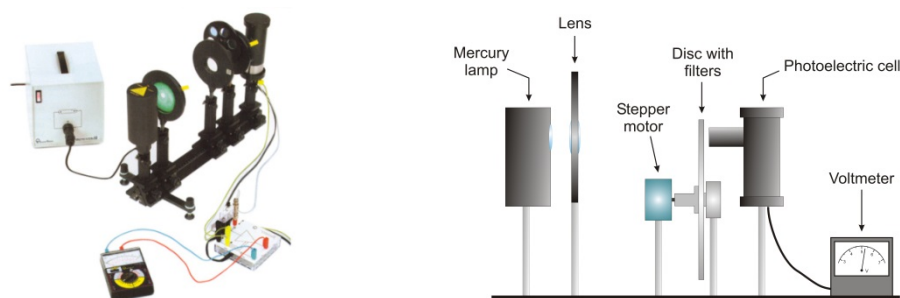


Figure 1: (a) Commercial solution from Leybold Didactic for the photoelectric effect experiment; (b) scheme of the experimental assembly.

The electrical diagram of the assembly is shown in Fig. 2b. With this arrangement, the monochromatic light emerging from the interference filter F passes through a platinum ring A (anode) and is incident on a surface of potassium K (cathode). Photons liberate electrons from the cathode, which will gradually charge positively, what involves the simultaneous charging of the capacitor C. The potential difference V between the capacitor plates is also established between A and K. Then the photoelectrons experience a force in the direction opposite to their displacement (towards the anode) and the potential difference between the plates of the capacitor reaches a stationary value V_0 . The stopping potential satisfies the following relationship:

$$eV_0 = h\nu - W_0 \quad (2)$$

From this expression, students experimentally determine the Planck's constant h by measuring the potential V_0 corresponding to each of the selected frequencies.

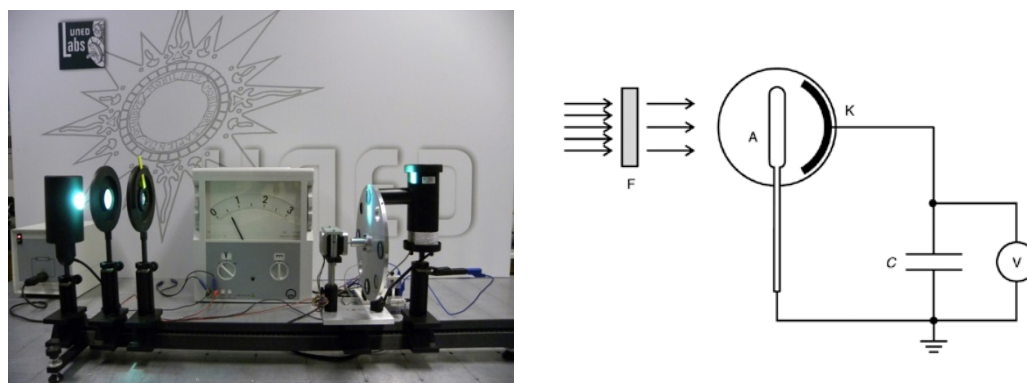


Figure 2: (a) Experimental setup for the remote lab; (b) electrical diagram of the assembly.

3. Study of diffraction of light

The objective of this lab is to study the diffraction of light in Fraunhofer approximation. For that purpose, we built an experimental assembly specially designed for its remote use. This assembly allows studying the diffraction patterns produced by different diffracting objects in two levels of precision.

The experimental setup consists of a He-Ne laser, a collection of diffracting objects whose sizes are between 5 and 100 μm , a translucent screen with a webcam pointing to it from behind and a photodiode connected to a digital multimeter (see scheme in Fig. 3).

When working with this lab, students first observe the figures projected over the translucent screen thanks to the webcam. From the visual analysis of these figures, they can check the validity of the theory of the diffraction of light and, by determining the position of the minimum of intensities, estimate the size of the diffracting objects that create those figures. In a second phase, students obtain the intensity profile of one of the diffraction figures by means of the measurement of intensities using the photodiode. This allows characterizing the figure observed, confirm the validity of the theory and calculate the size of the object with quite good precision. Fig. 4 shows the

assembly of this remote lab.

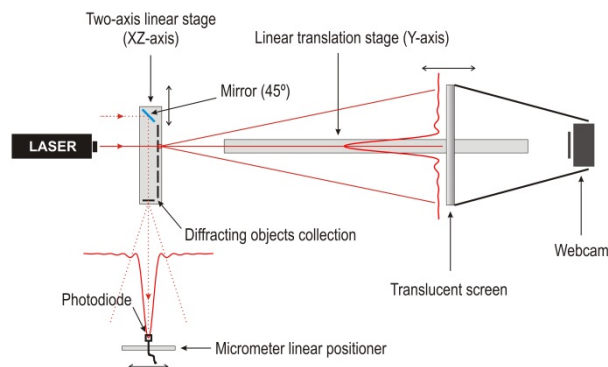


Figure 3: Scheme of the experimental assembly to study of diffraction of light.

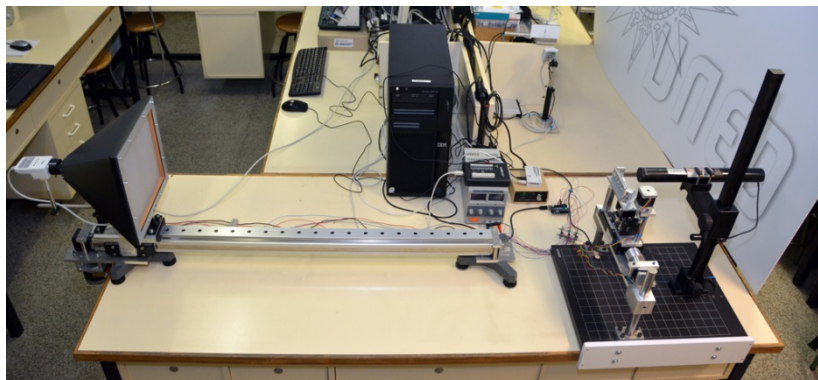


Figure 4: Experimental setup for the remote lab to study of diffraction of light.

To make this experiment remotely accessible, the collection of diffracting objects is mounted over a two motorized linear positioners: one, horizontal, of 10 cm and a second, vertical, of 25 mm so the objects can be moved in two directions (X and Z). The translucent screen with the webcam is attached to another motorized linear positioner of 1.5 m. This allows changing the observation distance (Y axis) depending on the diffracting object selected. There is also a mirror mounted over the motorized linear positioner with the different diffracting objects. This mirror is oriented 45° in relation with the direction of the laser (Y axis). This way, getting the mirror in the trajectory of the laser, it can be deflected in a perpendicular direction (X axis) in order to obtain the diffraction pattern of a different object. This new pattern is projected on a screen with a photodiode, also mounted over a motorized linear positioner with micrometric precision.

4. Vibrating string with fixed ends

The main purpose of this experiment is to obtain relationships between the frequency of a stationary wave and the physical parameters associated to the string that produces that stationary wave, namely the length, its density and tension it is fixed at. This experiment has been massively proposed in the literature, both for the damped string (Ferri and Ferri 2014) and the forced string which exhibits more complex phenomena (Molteni and Tuffaro 2004). Here we restrict the study to the simplest case of the non-damped non-forced string. Future works will include these non linearities in order to study more complex cases.

From a physical point of view, we consider a small displacement of length dx on a string of a total length L , cross section s and mass M that oscillates in the plane XY under a constant tension T (see Fig. 5).

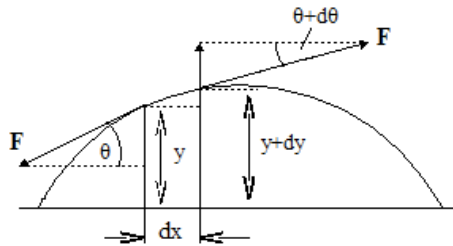


Figure 5: Tensions applied in the string after a small displacement dx .

Total tensions in the string will be given by

$$F_x = T \cos(\theta+d\theta) - T \cos(\theta) \quad (3)$$

$$F_y = T \sin(\theta+d\theta) - T \sin(\theta) \quad (4)$$

Under the regime of small perturbations we obtain, expanding in Taylor up to the first order, the famous wave equation

$$\partial_{xx}y(x,t) = 1/v^2 \partial_{tt}y(x,t) \quad (5)$$

with v the propagation velocity of the wave. The solution of the wave equation is, for a given string with fixed ends

$$y_n(x,t) = A_n \sin(n\pi x/L) \cos(\omega_n t) \quad (6)$$

with the following relation between the fundamental frequency ($n=1$) and the physical parameters of the string

$$f = 1/2L (T/s\rho)^{1/2} \quad (7)$$

where ρ is the volumetric density which, of course, depends on the material.

The aim of this work is to verify, for a given control parameter, the relationship between that parameter and the frequency.

The construction of the string experiment is depicted in Fig. 6. We use six different strings made from iron, copper and kanthal. For each material we select two diameters $\phi = 1$ mm and $\phi = 3$ mm, respectively. The strings are fixed at one end and attached to a dynamometer and to a straining screw at the other end so that we may select a particular tension value. Above each string we have a small lamp and, below the string, a photocell which captures the shadow of the string over a diaphragm. The photocell is attached to a stepper motor that will control its position, allowing the user to choose between each string. A LEGO MINDSTORM robot moves a cross bar fixing the length of the string, L .

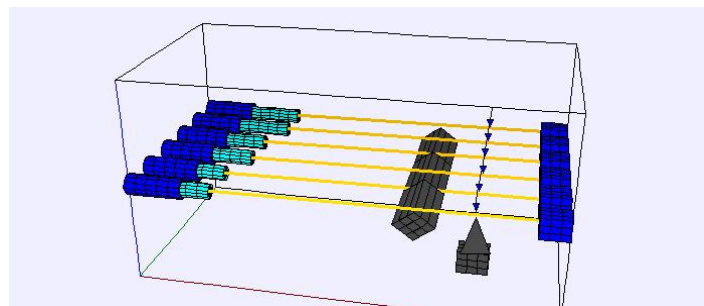


Figure 6: 3D model of the string experiment done with EasyJavaSimulations.

The photocell is connected to a digital oscilloscope that transmits the voltage signal to a PC. An API developed by the manufacturer allows us to obtain the voltage as a function of time in a plain-text file, which can be understood by the front-end. The stepper motor is controlled through an EasyDriver board to an Arduino board, and finally connected to a PC. The LEGO MINDSTORM

robot is connected directly to the PC via the USB interface provided by the brick. The three electronic devices are recognized in a LabView/Simulink interface, all of them with a front-end made in Easy-Java Simulations (EJS), application deployed into an online Moodle course.

To sum up, the user is able to manipulate the material (and, hence, the density ρ), the diameter of the string (cross section, s) and the length of the string (L). Fixing two of them, one can obtain pairs of data with the value of the remaining free parameter and the frequency of the fundamental mode of the string. On a next step, the user may fit the pairs of data into a specific linear, quadratic or inverse function (depending on the free parameter chosen). Finally, through the minimization of the error in the fitting curve, one can compare the fitting parameters with the physical parameters, and hence estimate the goodness of the model.

On a future stage, using a high frequency oscilloscope, we can also study the damped string that shows a decay of the fundamental mode due to frictional forces. This can be seen through the evolution of the signal provided by the photocell, trying to obtain a good adjustment between the amplitude of each temporal wave and its exponential decay.

In conclusion, this experiment allows the user to experiment between a wide range of parameters which have different dependencies with the frequency, ensuring a good comprehension of the physical reality of the wave equation. This kind of experiments, with relationships between linear, quadratic or inverse quantities, seems very useful in order to familiarize the user with the concept of regression analysis, and can be easily ported from undergraduate students of first courses to students of higher level, giving a long term utilization of the experiment. Moreover, the virtualization of the experiment is, undoubtedly, a great help for distance education students, where the access to a laboratory may be, sometimes, difficult. In that sense, it is important to continue investing in remote laboratories, regardless of the complexity of the experience so that, at the end of the day, students can learn above physical processes easily.

5. Conclusions

Three new VRL son Physics are being prepared for UNEDLabs: the photoelectric effect, the diffraction of light and the vibrating strings. All of them will be deployed into the online courses along with the necessary documentation to allow students to work in an autonomous way: a practice guide, a manual explaining the applications' user interfaces, etc.

References

- de la Torre L, Sánchez JP, Heradio R, Carreras C, Yuste M, Sánchez J, Dormido S (2012) UNEDLABS - An Example of EJS Labs Integration into Moodle, Proceedings of the World Conference on Physics Education, 537-546.
- Dormido S, Sánchez J, de la Torre L, Heradio R, Carreras C, Sánchez JP & Yuste M (2012) Physics Experiments at the UNEDLabs Portal. A network of remote and virtual laboratories for physics education, International Journal of Online Engineering (iJOE), 8, <http://dx.doi.org/10.3991/ijoe.v8iS1.1945>, accessed 2014 september.
- Vargas H, Sánchez J, Jara CA, Candelas FA, Torres F, Dormido S (2009) A Network of Automatic Control Web-Based Laboratories, IEEE Transactions on Learning Technologies, **3**, 197-208.
- de la Torre L, Sánchez J, Dormido S, Sánchez J P, Yuste M, Carreras C (2011) Two web-based laboratories of the FisL@bs network: Hooke's and Snell's laws, European Journal of Physics, **32**, 571-584, <http://iopscience.iop.org/0143-0807/32/2/027>, accessed 2014 september.
- Dearing R (1997) Higher education in the learning society, Report of the Committee of Inquiry into Higher Education, <http://www.ncl.ac.uk/ncihe/index.htm>, accessed 2009 july.
- McDermott LC (2004) Physics Education Research: The key to student learning and teacher preparation, in Quality Development in Teacher Education and Training, Selected Contribution of Second International Girep seminar, Michelini M ed., Forum, Udine, 30-34.
- Compadre, <http://www.compadre.org>, accessed 2009 july.
- Ferri Aldo A and Ferri Bonnie H (2014) Simple Guitar String System for Teaching Fundamental Concepts in a Variety of ECE and ME Courses, Proceedings of the American Control Conference, 2536-2542.
- Molteno TC and Tuffillaro NB (2004) An experimental investigation into the dynamics of a string, American Journal of Physics, **72**, 1157-1169.

REVISITING HISTORICAL EXPERIMENTS WITH NEW TECHNOLOGIES: TRACKING HUYGENS' FOOTSTEPS.

Pasquale Onorato, Massimiliano Malgieri, Anna De Ambrosis, *Department of Physics University of Pavia, Via Bassi 6, I-27100 Pavia, Italy*

Abstract

Research has shown that reproducing experiments with historical significance conveys additional value to educational laboratory practice, raising physical problems which are engaging and emotionally involving for students. In our work, students were presented with experiments related to the most important achievements of Christiaan Huygens in mechanics: the solution of the tautochrone problem and the proof of the formula for the center of oscillation of a physical pendulum. Measurements were carried out by means of a camera and video data analysis software, which allowed students a direct exploration of even complex, subtle and non trivial physical phenomena.

1. Introduction

Many researches have shown that apparatuses and demonstrations derived from historical experiments provide grounding for experimental and theoretical problems suitable for physics students and improve understanding of physics concepts. (Höttecke, 2000) In this paper we present two experiments on the pendulum based on the researches of Christiaan Huygens (Huygens, 1661).

Huygens' studies on pendulum, finalized to the construction of small and precise clocks, are an exemplar case and a crossing point for theory and practice in mathematical science in the XVII century (Mahoney, 1980).

After Galileo's work, two were the main objectives of Huygens' early researches on the pendulum: a rigorous treatment of isochronism and the analysis of a non ideal compound pendulum. In fact although Galileo had asserted the independence of the period of a pendulum from the amplitude of its swing, others (Mersenne in 1644; (Koyre 1953)) had determined that a simple pendulum is isochronous only for small oscillations. Moreover Galileo's pendulum was essentially an ideal point mass attached to an inextensible massless wire, while pendulums, to be used for example as clocks, should be treated as real objects whose weight is not concentrated in a single point.

Thus Huygens directed his researches towards:

- the solution to the tautochrone problem and the cycloidal pendulum
- the proof of the formula for the center of oscillation of a physical pendulum

In section 2 we analyze theoretically and experimentally the motion of a pendulum whose mass is constrained to move on a cycloid path and the motion of a small sphere running on a frictionless cycloid track. In section 3 we present the reconstruction and the analysis of a gedanken experiment designed by Huygens with the aim of calculating the "radius of gyration" (centrum oscillationis) for a compound pendulum. Through the use of Tracker, an open source video analysis and modelling tool, we obtain quantitative experimental results and perform a detailed quantitative comparison between the measurements and the theoretical prediction is obtained. In section 4 we report the discussion of a group of students teachers who tested the experiments.

The experiments address many relevant topics in the physics curriculum, and appear appropriate to be used in high school and in undergraduate physics courses

2. Studying motion along cycloidal paths

2.1. Experimental setup

a. *The Cycloidal pendulum.* In Figure 1 the structure of the cycloidal pendulum is shown. Two halves of a cycloid are positioned so as to produce a cusp. They are made of a thick plexiglass plate and generated by a circle of radius $a=9.5\pm 0.5$ cm. A bob ($m=0,25$ kg) is suspended from a plastic tape. The total length of the pendulum from the point of suspension to the center of mass of the bob can be varied. The amplitude $x(t)$ of each oscillation is obtained by measuring the

projection along the horizontal axis.

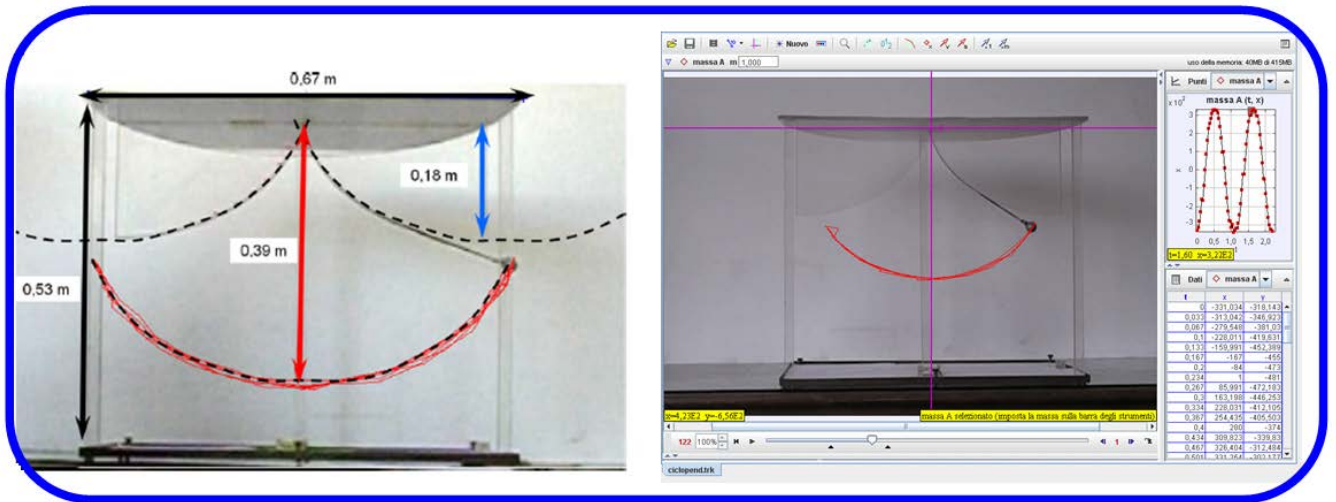


Figure 1 A cycloid was drawn on a plexiglass sheet and cut into two halves at its centre. A cuspid was obtained from the two halves and a pendulum, with variable length, was suspended at the apex of the cusp. The experimental trajectory of the pendulum obtained using the Tracker video analysis software is translated to overlap the two halves of the cycloid.

The bob starts from a position in which the plastic tape covers the cycloidal perimeter of one side of the cusp. The trajectory of the pendulum becomes a cycloid if the length is $L = 4a$ while if the length is smaller or larger a more complex trajectory is followed by the suspended mass.

b. *The Cycloidal track and the inclined plane.* A small sphere of steel (mass=0.033 kg; diameter 1.6 cm) run over the cycloid or the inclined plane tracks starting from different positions. The tracks were made of cardboard sheets. The cycloid in Figure 2.A was generated by a circle of radius $a=10.0\pm 0.5$ cm while the plane has an inclination angle of 20° as shown. The cycloid in the inset of Figure 2.C was generated by a circle of radius $a=40.0\pm 0.5$ cm

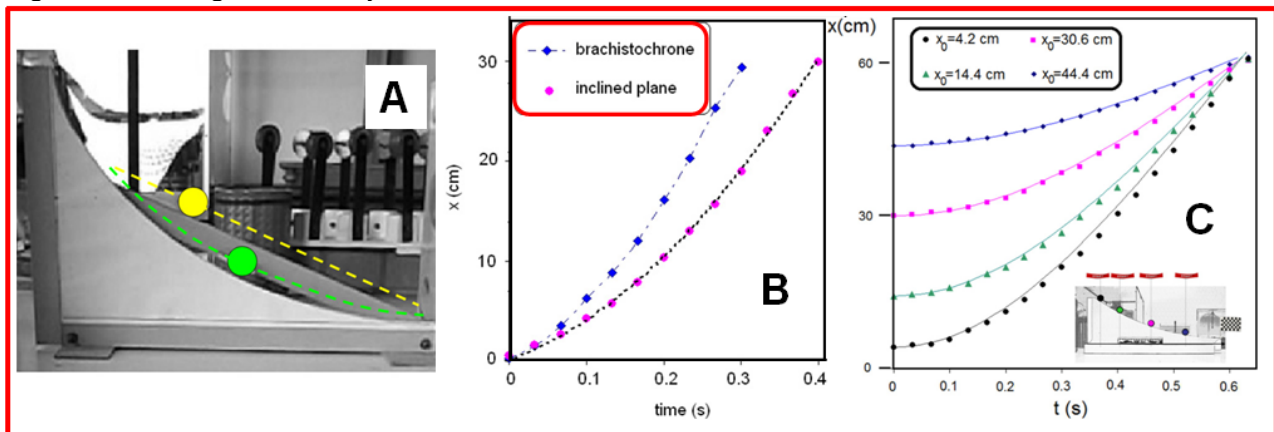


Figure 2 (A) Tracks made of cardboard sheets. The cardboard sheets were attached to a wooden structure that supported the system. (B) Comparison of the position versus time plots of the motion of a sphere along the inclined plane and along the brachistochrone. (C) Position versus time plots for a sphere moving along the cycloidal track and starting from different heights.

2.2. Experimental results

By analyzing with Tracker the videos acquired during the motion we are able to make measurements on the different systems.

First of all it is possible to visualize the trajectory of the Huygens pendulum with $L=4a$ and compare

its shape with the two halves of the cycloid forming the cusp. As shown in Figure 1, a good overlapping is obtained.

a. Harmonic and anharmonic oscillations of pendulums. Figure 3 displays the experimental results for the ratio of the period T to the asymptotic value for small amplitude T_0 as a function of the generalized amplitude $R = A_{\max}/L$ for Huygens' pendulum (dots) and for a simple Galileo pendulum (squares). The results are compared with the theoretical prediction for a simple pendulum (dashed line). As expected, for the cycloidal pendulum with $L \approx 4a$ the period that is almost independent of the amplitude.

In Figure 3 B the values of T/T_0 vs the Amplitude (in units of R) are reported for pendulums shorter or longer than $4a$. Graphs show that the period depends on the amplitude. It is interesting to note that the period increases with R for longer pendulums and decreases for shorter ones.

b. Tauto-chronic motion along a cycloidal path. In Figure 2.C position versus time plots for a sphere moving along a cycloidal track are reported. Comparison with theoretical prediction shows a good agreement: the graphs confirm that the time of descent does not depend on the starting quote. Its value, $t \approx 0.625$ s, is consistent with a cycloidal path generated by a circle of radius $a \approx 40$ cm, according to the relation $t = \pi\sqrt{a/g}$.

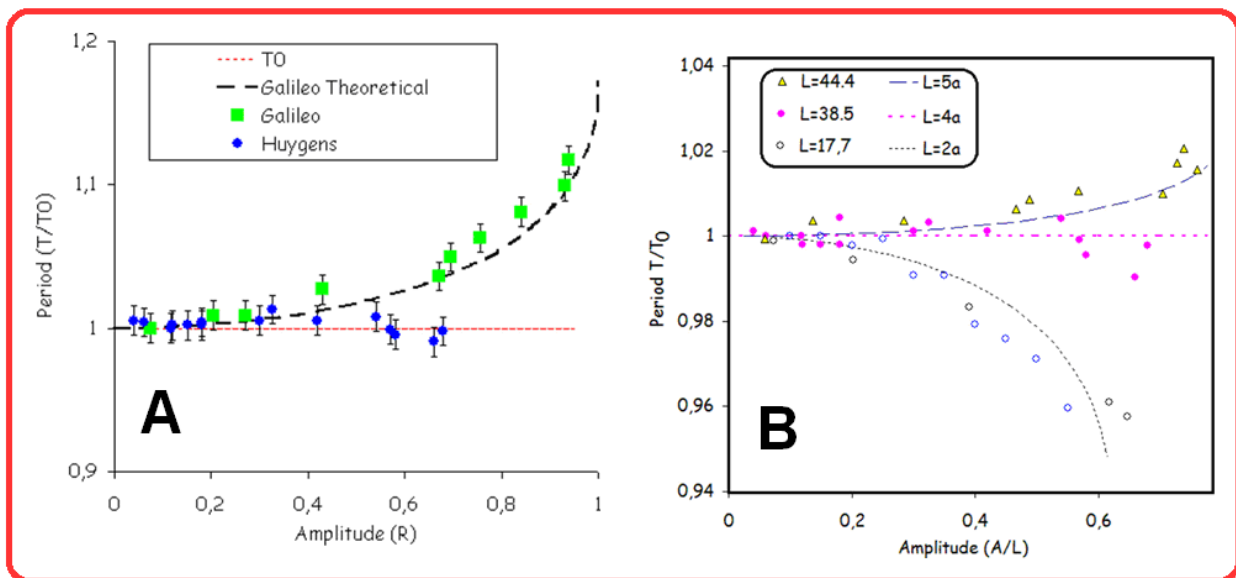


Figure 3 Experimental results for the ratio of the measured period T to the asymptotic value of the period for small amplitude T_0 as a function of the ratio of the amplitude of oscillation to the length of the pendulum R . (A) Comparison between the Huygens and the Galileo pendulums. Huygens pendulum has length $L=38.5 \pm 0.5 \text{ cm} \approx 4a$ ($T_0 \approx 1.24 \text{ s}$) and the simple pendulum has length $R=30 \pm 0.5 \text{ cm}$ ($T_0 \approx 1.1 \text{ s}$). The black dashed line corresponds to the theoretical anharmonic Galileo pendulum. (B) Huygens pendulums shorter or longer than $4a$: the period depends on the amplitude with increasing period for longer pendulums ($L \approx 4a$) and decreasing periods for shorter ones ($L \approx 2a$).

c. The brachistochrone property of the cycloid. The apparatus of Figure 2.A was used to measure the times of descent and the position versus time during the motion of a rolling steel ball for identical height drops on both the cycloid-shaped slope and the inclined plane. For each starting height descent on the cycloidal track took a shorter time. Figure 2B shows the position versus time data for the two balls emphasizing the time of descent and the fact that the height (y) versus time plot deviates from the quadratic behaviour followed by the ball moving on the inclined plane. This is in agreement with the brachistochrone property of the cycloid.

3. The Huygens compound pendulum

Based on Huygens' drawings of 1661, the experiment on the compound pendulum was reconstructed by using a system of five "ideal" pendulums constrained to swing together for a quarter of an oscillation (Bevilacqua, 2006), and then suddenly freed of their constraints to swing individually (Figure 4). This apparatus, with its limited number of masses localized in regular positions reproduces the ideal system through which Huygens studied the unknown properties of a physical pendulum by using the known laws of Galileo's simple pendulums.

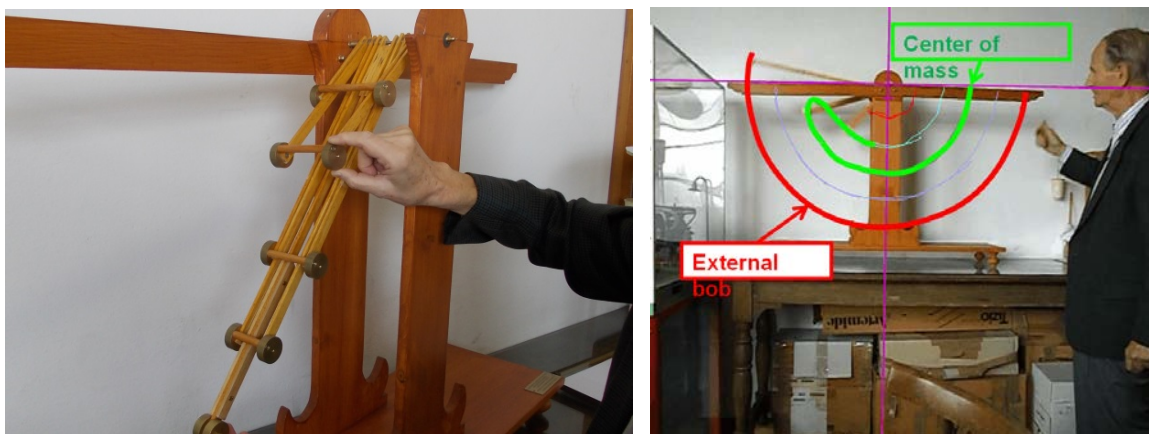


Figure 4. Reconstruction of Huygens' pendulum. Unilateral constraints (left panel) allow the device to swing as a rigid body in the first quarter of an oscillation and as separate simple pendulums in the second quarter (right panel)..

The motion of the pendulums during a complete oscillation is registered by a 30 frames per second CCD digital camera and a video is obtained. The TVA software allows tracking the positions of the masses in the video, obtaining a complete set of position versus time values for each mass. Through this setup we can easily measure the amplitude of the pendulum oscillations or the maximum height reached by each mass at the end of its free oscillation with an uncertainty of less than 1 cm. Details of the physical analysis and video data modeling of the system have been described elsewhere (Malgieri et al., 2013; Malgieri et al., in press). We mention here two aspects which at first sight can challenge students' physical intuition and which, when reflected upon, can deepen their comprehension of important physical concepts: (i) The outermost pendulum, in his free swing, reaches a maximum height which is noticeably higher than the level it initially started from in its constrained oscillation, while pendulums nearer to the pivot reach a lower height than their initial one. (ii) It can be observed through video data analysis that the centre of mass of the system in the second part of the oscillation does not ever reach the same height it initially started from. Furthermore the centre of mass trajectory, also might appear counterintuitive.

4. Discussing with students

The experiments were proposed to 29 students of a postgraduate course for high school physics teachers. During the activities data were collected from multiple choice and open questions and from students' final reports. Students' answers and supporting arguments were analysed with a phenomenographic approach. Data show that the work done with the experiments improved students' understanding and confidence with central concepts in mechanics. Also, a positive influence of the data analysis software in the process of appropriation of physical ideas and models emerges from students reports. We had extremely positive feedback on the use of the Tracker software and student teachers underlined the crucial role of video data analysis in favouring appropriation of physical concepts. For example, in their final reports student teachers wrote: «The experiment allows not only to deepen and extend the comprehension of previously introduced concepts, but also to observe phenomena which appear to be in contradiction with what has been studied. (...) The rupture of equilibria which is produced through the observation of such

phenomena can be the starting point for a deeper reflection leading to an explanation of the unexpected which has been experienced.»

«I think experiences like this one can, and should, be proposed to high school students; they would allow students to grasp the meaning of complexity. (...). From such an activity, the beauty of debating on problems, and even of the progress through indecisions and errors which are unavoidable when approaching a complex system, should emerge.»

«Use of the tracker software opens a wide range of possibilities, and first of all it allows to visualize all the kinematic quantities, allowing a direct connection between model and reality.»

5. Conclusive remarks

Experiments based on Huygens' studies on pendulums were reconstructed and investigated in an educational perspective.

By coupling the apparatus with a video data analysis and modelling tool such as TVA Tracker we create an interactive learning environment offering students the opportunity to deepen their understanding of many basic concepts such as harmonic and anharmonic motion, centre of oscillation, conservation of energy, moment of inertia, and constraint forces.

Using the experimental results as a starting point, the theoretical analysis can be discussed at the level of sophistication appropriate to the background of the students, combining experimental, analytical, and numerical approaches.

Students teachers appreciated the capabilities of the TVA software, and in particular the possibility of computing and showing the time evolution of positions, velocities, energies and other mechanical quantities of drawing the trajectory of the centre of mass of a multiple mass system and comparing such data to known laws, in a very short session time.

References

- Höttecke, D. (2000) How and what can we learn from replicating historical experiments? A case study. *Science & Education*, 9, 4, 343-362.
- Huygens, C. (1661) De centro oscillationis sive ad invenienda perpendicularia simplicia isochrona propositis perpendicularis compositis", *Oeuvres complètes XVI* 415-427, M. Nijhoff, The Hague (1888-1950)
- Koyré, A. (1953). An experiment in measurement. *Proceedings of the American Philosophical Society*, 97(2), 222-237.
- Mahoney M. S. (1980) Christiaan Huygens: The measurement of time and longitude at sea. *Studies on Christiaan Huygens*: 234-270
- Bevilacqua F., Falomo L., Fregonese L., Giannetto E., Giudice F. & Mascheretti P. (2006) The Pendulum: From Constrained Fall to the Concept of Potential. *Science & Education*, 15, 553-575.
- Malgieri M., Onorato P., Mascheretti P. De Ambrosis A. (2013) Reconstruction of Huygens' gedanken experiment and measurements based on video analysis tools. *Eur. J. Phys.*, 34(5), 1145.
- Malgieri M. Onorato P. Mascheretti P. & De Ambrosis A. Pre-service teachers' approaches to a historical problem in mechnics. *Physics Education*, in press.

SOUND AND NOISE: PROPOSAL FOR AN INTERDISCIPLINARY LEARNING PATH

Vera Montalbano, *Department of Physical Sciences, Earth and Environment, University of Siena*

Abstract

A learning path is proposed starting from the characterization of a sound wave, showing how human beings emit articulate sounds in the language, introducing psychoacoustics, i. e. how the sound interacts with ears and it is transduced into an electrical signal for transmission to the brain. What is perceived as noise is presented and the concept is extended to physical measurements. The interdisciplinary teaching process is focused on active learning through activities at school and outside performed with an open source software allowing to record sounds and analyze spectral components.

1. Instructions

The sound can be studied in acoustic and correlated to other wave phenomena such as light. However, in order to define the noise, more information are required. In particular the concept of noise depends on human perception of sound, that is from psychoacoustics.

We propose a learning path that starts from the characterization of physics aspects of a sound wave and continues by giving some elements of phonetics, i.e. as human beings emit articulate sounds in the language. The next step is introducing psychoacoustics, that is how the sound interacts with our ears and in what way it is transduced into an electrical signal which is transmitted to the brain. Finally, what is perceived as noise is presented. The path ends with the extension of the concept of noise in physical measurements. The teaching process is focused on the relationship between related topics in different disciplines such as physics and biology. The learning process is favoured by activities in which students are encouraged to active learning. In particular, the characterization of sounds, phonemes and noise is proposed to students through activities to do both at school and outside by using an open source software allowing to record sounds with a computer and then to analyze the various spectral components. Many useful MM tools for sound and related topics are available and a selection of them can be used or proposed for further activities, but a particular care is given in designing measures in which students can choose which sounds are under examination. They are encouraged to compare different sounds from their environment, to analyze and evaluate them from the point of view of physics. Another aspect is the clarification of very important concepts in physics, commonly used in the practice of the laboratory, such as resonance and the signal-to-noise ratio.

The next section describes the motivation and purpose underlying this proposal and methodologies. In section 3, the sequence of activities in learning path is given outlining the relevance, interdisciplinary aspects and analogies. The role of Multimedia tools in favoring active learning is discussed. A pilot experience performed within the Italian National Plan for Science Degrees² is presented in section 4. Finally, some remarks and conclusions are given in last section.

2. Interdisciplinary path and active learning

The main purpose for proposing a learning path on sound and noise is that it links a classical topic in physics, sound, with an actual problem in our society, noise. The path correlates physics to student's day life and remedies their lack of awareness of the damage caused by noise. Moreover, it is a good example in which physics is useful for a better understanding of other sciences like biology, physiology, phonetics, electronics, etc. The best way to achieve these results is to design an interdisciplinary learning path.

According to H. H. Jacobs, an interdisciplinary path is obtained when a knowledge view and curriculum approach consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem, topic, or experience (Jacobs 1989). Thus, it is possible

² Piano nazionale per le Lauree Scientifiche, i.e. PLS
(see Montalbano 2012 for a survey on PLS actions and methodologies).

to build a bridge between different disciplines and allow a better understanding of complex concepts utilized in science (in this case for example energy transport and transfer, resonance, transduction). Moreover, an interdisciplinary approach allows a synergy in acquiring a deeper knowledge of the world in which we live and, in this sense, it promotes an advanced scientific literacy.

An effective way for pursuing these aims is active learning (Laws 1999, Niemi 2002, Meltzer 2012, Benedetti 2014). Students must be intellectually engaged and actively involved in their learning, and traditional instruction is usually failing to provide this engagement. On the contrary, a well-designed laboratory can achieve active learning through exploring and inquiry-based activities (Montalbano 2014a). In the laboratory context, multimedia tools can play a relevant role by enhancing the comprehension of some topics (e.g. transduction by means of applets as shown in fig. 3). Moreover, they can be used with mobile devices allowing students to perform measurements outside physics laboratory, at home or outdoors. Least but not less, many multimedia tools, like the one utilized for recording and analysing sounds in the following, are freeware so every teacher and every student can easily use it.

3. A learning path on Sound and Noise

The idea of an interdisciplinary learning path on sound and noise arose from a pilot experience in a deepening laboratory for motivated and talented students reported in the next section. Many activities are designed and tested with small groups of students. Disciplinary knots which were encountered, ideas for overcoming them and effective actions are merged in the proposal. In order to obtain an effective improvement in teaching/learning process a careful designing on all activities is suggested. A good way for promoting an effective design and a real interdisciplinary approach could be to organize an updating course for physics, mathematics, science teachers in-service in the school with the purpose of discussing and determining nature, degree of integration, scope and sequence of activities. The teacher's team should be empowered to shape and to edit the curriculum according to the students' needs.

The learning path starts from introducing waves and characterizing sound as a particular wave. Vary wave properties can be explored in lab, from energy transport and conservation to resonant systems. The next step is to understand how human being can produce sounds and which kinds of them are utilized in language. Moreover, noise is introduced analyzing day-life situations where students discover that a sound can be perceived like noise or not. Understanding how sound is perceived by the brain is necessary for arriving to a shared definition of noise. The last issues can be shaped directly on students interests (environment, pollution, health, music, electronic, advanced topic in science, etc.).

3.1. Waves and sound

Waves are introduced in physics course but usually lab are centered on reflection, diffraction and interference of light. A way to study waves can be, starting from vibrating mechanical systems, to arrive to observe simple mechanical waves and to identify analogies and differences in both cases. A particular care is due because vibrating systems and waves are described by a very similar mathematics (harmonic functions) but few well-designed experiences in lab can clarify this delicate issue. Sound waves can be characterized and some common wave behaviors can be observed in a quantitative experiment, e. g. interference of sound waves, which allows to measure the speed of sound. An oscilloscope can be used for visualizing sound waves and allows to perform period and frequency measurements, verify the principle of superimposition, characterize harmonic waves and musical notes, compare them with known height (tempered scale), study sound beats and compare it with the analog phenomenon with light (Moiré fringes).

Energy considerations are relevant in defining waves, superposition effects, etc. In particular, resonance is a central topic for linking physics aspects to biological systems related to sound.

A very effective activity for understanding resonance (Montalbano 2014b) is the study of Chladni figures showed in figure 1. By using a speaker connected to a function generator, a resonant system can be obtained by placing a metal plate over it. When sound is resonant with the

frequency of a normal mode of the plate, salt starts jumping, leaving from the vibrating surface and cumulating in fixed zones. The figures formed by salt (Chladni figures) depend on the shape of plates, materials, thickness and boundary conditions (existence of constrained points). In this case is very easy to recognize resonance.

Applets (see for example Physclips or Wikipedia) can be useful to figure out energy transport from sound wave to the plate and finally to the salt.

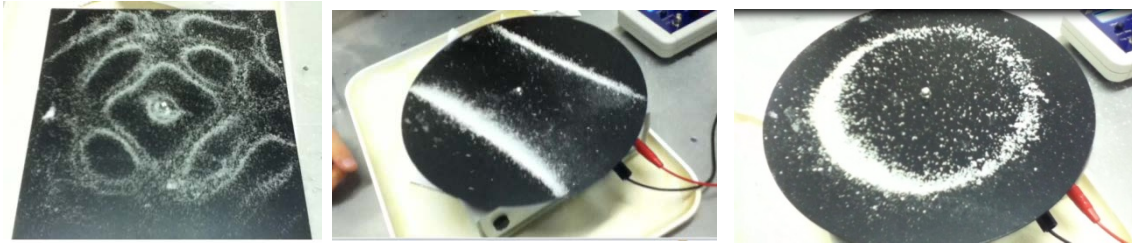


Figure 1: A Chladni figure appears when a sound wave has the same frequency of a normal mode of the plate, thus the plate vibrates in a resonant way allowing a relevant exchange of energy from sound wave to the vibrating plate. Salt outlines the nodal positions of the normal mode.

This part of the learning path can be realized by physics teachers, but a important role can be played by mathematics (harmonic functions, spectral decomposition, Fourier series, function in several variables) giving rise to an interesting interdisciplinary connection.

3.2. Sound production: phonetics

Sound is the basis of our communication system: The language. Phonetics studies the sound production: From the electrochemical signal processed by the brain to the sound produced by the human voice. The speech sounds are called phonemes. The position, shape, and movement of articulators or speech organs, such as the lips, tongue, and vocal folds allow to emit phonemes.

Speech organs (see fig. 2, picture in the middle) can be modellized as resonant boxes which amplifies only sounds with the resonant frequencies (as the one showed in fig. 2 on the left).

The first activity is to analyze some phonemes by using an open source software (e. g. Audacity, fig. 2 on the right). The software allows to record sounds by a personal computer or a mobile device. The recorded file contains a digital sampling of the analog electric signal in which sound energy is transduced by a microphone. Recorded files, as well as any other file that contains digitized sounds, can be read, modified, superimposed to other ones or decomposed into its spectral components by the software. Again, physics teacher is involved but collaboration with science teacher is unavoidable.

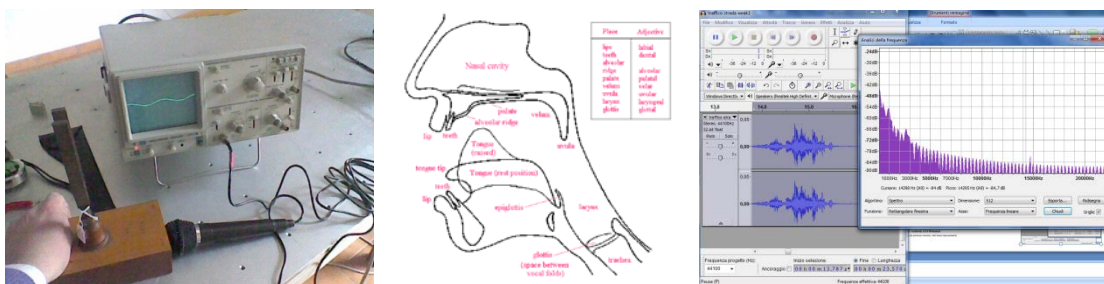


Figure 2: On the left a resonant box for a note is showed together with the system microphone-oscilloscope used for obtaining a visualization of the electric analog signal in which the sound wave has been transduced. In the middle, a schematic picture of human speech organs is given (Fuaiméanna). On the right, some windows of the software are displayed.

Students can characterize phonemes produced by themselves (simpler phonemes as a, e or ma, ba, da, mo, bo, lo,....). They can explore phonemes like an inquiry-based activity, posing questions (What happens if.....?) and checking hypothesis directly in the physical system (Let's try). They learn to use properly PC-software system and advanced topics can emerge and be discussed.

3.3. Noise and psychoacoustics

What is noise? In day life, we means mixed and unidentified sounds. For a well-defined concept of noise it is necessary to know how sounds are perceived by humans, i. e. how sound waves are detected by ears and transduced to an electrochemical signal ready the brain. Energy aspects are relevant in psychoacoustic and they remain a key for understanding how sound is transduced by a vibrating mechanical system to a travelling wave in a viscous medium in the cochlea and finally in an electric signal by inner and outer hair cells (pictures from applets in fig.3). Moreover, the use of applets this time is not only useful but unavoidable. The subject requires a deep interdisciplinary collaboration between physics and science teachers and heath aspects can be discussed (see fig. 3 on the bottom where hair cells damaged by noise can be compared to the normal ones).

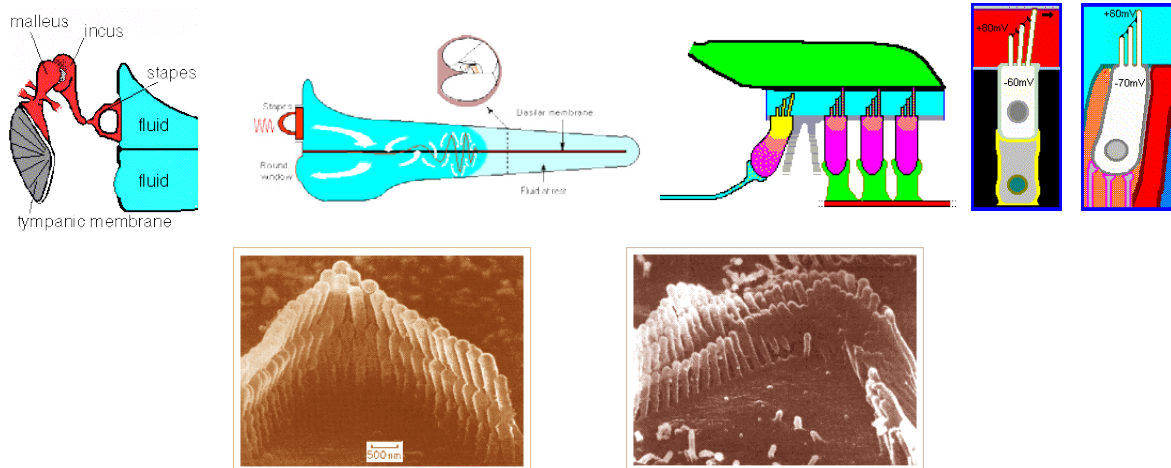


Figure 3: On the top, vary applets useful for understanding signal transduction in the ear (from The Cochlea Site). On the bottom, normal and damaged hair cells (applets and electronic microscope images, from The Cochlea Site).

3.4. Advanced issues on noise

Students can deal with noise concept and related advanced issues, such as environment question (sound pollution, how it is defined, legal limit for noise, health aspects, how it is possible to reduce it, etc.). Students can comprehend that ear is an active transducer with well defined limit and their consequences on health.

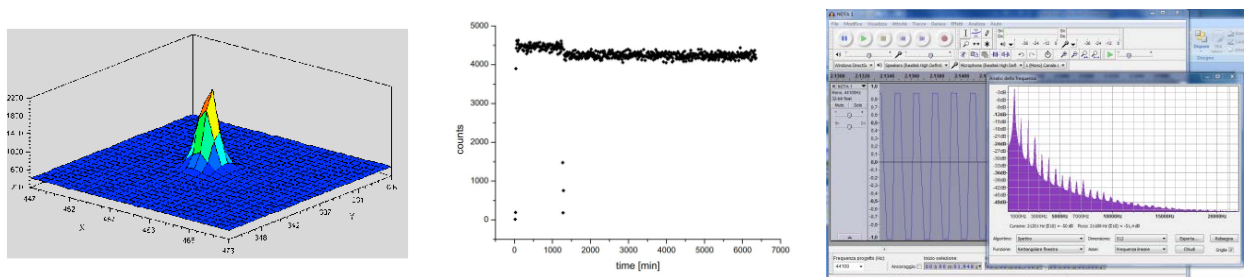


Figure 4: Two measures with different S/N ratio (on the left, 4 in a measure on a fluorescent marker in a confocal microscope and, in the middle, 0.05 in a measure on weak radioactive source). On the right, a sound shows a cut off in the digital sampling.

Finally, it is possible to turn back to physics and define signal-to-noise ratio (see fig. 4) and its importance in measurements. Students can compare S/N ratio for some physics measure and the case or ear for measured sounds. Moreover, they can explore sounds outside, in noisy environment, in the natural contest or other interesting sounds like white or colored noise and merge them with another sound for comparing the sensation from the ear. A limit in sampling can be found in the sound showed in fig. 4 on the left.

4. A pilot experience

Almost all issues proposed in previous section were designed and tested with students in a PLS laboratory. It was a deepening laboratory for motivated and talented students (3-4 students from scientific high school). The laboratory last for 3 years (4-5 h/month for a total 16-20 h/y) and students were very engaged and active. At the end of the PLS laboratory, a report was presented where many measures on different sounds were performed and analyzed by themselves using the open source software (see fig. 5).

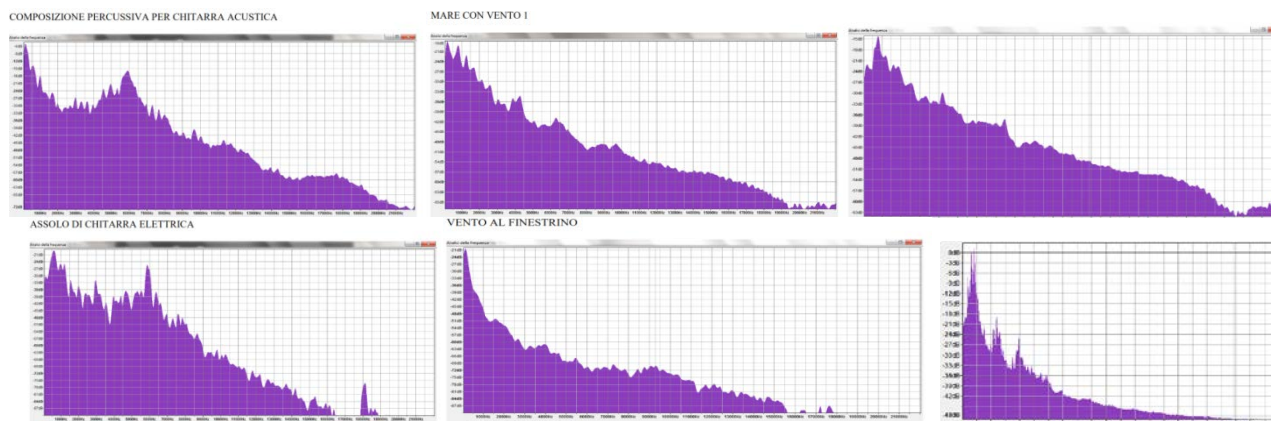


Figure 5 Spectral analysis of sounds recorded and analyzed by students: acoustic guitar, wind on the sea beach, car stereo, electric guitar, wind on car window, phoneme A (from top on the left to bottom on the right).

5. Remarks and conclusion

Pilot experience showed limits in an optional laboratory. Activities are too distributed in time. Analysis and final understanding are limited due to lack of discussion with teacher at school. In all activities in physics laboratory and in outdoor measurements students were very engaged and active but the optional aspect and the weak assessment which had no consequences at school render the lab not fully effective.

On this basis it has been proposed an interdisciplinary learning path at school with physics, mathematics, science teachers involved. The activities can be adapted to different situations and enlarged following students' interests. The use of multimedia tools clarifies complex biophysics, implies an increasing of possible measures and makes students more independent in exploring the phenomena.

References

- Audacity, <http://audacity.sourceforge.net/>, accessed 2014 february
- Benedetti R, Mariotti E, Montalbano V, Porri A (2014) Active and cooperative learning paths in the Pigelleto's Summer School of Physics in *Frontiers of Fundamental Physics and Physics Education Research*, S. Burra, M. Michelini, L. Santi eds, Springer Proceedings In Physics, vol. 145, Milano: Springer-Verlag Italia
- Fuaimeanna na Gaeilge – The Sounds of Irish, Introduction, https://www.uni-due.de/FnG/FnG_Intro.htm, accessed 2014 february
- Jacobs H H (1989) *The Growing Need for Interdisciplinary Curriculum Content in Interdisciplinary curriculum: Design and implementation*, Jacobs H H ed., 1-11
- Laws P, Sokoloff D, Thornton R (1999) Promoting Active Learning Using the Results of Physics Education Research. *UniServe Science News*, 13. http://sydney.edu.au/science/uniserve_science/newsletter/vol13/sokoloff.html, accessed 2014 march
- Meltzer D E, Thornton R K (2012) Resource Letter ALIP–1: Active-Learning Instruction in Physics, *Am. J. Phys.* 80, 478; doi: 10.1119/1.3678299
- Montalbano V (2012) Fostering Student Enrollment in Basic Sciences: the Case of Southern Tuscany, in *Proceedings of The 3rd International Multi-Conference on Complexity, Informatics and Cybernetics: IMCIC 2012*, ed. N. Callaos et al, 279-284, arXiv:1206.4261 [physics.ed-ph]
- Montalbano V, Mariotti E (2014) A multipurpose action for learning/teaching process: The Pigelleto's summer

school of physics to appear in Science Education Research for Evidence-based Teaching and Coherent Learning Proceedings of the ESERA 2013 Conference, Constantinou C P ed., Nicosia: European Science Education Research Association, Nicosia, arXiv:1401.1929 [physics.ed-ph]

Montalbano V, Di Renzone S (2014) An empirical study on a learning path on wave physics focused to energy, in Proceedings of The World Conference on Physics Education 2012, editor Mehmet Fatih TAŞAR, p. 293-301, Ankara: Pegem Akademi

Niemi H (2002) Active learning—a cultural change needed in teacher education and schools, Teaching and Teacher Education 18, 763–780.

Physclips, <http://www.animations.physics.unsw.edu.au//jw/SHM.htm#chladni>, accessed 2014 february

The Cochlea, <http://147.162.36.50/cochlea/index.htm>, accessed 2014 february

Wikipedia, http://en.wikipedia.org/wiki/Vibrations_of_a_circular_drum, accessed 2014 february

TEACHING PHYSICS USING MODERN TECHNOLOGY

Bostan Carmen-Gabriela, *Institute of Educational Sciences, Bucharest, Romania*

Abstract

The paper presents modern means used in teaching/ learning physics in class and in the laboratory - supplementing traditional teaching process with simulations/ computer modelling, experimental data processing and graphics obtained through specialized software. It also presents the achievement of a physics experiment on laboratory that will be supplemented with computer simulation. I propose an outline of the lesson plan and illustrate how the teacher can by integrating multimedia educational resources on instruction at various stages of learning units.

1. Introduction

Into "Lisbon Agenda for growth and jobs" objectives is education and training in the Horizon 2020 light. It intends to improve the skills of all citizens required for competitiveness, equity and social inclusion by creating a knowledge triangle.

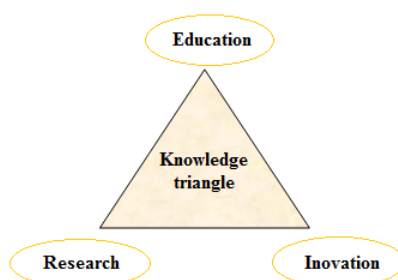


Figure 1: Knowledge triangle

It requires a new vision of education that to be in consistent with modern society, technological and informational in which we live. Educational reform requires taking into account both student and teacher in accordance with social, political and economical changes. It is important that the teacher training system to respond to developments in curriculum, teaching/ learning methodologies, resources and educational means that teachers must be trained to use them properly.

Present curriculum reform trends in European documents are: adapting education to the labor market, education for all, the relevance of the curriculum to the individual and society, the development of desirable attitudes and values, skills, critical thinking, concern for the adequacy of training to the needs of each individual, maximizing the potential of every child, student-centered teaching and learning.

One of the eight key competences defined by the European Commission is the digital literacy, to be developed by the end of compulsory education for to act as a foundation for lifelong learning. We will be analyzing which are the bridges between digital competencies and skills in math, science and technology.

Digital competence involves:

Knowledge - understanding and knowledge of nature, knowing the role and opportunities of ICT (Information and Communication Technology) in everyday contexts: in personal, social, professional life.

Skills - the ability to search, collect and process information and use it in a critical and systematic way; abilities to use digital tools to produce, present and understand complex information; the ability to access, search and use Internet-based services, using ICT to support critical thinking, creativity and innovation.

Attitudes - critical and reflective attitude towards available information, accountability in the use of interactive means, interest in community involvement, cultural, social or professional networks.

Competence in science refers to the ability and willingness to use a set of knowledge, experimental devices, ideal models, theoretical and methodologies in order to explain the natural world, to identify questions and to draw evidence-based conclusions.

Depending on the purpose of training, are used in teaching various ICT tools that can play different roles to support the process. From the perspective of learning situations ICT permits are divided into four categories: information tools, modeling tools, building knowledge and communication tools.

- Information tools provide a vast amount of information in different formats (text, audio, images, graphics, or video), allowing the student the access and use of relevant information to work - multimedia encyclopedias and web resources available, representing huge resources and passive tools. Using ICT meet the needs of information, and suppose on the hand the knowledge of the best ways to select and use the information available in different formats and on the other hand, the creation of electronic materials in different formats. An important step, as the user, is to select and use information available in different formats (text, video, audio). Also, it can create electronic materials for knowledge presentation in various formats (text, video, audio).
- Modeling tools - the student learn in virtual environments that allow him to experience different situations: simulations, real-time modeling, online games or virtual reality. Using ICT to meet experiential learning needs requires: selecting and using ICT tools to provide access to virtual learning experiences to participate in these learning activities through ICT.
- The knowledge building tools are aids that can be used to manipulate information and build their own (self) knowledge. These tools allow students to achieve tangible products for specific educational purposes and personal web pages, personal blogs through which to communicate their ideas, online portfolios or self-assessment tools.
- Tools of communication between teachers and students or in the student communities to different learning activities that allow overcoming the space/ time borders (via audio-video meetings, communication via email, chat or discussion forums). Using ICT to meet communication needs assume selecting and using the appropriate technological support necessary to establish and maintain channels of communication.

These three key skills are developed in the Physics class.

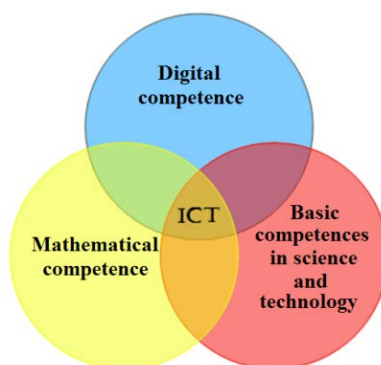


Figure 2: Venn Diagramm

2. Learning unit planning. Didactical process managing

2.1. Theoretical Background

Carnot Cycle reveals an ideal thermal engine whose work consisting of two adiabatic transformations and two isothermal transformations. It is one idealized reversible cycle is which occurs between a hot and a cold thermal reservoir at temperatures of T_1 and T_2 respectively.

Studying the efficiency heat engines, Sadi Carnot formulated the following theorems:

- Efficiency of a reversible thermal machine depends only on the temperature of the hot source and of the cold source and does not depend on the nature of the working substance.
- Efficiency of a irreversible thermal machine is always less than the efficiency of a reversible heat engine that operating between the same temperature limits.

The Carnot cycle provides an upper limit on the performance of a real cycle operating between the same two thermal reservoirs. It consists of the following four reversible processes: isothermal expansion, adiabatic expansion, isothermal compression and adiabatic compression (Figure 3).

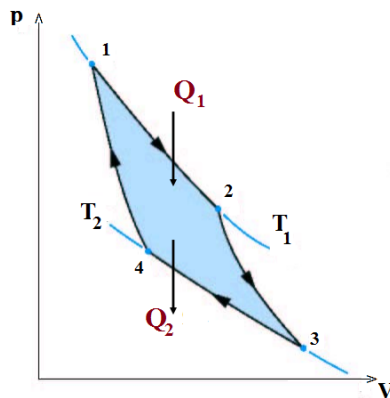


Figure 3: Carnot Cycle on p-V diagramm

Final result for the efficiency of an ideal Carnot engine is:

$$\eta = 1 - \frac{|Q_2|}{Q_1} = 1 - \frac{T_2}{T_1} \quad (1)$$

where

T_1 =temperature of hot source, and T_2 =temperature of cold source,
 Q_1 = heat transfer to the gas, and Q_2 =heat transfer from the gas.

It observe that for Carnot cycle the ratio of heat supplied to heat dumped is just the ratio of the absolute temperatures!

2.2. Computational Background

For modeling function of Carnot engine it can use Adobe Flash Player, attractive software who allows drawings, animation, computer modeling and facile user interfaces.

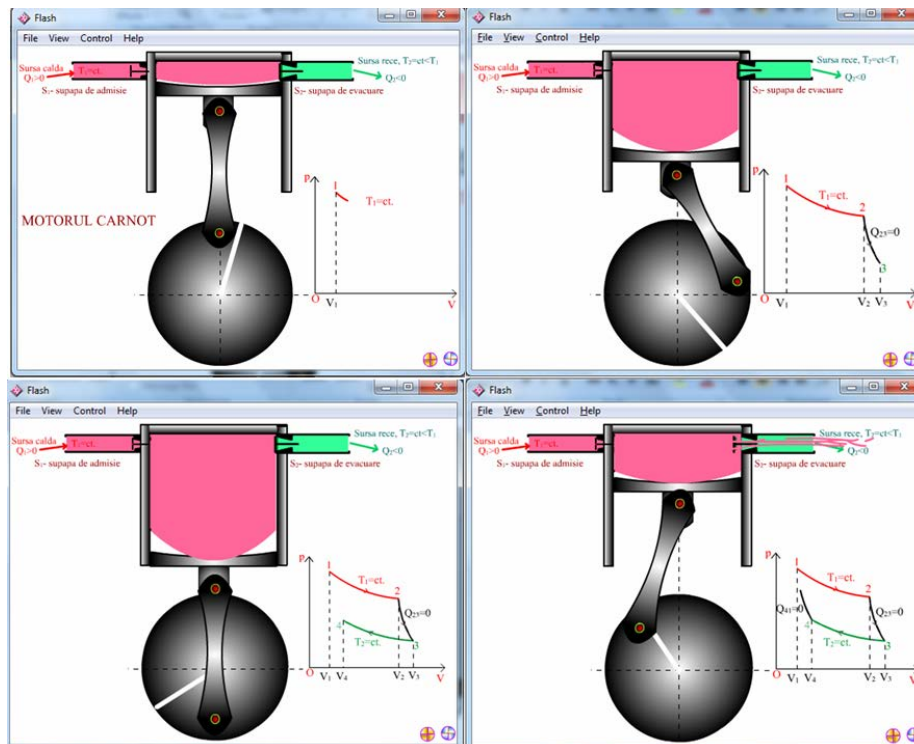


Figure 4: Carnot engine on Flash Player – modeling on computer

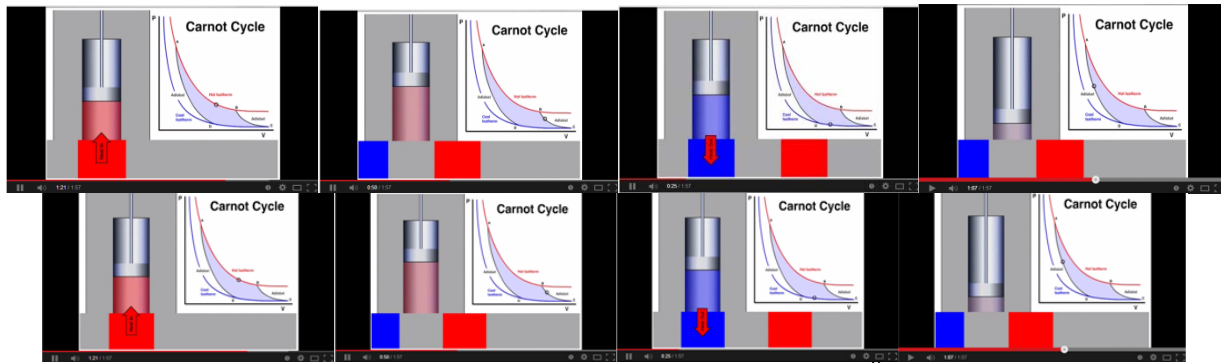


Figure 5: Carnot engine on Youtube caption³

2.3. Didactical Methods

Teaching methods used are: explanation, conversation, experiment, demonstration, discovery and computer modelling.

Didactic means used are: modeling tools, information tools – internet resources.

Educational resources used are computer, Adobe Flash Player software and interactive whiteboard.

2.4. Lesson's plan

Unit by learn: Second Law of Thermodynamics. Thermal engine

Activity of learn: Carnot cycle

The form (gradual level): the class-10th grade (the student's age – 17 years old)

The type of the lesson: teaching/ learning

Didactical tools: video, simulation on the computer (Flash Player)

Didactical intention: to understand the working principle of the Carnot engine, working principle of thermal engine

How can teacher integrate multimedia educational resources:

- The teacher will verify the Second Law of Thermodynamics - knowledge, which the students have learned.
- The teacher will make connection with the new lesson – Applications of Second Law of Thermodynamics; Carnot Cycle.
- The teacher starts a simulation on the computer – modeling of Carnot engine on Flash Player. Students will observe the working principle and diagram drawing step by step
- The teacher discuss with students about information tools – youtube resources.
- The teacher will guide the students to draw conclusions, to generalize their observations.
- The teacher writes the equations on the board, draw the diagrams and the students write it in their notebooks.
- Lesson concludes with feed-back and homework.

3. Conclusions

Order to face uncertainties surrounding and continuous changes characteristic of market economies, students need strategic skills such as the ability to learn how to learn, problem solving skills, evaluation skills. The change of perspective of mass production requires skills and knowledge more extensive than those provided by previous specializations. Educational systems must respond to changes in external conditions that redefine the needs that society as a whole has towards future generations. Education for all children is an imperative for educational policies and practices, guidelines and directions can lead us and to practice changes are required depth and orientation. May be determine the guidelines and new directions who can lead us through new teaching practices, didactical practices, required for a depth way in orientation of educational changes. The current learning facilities and environment are not the only privileges of traditional

³ http://www.youtube.com/watch?v=s3N_QJVucF8

schools. Formal education can also be accessible through other teaching means: multimedia resources and the Internet. The new interactive aids of teaching/ learning underline the role of technology-enhanced environments in science learning: such backgrounds allow students to observe and explore scientific phenomena interactively on the computer. The school is an institution in progress; it must contribute to cultural and informational progress. Profound revolution in technique and technology require school systems to adapt, and this progress is ongoing. Science phenomena are growing interesting if will be attached simulations, animation, and interactivity have especial interest for us.

Software modelling experiments in real time contribute to a better understanding of natural phenomena.

References

- Bostan, C-G, (2012), Integrating key skills in ICT school discipline, Sigma House, ISBN 978-973-649-725-4, Bucharest
- Tasica L, Botnariuc P, (2003), Implementation methodology of implementation of the key competences in school curriculum applied, Digital competence, Institute of Educational Sciences, Bucharest
- Key competences for lifelong learning,
http://europa.eu/legislation_summaries/education_training_youth/lifelong_learning/c11090_en.htm
- Carnot Cycle 1, http://www.youtube.com/watch?v=s3N_QJVucF8

TEACHING SCIENCES FOR PRIMARY SCHOOL

Bostan Carmen-Gabriela, *Institute of Educational Sciences, Bucharest, Romania*

Abstract

Goal of paper is to illustrate how can teach sciences for primary school students through various tools. The means used are observing and conducting simple experiments supplemented by computer games. Content of this paper is derived from experiences with EduTeca games, modelling of natural phenomena, completing the scientific knowledge, and the experience gained by the teachers of Physics and pupils.

4. Introduction

Directorate General for Education and Culture of the European Commission conducted compatibility studies of the educational systems of EU countries through „Programme of Education and Training 2010”

Information and Communication Technology (ICT) is integrated into didactical process on all levels. Teachers use ICT in innovative ways as a tool to enhance teaching/ learning in curriculum. ICT help science teaching, teachers find it an important resource that helps them recognize where, when, why and how ICT can be used.

Digital competence involves critical and responsible use of media and communication in education, work and leisure process. It aims in particular the development of critical thinking, communication and information management to high standards.

Digital competence requires a good knowledge and critical thinking in the use of electronic media for work, leisure and communication. This competence is intrinsically linked to logical and critical thinking, high level skills information management and communication. At the basic level, this involves the use of multimedia technology to access, assessment, storage, production, exposure and exchange information and to communicate and collaborate in the Internet network.⁴ Digital competence is described in European documents as the knowledge, skills and attitudes specific.

Knowledge and understanding aimed at a better understanding and knowledge of the nature, role and possibilities of information and communication technology (ICT) in daily life: in personal life, in society and in the workplace. Skills and abilities involve using a diverse range of ICT applications in daily life. Attitudes refer to the inclination to use ICT to work independently and in teams, critical and reflective attitude in evaluating the information available.

Applications ICT and develop of digital competencies into school are important in our modern society because can be use different software to model real-time experiments, to complement and deepen the knowledge acquired in the classical laboratory experiments. Through computer can be collected and processed experimental data, can be made quantitative and qualitative evaluations, may be created databases and subsequent statistics. Beginning of primary school may be used applications developed by different IT companies. Learning sciences in primary school serves development scientific thinking to children.

Merrill's Instructional design models suggest that the most effective learning environments are those that are problem-based and involve the student in four distinct phases of learning: (1) activation of prior experience, (2) demonstration of skills, (3) application of skills, and (4) integration or these skills into real world activities (like in Didactical activity details, in this paper). The instructional design is based on follows didactical principles:

- Learning is facilitated when learners are engaged in solving real-world problems.
- Learning is facilitated when existing knowledge is activated as a foundation for new knowledge.
- Learning is facilitated when new knowledge is demonstrated to the learner.
- Learning is facilitated when new knowledge is applied by the learner

⁴ Key Competences For Lifelong Learning, European Reference Framework, Online: http://ec.europa.eu/dgs/education_culture/publ/pdf/ll-learning/keycomp_en.pdf, European Commission, 2004.

- Learning is facilitated when new knowledge is integrated into the learner's world.⁵

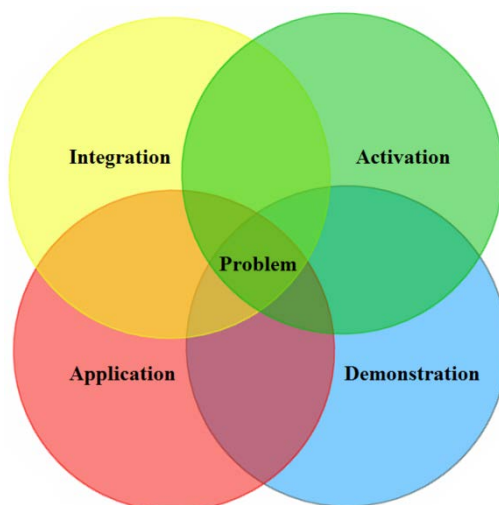


Figure 1: Venn Diagram

Four additional areas that should be considered during the instructional design process for technology-rich lessons are motivation, socialization, audience and technology needs.⁶

5. Didactical activity details

Specific skills targeted: Showing curiosity for observing phenomena/ processes/ repetitive structures in immediate environment in order to identify the regularities.

Learning Activities:

- Monitoring of plant growth through observing the factors that maintain life; food as a source of energy: the importance of nutrition for growth and development; living conditions (water, air, light, heat);
- Direct observation in the natural environment of plants, insects, natural phenomena etc.;
- Exploration of age-appropriate educational software - EduTeca software, Nature wakes up to live.

The lesson is designed to preparatory class for children of 6 years old.

Detail of content: survival behaviors of the plant - environmental conditions necessary for survival.

Stages of instruction in didactical process are:

- Gain student's attention
- Inform students about objectives
- Remember of prior learning - relating new information to something students already know or something they have already experienced.
- Present the content
- Provide learning guidance
- Elicit performance (practice)
- Provide feedback
- Assess performance

Instructional design must create effective instruction based on learner needs and requirements age.

5.1. Details of worksheets

Goal: Update knowledge concerning the characteristics of living world.

⁵ http://www.instructionaldesigncentral.com/htm/IDC_instructionaldesignmodels.htm

⁶ <http://www.msuedtechsandbox.com/maetELY1-2012/cep811/session-1-july-8th-9th/instructional-design-principles/>

The learning activity consists in indirectly observations, through educational software EduTeca - Nature wakes up to live. Environment observed through the game contains elements of the living world - plants, of inanimate world - sun, clouds but also phenomena of nature - rain, wind. Children will play in Chapter 2 - Bouquet of spring: Water in clouds - good news for the flowers! Now is the day, now it's night! My garden!

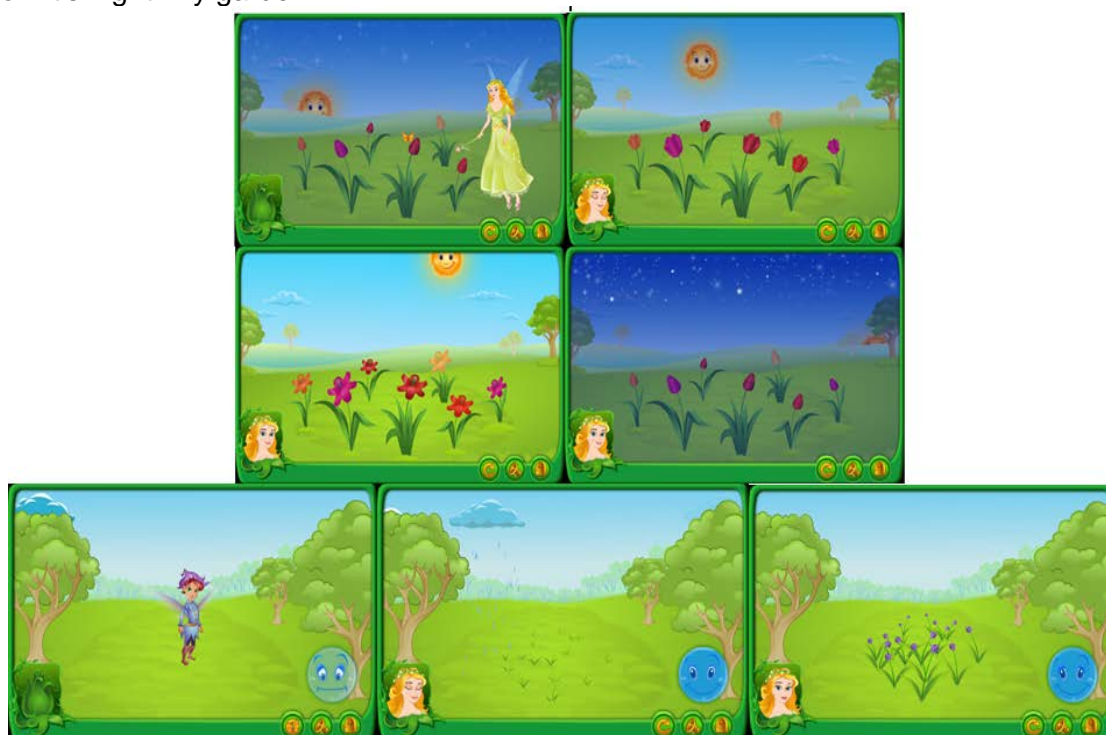






Figure 2: Bouquet of spring Print Screens

After observing and describing components, students will complete the table together with the teacher

Table 1: Worksheets

Component observed	It moves	It feeds	Increase	Conclusion
	X	-	X	Not alive
	X	X	X	Alive
	X	X	-	Natural phenomena
	X	-	-	Not alive

Will be discussions on the phenomena observed and will be highlighted the influence of light and water on plant development.

Teacher will initiate the next experimental activity, which will be held in the range of several weeks. Students will plant in pots with sand the mustard, wheat and beans. Some pots will be placed to window, others in a closet, on dark.

Students will complete the observations on worksheet, and will draw conclusions. Observations will be made by the entire class and will be marked with teacher's help. Data will be filled with pictures taken during the experiment, which can be electronically. It can be used in portfolio class on

Mathematics and Natural Sciences subject.

6. Conclusions

New ICTs technologies have great potential to support the learning process, it going beyond mere collection of information or reminder of the facts. They facilitate the higher thought processes - multiphase strategic processes, such as design, decision making and problem solving and that involves processes of analysis, evaluation, establish connections, elaboration and synthesis.

It was identified five categories of learning outcomes: verbal information, intellectual skills, cognitive strategies - defined as different ways in which students directs their own learning, thinking, action, feeling, attitudes and motor skills. In turn, intellectual skills are ranked: discrimination, concrete concepts, defined concepts, rules for problem solving by combining simple rules. Through these types of learning outcomes the cognitive strategies, superior rules and problem solving require higher thinking processes.⁷

Involving students in higher order thinking processes is generated rather of lesson objectives and the teaching strategies than using different ICT tools. Using ICT in learning can be successfully used or can lead to failure; when placed in teaching, is required experience for teacher.

In school practice is known the need to overcome a structuring of contents on the transmission of knowledge, focusing on teaching process, per approaches student centered and per learning modes.

To understand the phenomena and processes specific for the natural sciences, it is well that teaching unit design properly to take into account the covering several stages: familiarization, structuring and implementation.

Familiarity involves accommodating pupil with new content through problem situations or experiments. The student discovers objects and phenomena in immediate reality, using previously acquired knowledge and skills. This teaching approach develops a reflective attitude, expressed through observation, comparison, search and analyze of ways to solve given tasks. The role of the teacher is to cause and maintain the interest of children, to coordinate the learning, to specify in simple words next steps. Work tasks are designed gradually to enable students to find solutions themselves. The search and discovery activities required by the problem situation will highlight updating their knowledge in relation to previous knowledge, through introducing new tasks from the teacher. Advantages of this stage are: providing pretext-issue motivator and structuring acquisitions earlier. Experimental exploration is the base of learning activities, the subsequent learning will be built through these experiences.

By patterning the student will develop and systematize their own procedures of action and will strengthen the own skills. According to targeted cognitive stage, learning activities will be moments of observation, experimentation, reflection and analysis of the phenomena studied. Aims of learning in this stage are: to identify the cognitive elements or operator, the confrontation experimental results and explain them in an appropriate language. The role of the teacher is to help students structure their concepts through analyzing how solving of learning tasks.

In sequence of implementing, the teacher provides opportunities for training, development and consolidation of knowledge. Teacher interventions will be focused on strengthening and developing of methods to solve problem situations, the application of theory that explains the modeling of phenomenon studied. Is important the own reflection of child about applying of new concepts in solving learning situations proposed.

The computer should not be the only means teaching; the knowledge gained through software must completed by practical activities. Familiarity stage has been done through the game on your computer. Knowledge patterning was made through filling of table and after, through carrying out practical activities, experimental. Applying the knowledge learned and implementing was achieved through experimental activities. In this way, we can have a complete knowledge process.

The informative and technologies society needs important changes in educational programs. Generations today are digital generation, and ICT has become the key concept in education. Multimedia has important applications in teaching process, especially in natural sciences teaching,

⁷ Principles of instructional design in 1992 , Gagne , Briggs and Wager

where the modelling of experiences in real time is most important and completes the knowledge of students. In schools, ICT can become a concept to make radical changes in education. The computer can become a tool for all those who wish to find in him a friend and the mysteries will turn into knowledge. This tool is equally useful to students and teacher. Computer used in class aims to develop skills related to communication, procurement, presentation and transmission of information in forms as varied. In this manner we can realize in inter and trans-disciplinary learning. The physics is the science that explain the natural phenomena, the physics is the science that contribute to the technical progress and the students must learning that the physics science is a science of life, a science that can be useful in a long life day and he's progress contribute to enjoy facilities for our everyday life. Didactical process will be improved if participants learn by "play"; computer can become a tool for all those who wish to find in him a friend and the mysteries will turn into knowledge.

References

- Gagne, R., Briggs, L. & Wager, W. (1992), Principles of Instructional Design (4th Ed.). Fort Worth, TX: HBJ College Publishers.
- Merrill, M. D. (2007). First principles of instruction: a synthesis. In R. A. Reiser & J. V. Dempsey (Eds.), Trends and Issues in Instructional Design and Technology, 2nd Edition (Vol. 2, pp. 62-71). Upper Saddle River, NJ: Merrill/Prentice Hall.
- Ministry of Education, National Council for Curriculum, (2001), Guide methodological for implementing the Natural Science school curriculum, Bucharest, Romania, ISBN 973-8294-45-2
- EduTeca software, (2012), Spring - CD6: People and spring, Spring - CD5: Nature wakes up to live, Bucharest, Romania
- Gagne, R., Conditions of Learning, <http://irc.binus.ac.id/downloads/TE/Gagne.pdf>, accessed 2014, Jan.
- UNESCO Institute for Information Technologies in Education,(2012) ICT in Primary Education, Analytical survey , <http://iite.unesco.org/pics/publications/en/files/3214707.pdf>, accessed 2014, Jan.
- What the research says about using ICT in science, (2003), Becta ICT Research, <http://webarchive.nationalarchives.gov.uk/20130401151715/https://www.education.gov.uk/publications/eOrderingDownload/15015MIG2801.pdf>, accessed 2014, Jan.

THE IWB AS A BRIDGE BETWEEN PHENOMENA EXPLORATION AND INTERPRETATION OF ELECTROMAGNETIC PHENOMENA IN CONSTRUCTION OF FORMAL THINKING

Stefano Vercellati, Marisa Michelini, *Department of Chemistry Physics and Environment, University of Udine, Italy*

Abstract

The diffusion of the Interactive Whiteboard in schools is in continuous increasing, but, too often, it was simply used to catch students' attention or transpose on the "big screen" the class activities. In this paper is described a pilot study regarding the development of a Module of Formative Intervention for Prospective Primary Teachers in which the IWB as the role of supporter for the creation of a powerful context in which developed formal interpretation of electromagnetic phenomena starting from the analysis of experimental situations.

1. Introduction

Interactive Whiteboard (IWB) promotes the in-class cooperative activity and students' involvement (Glover et al., 2005). Its intuitive and friendly interface has the potential to support dynamical cooperation between students, opening discussions that, with the support of the graphical interface, promote the description of students' ideas.

The added gain which motivates the use of the IWB is related to its structural characteristics and the adopted interactive strategies in addition to the innovative educative styles that it promotes (Bell, 2002). The nature of IWB as open environment proposes new learning goals for science education, such as the gradual construction of scientific models of interpretation from those based on spontaneous common sense. The ways in which it become effective should be the object of teachers' formation in the view of allowing them to acquire operational skills (Michelini et al., 2013). A research based on a new approach to IWB use, which we call "Conceptual Modeling" was carried out in a Module of Formative Intervention (MIF) concerning electromagnetic interactions within the Physics Education course held at the University of Udine for Prospective Primary Teachers (PPT) during the academic year 2012-13.

2. IWB and electromagnetic phenomena analysis

In electromagnetic phenomena, literature highlights different kind of conceptual knots on magnetic and electromagnetic interactions, both in static (Viennot and Rainson, 1992; Tornkvist et al., 1993; Guisasola et al., 1999; Thong W M and Gunstone, 2008) and in dynamic situation (Maloney et al., 2001).

Pedagogical Content Knowledge (Shulman, 1987) in teacher education experiential model (Fera et al, 2012) require the contribution of content research by means of design based research on experimented educational path implemented and analyzed with empirical researches to provide examples of strategies and methods to overcome conceptual knots, but this is not enough.

Vertical curricular perspective have to be taken into account in each step of the gradual building of concepts in learning (Vosniadou, 2008; Michelini, 2005). To highlight the inner coherence that the continuum learning process have to guarantee starting from primary school in the electromagnetic topic treated.

In particular, the role of the field lines representation in the interpretation of the electromagnetic phenomena, is pivotal because field lines are a formal tool that, if used in the proper way, has a real powerful predictive role having an iconographic nature that do not need the mathematical treatment of the electromagnetic interactions (Vercellati, 2010). Therefore, the construction of the field lines representation and their properties had to be one of the main goals in the teaching of the electromagnetic phenomena because they act as referent conceptual tools (Vercellati, 2012).

The use of the IWB in connection with a webcam and simulations allows to create a powerful environment in which students explore the field lines characteristics and their role in a sort of modelling which is conceptual, i.e. *Conceptual Modeling*.

Using the webcam the actual experimental situation can be seen in real time, while with the IWB, the students can represent on a virtual transparent layer their spontaneous interpretative model drawing direct them on the acquired images.

Then, the IWB offer the context in which share and compare the different models and creates the context in which developed a shared model. In addition, the possibility to move this transparent layer on the visualization provided by simulation allow comparing the students' model with the one proposed to the simulation and, interchanging the simulated and the real situation, the core elements of the field line representation are explored and individuated.

3. The Conceptual Model activity

A learning path (Michelini and Vercellati, 2012), developed with a design based research aimed at achieving the development of a vertical learning path concerning electromagnetism (Vercellati, 2012), was used as base of a MFI for PPT. The MFI involved two small groups of ten students, in an activity attained at the development of an interpretative model from the experimental analysis of the magnetic and electromagnetic phenomenology.

The experimental learning path designed for the primary pupils (Michelini and Vercellati, 2012) was first experience in an Interactive Lecture Demonstration by PPT of phenomena exploration (Michelini and Vercellati, 2011).

Each conceptual step of the explorative path was re-analyzed by means of IWB discussing descriptive and interpretative aspects and adopting spontaneous iconographic representations of the interpretative ideas. Cooperative discussion of models gradually improves the spontaneous conceptual model in a sort of peer review in the group of teachers.

The role of the IWB became important as tool adopted in order to support the bridging from a local to a global interpretation of the different situations observed. This process is one of the most difficult in physics education and the development of educational context aimed to promote this change of prospective is one of the main goals of the educational research.

The situations proposed starts from the simpler ones to the more complex and in particular were addressed the interaction between magnets, magnets and iron objects and between magnet and compasses. The use of the IWB was pivotal to promote the process of clarification and the explicative efficacy of the different interpretative models. Every situation was recorded by a webcam and displayed on the IWB, so that, PPT, using the multilayer function provided by the IWB, could represent their iconographical explicative model drawing them directly on the actual situation acquired; see Fig.1.

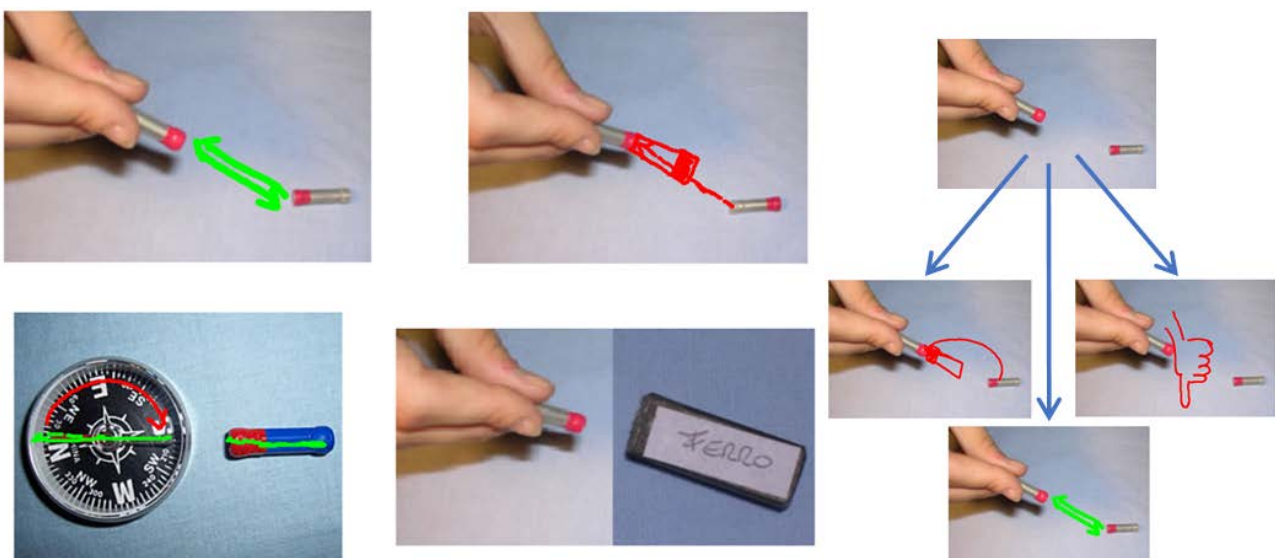


Figure 1: Examples of students' representation concerning the magnetic interaction proposed.

During the MFI, data were collected by audio recording of the discussions and using the IWB as a repository of the different proposals emerged.

In the first phase of the Conceptual Modeling activity, the different proposals coming out from the PPT were collected and stored to create a database of the proposed explanations and in the meanwhile have the opportunity to record the path of reasoning followed by the group of PPT (Robinson, 2008). The appropriate role of symbols is found to be a result gained from this phase of the discussion, which was started in a perspective in which arrows and trajectories were used as representations of states of motion or graphical icons rather than as formal symbols despite the PPT knew their formal appropriate meaning. As example, in the upper left frame of Fig. 1 the interaction between the magnets is represented as two opposite arrow, while in the other frame different proposals are reported (i.e. description of the motion of the magnets, representation of the final situation and intuitive iconographical representation represented as a thumbs-down to indicate that there is not attraction in that situation).

After this initial phase there was a cooperative phase in which PPT, discussing as peers, highlighted strengths and weaknesses of each representation. The level of interpretation (i.e. descriptive, interpretative...) of each proposal was individuate and the proposals were categorized on the base of it. This process allow PPT to isolate the interpretative from the descriptive aspects and the need of provide argumentation during the peer discussion empowered a process of deepening in the understanding of the causes of the phenomena. The evolution of reasoning has gone through the need of recognize the bipolar structure of each magnet and the interaction of each pole with both poles of the other magnet. The transition from the examination of the single interaction (force) to a couple of forces allowed PPT to account the rotation of the magnet while equal poles are approached; indeed a sort of principle of virtual work was used to justify it.

The structure of this activity was then re-proposed for the analysis of the field line representation. The field lines were constructed, step by step, starting from the exploration of the actual system using compasses with the aim of investigate the properties of the magnetic field that emerges from this type of investigation. The obtained pattern of lines is reported in the right frame of Fig. 2.

The obtained pattern of lines was overlapped to a simulation, left frame of Fig. 2, and its main properties (i.e. the symmetry of the pattern, the presence of zones with a greater thickening of lines, the not-constant distance between the lines) were discussed in connection to the representative meaning of the lines as the envelope of the directions of orientations of a compass placed in the space surrounding a magnet.

The distinction between the property of the space represented by the filed lines to the force acting at a point in the space has been addressed indicating the tangent direction at the field lines in one point and the direction of departure of a ferromagnetic ball placed at the same point. In this way, from the cooperative discussion based on the representation in the IWB, emerged the distinction between magnetic field vector force vector at a point of the space near a magnet (Fig. 2). The PPT's graphical symbols, earlier used almost only with iconographic role, now became symbols related with a specific physical meaning in the explored context.

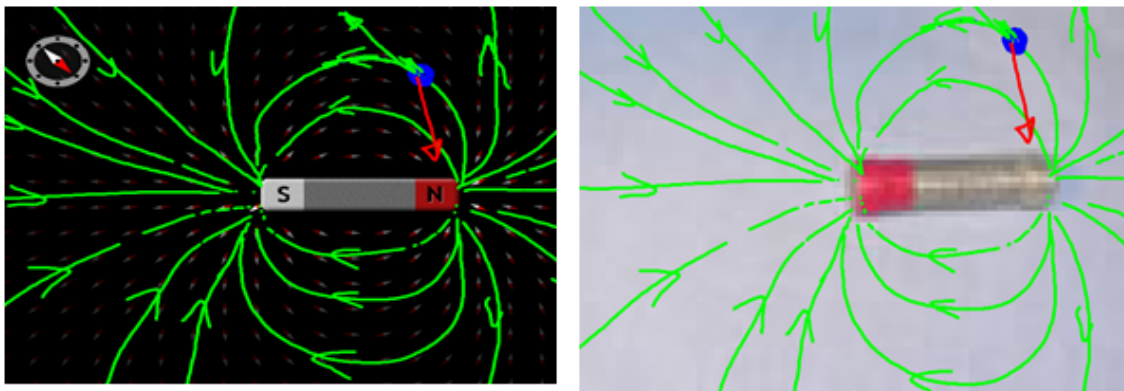


Figure 2. PPT representation of magnetic field lines and their overlapping to actual and simulated situations.

The possibility to overlap the field lines to different images, allow to explore the portability of the model and the properties of composition of the magnetic field around a magnet. By comparing the patten obtained with the one generated by two magnets placed orthogonal to one another, the discussion highlighted the hypothesis of vector composition of the magnetic property of the space at equal distance from the poles. This conceptual modeling lays the basis of the vector nature of the magnetic field in the view of a quantitative analysis of the magnetic field vector (Vercellati, 2012).

Indeed, as final activity, the field lines representation was also used to interpret situations of electromagnetic induction in which the predictive and explicative power of this tools was used to identify and explain the situation in which the phenomenon of the electromagnetic induction occurs.

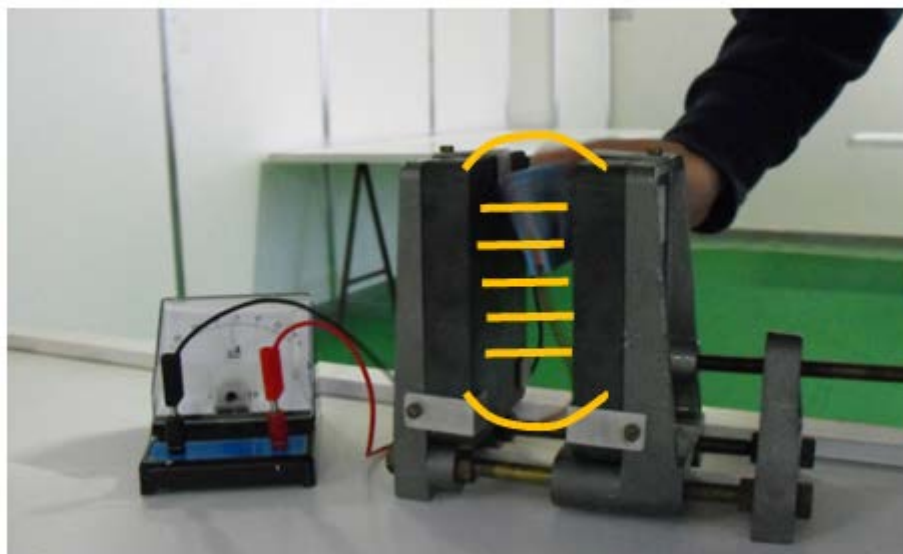


Figure 3. Representation of the magnetic field lines of two magnet to explain electromagnetic induction.

It was done by acquiring in real time the actual situation proposed in Fig. 3 representing the field lines of the magnetic field in the surrounding of the couple of the two big magnets and exploring the set of actions that are able to generate an electric current into the wire. In this way the action done were seen by all of the component of the group and, more important, the presence of the representation of the magnetic field as its pattern of field lines represents an objectification of tit that makes it visible and allow PPT to use it effectively in the interpretation of the electromagnetic induction.

4. Conclusions

The nature of the IWB as open environment offers many opportunities for new learning goals in the social constructivist perspective. The management of an open environment requires a teacher

familiarization not only with its features and potentiality, but also with learning situations that can be produced with it. The addressed MIF of electromagnetism with PPT highlighted the importance of the sharing and the comparison of ideas to acquiring a mastery of the simplest interpretation of the simplest elements, which characteristics, often taken as obvious in an instructional approach, are not recognized and re-used in the analysis of simple phenomena.

In particular, the IWB offers the opportunity of a conceptual change in the interpretative models that allows the bridging from a common sense to a scientific interpretations of the phenomena in a context of cooperative discussion between learners. The need of conceptual learning of the physical descriptions of phenomena is realized and empowered in terms of conceptual modeling using the IWB when the explicitation of the individual models becomes a kind of peer review work on the interpretations. The experience gained in the context of the magnetic phenomena shows that this process not only leads to the achievement of the peculiar characteristic of abstract entities as the magnetic field, but also to the gradual acquisition of formal meaning of symbols initially naively represented only with an iconographic nature.

The specific facilities of combinations of multi-layer promote PPT reflection on the consequences of some representations and allow them to construct hypotheses concerning important proprieties as the composition in the case of the presence of different magnetic sources. The multimedia nature of IWB allows the connection between the views of dynamic processes, such as the insertion of a coil in a uniform magnetic field, with the representation of the field itself. The connection between the generation of an induced current in the coil and the cutting of the field line is seen, allow to builds a first conceptual modeling (that differs from the previous ones) for the recognition of the variables and the process which produces electromagnetic induction.

The use of the IWB on the educative and the contents planes is needed to have an effective gain from its use in physics education. The use of multilayer representation report to be an effective tools in providing a way of approach in the analysis of the electromagnetic phenomena because it allow to support PPT's peer discussions producing an increasing of the clarity in the way in which the students explain their idea and, in the meanwhile, promote the sharing of opinions.

In addition, the possibility to trace the different proposals and their development among the discussion allow to document the path of reasoning that the discussion followed providing so an effective tool for the acquisition of the consciousness of each one of the sub-bridging argumentation that will construct the bridge between naïve and scientific interpretation.

Acknowledgements

We thank Massimo Faggioli (INDIRE) for the useful discussions and the Promethean Ltd Company for the resources provided and the technical assistance.

References

- Bell M A (2002) Why Use an Interactive Whiteboard? A Baker's Dozen Reasons!, Teachers.net gazette, Vol. 3, 1.
- Fera G, Prasad Challapalli S R C, Michelini M, Santi L, Stefanel A, Vercellati S (2011) Formare gli insegnanti all'innovazione didattica e all'orientamento in e-learning: il master IDIFO, Connessi! Scenari di innovazione della Formazione e della Comunicazione, Minerva T, Colazzo L., Ledizioni, 411-420.
- Glover D, Miller D, Averis D, Door V (2005) The interactive whiteboard: a literature survey. *Technology, Pedagogy and Education* 14, 2, 155–170.
- Guisasola J, Almudi J M, and Ceberio M (1999) Students ideas about source of magnetic field, Proceedings of the Second International Conference of the European Science Education Research Association (E.S.E.R.A.) 89-91.
- Maloney D P, O'Kuma T L, Hieggelke C J and Heuvelen A V (2001) Surveying students' conceptual knowledge of electricity and magnetism. *Am. J. Phys. Supp.* 69, S12–S23.
- Michelini M (2005) The Learning Challenge: A Bridge between Everyday Experience and Scientific Knowledge, in GIREP book of selected contributions, Ljubljana, 18-39.
- Michelini M, Santi L, Stefanel A (2013) La formación docente: un reto para la investigación, *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, 10 (núm. extraordinario) pp. 846-870
- Michelini M, Vercellati S (2012) Pupils explore magnetic and electromagnetic phenomena in CLOE labs, *Lat. Am. J. Phys. Educ.* Vol 1 (10), 6.

- Michelini M, Vercellati S (2011) Exploring the sources of magnetic field and the interactions between them to interpret electromagnetic induction: a proposal of conceptual laboratory, in Teaching and Learning Physics today: Challenges? Benefits?, International Conference GIREP-ICPE-MPTL 2010 Proceedings, Université de Reims Champagne Ardenne, Reims 22-27 August 2010.
- Michelini M, and Vercellati S (2010) Primary pupils explore the relationship between magnetic field and electricity, in Raine D, Hurkett C, Rogers L, Physics Ed. Community and Cooperation: Selected Contributions from the GIREP-EPEC & PHEC 2009 International Conference, Lulu/ The Centre for Interdisciplinary Science, Leicester 2, 162-170.
- Shulman L S (1987) Knowledge and teaching: Foundations of the new reform. Harvard Educational Review, 57,1, 1-21.
- Thong W M and Gunstone R (2008) Some Student Conceptions of Electromagnetic Induction, Res. Sci. Educ.38, 31-44.
- Tornkvist S, Pettersson K A, and Transtromer G, (1993) Confusion by representation: on student's comprehension of electric field concept, Am. J. Phys.61, 335-338.
- Vercellati S (2012) Electromagnetic Induction: a vertical path for conceptual learning, PhD dissertation. Thesis.
- Vercellati S (2010) Construction of the concept of field seen as a process starting from an cal based rational reconstruction, New Trends in Science and Technology Education. Selected Paper, vol. 1, eds. L.Menabue and G.Santoro, CLUEB, Bologna 2010, 336-339, ISBN 978-88-491-3392-9 (2010).
- Viennot L, and Rainson S (1992) Students' reasoning about the superposition of electric fields, IJSE14, 475-487.
- Vosniadou S (2008) International Handbook of Research on Conceptual Change, Routledge, New York.

THE IWB FOR THE CONSTRUCTION OF FORMAL THINKING: PROPOSALS FOR PROSPECTIVE PRIMARY TEACHERS CONCERNING MOTION, ELECTRICAL AND MAGNETIC PHENOMENA

Stefano Vercellati, Giuseppe Fera, Marisa Michelini, Sri R. C. Prasad Challapalli, Alessandra Mossenta, Alberto Stefanel, *Department of Physics Chemistry and Environment, University of Udine, Italy*

Abstract

The Interactive Whiteboard is a multimedia tool that has a continuous increasing diffusion in schools, but, too often, it is used to a simple transposition of activities designed for other multimedia tools. The development of specific designed activities centered on the development of learning process as regards the methods of teaching and the contents of the specific disciplines is needed. In teaching/learning physics, IWB can become a tool for conceptual modeling. In this paper, examples of activities designed for primary school pupils are discussed in relation with motion, electrostatic, magnetism phenomena evidencing the role of simple tools of the IWB to stimulate the formalization and the collaborative discussion between pupils.

1. Introduction

The interactive whiteboard (IWB) is a teaching tool that aims to promote the meeting between the teachers' classroom practice and the pupils' learning needs in terms of content, strategies and meanings. It has the potential to support dynamic cooperation, building new cognitive skills related to visual and perceptual aspects. The characteristics of flexibility, interactivity, efficacy, and interactive multimedia have an important impact on motivation, concentration and active participation of students during the development of learning pathways (Glover et al., 2005) becoming a resource for the development of formal thinking and scientific learning. It, creating an environment which facilitates the representation and the comparison of the interpretative ideas, constitutes a new potential for science education and stimulates significant and radical changes in teaching offering more efficiency to the routine strategies (Ilyas and Al-Tabtabaie 2004). The history of student reasoning, often evoked as the basis for the progress in learning, can be well documented using the IWB and its features can make peculiar the dynamics of the teaching-learning process. The interactions between pupils and teacher becomes a resource: in fact, the delicate process of bridging from naïve representations based on common sense ideas to physical interpretative models constructed by the class community becomes a path of reasoning that could be acquired by the community itself if it is documented (Robinson, 2008).

1.1. *The IWB as part of the change in the didactic practice*

New technologies initially support, then extend, and indeed transform teaching strategies during the teachers' process of acquisition of competencies and expertise. Each one of those steps must be justified for its use in the context of the school curriculum as regard the teaching goals and the students' needs. The introduction of ICT technology in school cannot be considered a part of the context. The changes brought by the use of the ICT are strongly depended on the teacher's ideas about the types of functionality that it has for teaching. The IWB is in fact a catalyzer of attention of the class in the sense that it is able to promote active participation as well to depress it when it serves as a vehicle for transmission of information. Identify how specific characteristics of the IWB can contribute to the achievement of learning objectives and improve student understanding of key aspects of disciplinary knowledge significantly is a task that had to be reached. The effectiveness in obtaining a significant change in the teaching strategies depends on the ways in which IWB is adapted to the existing teaching approaches and priorities embedded in domain specific discipline and in its actual practice. The IWB must present itself as an opportunity to reconstitute the teaching approach, otherwise the risk is the enhancement of passive roles for students; for example, the increased speed of production and delivery of materials. The objective of teaching and learning process should be placed at the base of the choices of use of the IWB, in a context in which the

learner and his/her personal involvement in the proposed activities is placed at the core (Otero 2003; Michelini 2010). One of the central questions is therefore the teacher formation, both in-service and initial (Jang, 2010).

1.2. Prospects of use of the IWB for science learning

In science education, the use of the interactive whiteboard for simulations did not show significant increasing in performance compared to the one obtained with laboratorial activities, but it often encourage students to participate more actively creating interest and promoting personal involvement (Akbas et al., 2011). In fact, students consider interactive simulations and virtual experiments preferable than the real experiments because they provide an opportunity to have a better view of the contents (Akbas, 2011). The production of materials for the IWB is a need. In literature (Stoica, 2011) the potentialities of the IWB, declined taking into account the findings coming out the cognitive research, have been taken into consideration investigating the way in which teachers can promote an interactive learning in physics and stimulate the creative potential of the students, according to the theory of cognitive load. The role of the teacher emerges as the person who highlights the deficiencies in the integration of contexts and facilitates the transition from the everyday phenomenon to the scientific description, asks questions and provides answers and involves also the less active students in the learning process. Integration of IWB with other technological devices can be enhanced in this way: for example, it can be utilized to display data and graphs obtained in real time during an experiment assisted by computer. In a similar experimental activity, the student has the possibility to observe in real time the evolution of physical quantities, and the IWB can increase the interactivity of the observation. The IWB provides many advantages for teachers as the ability to manipulate objects in real time and the benefits of long-term planning of resources. The proposal of meaningful activities for learning that promotes the IWB therefore assumes relevance with respect to the potential and the quality of teaching. In particular, as regards physics education, the IWB could support the process of *Conceptual Modeling* to bridge students' knowledge from an everyday-life to scientific interpretation of the phenomena.

1.3. The context of the activity

On the base of the analysis of the potentialities of IWB those that promote the construction of formal thinking will be examined in the present paper. The next examples constituted a selection of emblematic situations that can be carried forward to other subject areas once clarified the role played by the functionality of the IWB. They will refer to activities done with prospective primary teachers enrolled in the second year of the master degree in Science in Education at the University of Udine. These proposals drew inspiration from earlier research, which led to the production of produce validated educational learning path in physics in which was adopted an inquiry based approach (McDermott, 1996). The rationale of those learning path lie on the developing of vertical learning pathways which, from the first exploration of the phenomenological reality introduced the construction of a formal interpretation of the phenomena in primary schools (Mossenta and Michelini, 2010) providing Modules of Formative Intervention (MFI) designed in the framework of the Model of Educational Reconstruction (Duit, 2007). The activities proposed, structured as conceptual micro-steps, are focused on the analysis of simple and everyday-like experimental situations in which the use of the IWB is proposed to improve the process of formalization of the phenomenological situation addressed. In this way, activities with the IWB took place in small group (max 10 people) with a duration of one hour. We present here the activities proposed under this feasibility study, referring to another location analysis process.

2. Electrostatics

A number of studies on the students' learning of electric circuits (Duit, 2006) pointed out several difficulties and the need to link electrostatics and electrodynamics to integrate macroscopic and microscopic aspects as a common basis of interpretation (Psillos, 1998). Group activities supporting hands-on activities with computer visualizations of the model were proposed to students

(Otero, 2003). Those activities allow the involvement of peers at small group level, but they are not able to allow a whole class discussion and a wider sharing of problems and meanings. The IWB use offers the possibility of a global group involvement. We proposed the IWB first as an instrument for the recalling of the previous acted hands-on activities, then for the construction of an interpretation of such phenomenological observations both on the micro-macro perspective in interpretation. Fig.1. Starting from the representation of the interpretative entities, we used the IWB to concretize procedures allowing, after the building of a model for the interpretation of an observed phenomenon, to separate it from the specific object of study and to transfer it to other phenomena, to validate it and finally to give it a global interpretative value as a model enriched and gradually specified on the basis of specific phenomenology.



Figure 1: Students' activities concerning electrostatics: identification of the link between the type of preparations and the effects of the interaction, and representation of interpretative models.

First students had to identify the connection between an action done on a system and the system behavior after it. Some pictures of adhesive tape pasted on different surfaces were proposed along with pictures of couples of adhesive tape strips moving towards or away from each other. On the methodological plane: a) the action on the systems is distinguished from their behavior, connecting the strips of adhesive tape placed on a surface with one (or more) suspended strips; b) the descriptive and interpretative planes are separated, identifying the repulsion (or attraction) of the strips as an interaction responsible for the observed strips movement towards or away from each other. As concerns contents, we addressed the problem of distinguishing between two different states of the ripped adhesive tape and the several different preparations determining them or, equivalently, the existence of only two electrified states. In this differentiation emerge: the same possibility to be charged of conductors and insulators; the distinction between nature and state of the electrified system (due to the type of the pair in the electrification process and not to the nature of the electrified object); finally, a cognitive pattern where differences of *causes* are associated with differences of *effects*. A reconstruction of the activity carried out allowed to discuss learning knots, emerged also during the revision of the interpretations, that can be overcome through sharing and peer discussion promoted by the IWB. The subsequent discussion, arisen from the request of representation of the models of the observed phenomena, highlights some features of the formalization process: in a macroscopic model the change of state was labelled by changing the color of objects (acting on a picture of the phenomenon) or by drawing representative symbols on them or representing them with a colored segment. Where, in the latter, emerges the selection that excluded physical features not relevant for the analysis of the phenomenon from the electrostatic point of view. Switching from the macroscopic to the microscopic model, the change of state emerges as the level of containment of entities, the charges, which are at the root of the macroscopic property that allows objects to interact. From a simple model in which each type of electrified object "contains" only one kind of entity (shown as colored spots, 2 colors depending on the kind) emerges an idea of the state of the electrical neutral matter as balanced composition of two types of charge. Charging of a system (a single tape strip) is viewed as a local change in the balance of charges maintaining at the global level (strip and surface of the table where it was

taped) the overall charge owned before the interaction resulting in charging. Not only the states are seen (macroscopic or microscopic as a result of the interpretation of phenomenology), but also the processes that determined them.

3. Magnetism

In physics, build the physical model of reality starting from the reality itself is one of the most challenging one (Michelini and Vercellati, 2012). To accomplish it, the IWB role in the development of educational contexts is pivotal. In fact, as promoter of the cooperative activities alongside the possibility to work in a graphical way by overlaying multiple layers to images of actual phenomena, makes the IWB an ideal tool to support the conceptual modeling process.

The situations proposed were: the interaction between two magnets, the interactions between a magnet and a compass and the interactions between a magnet and a piece of iron. Using a webcam, the real situations were displayed on the IWB acquiring the recording of the phenomena and using the frame images to analyze particular instants of the situation. Initially the involved students have designed their proposal explaining the phenomenon by overlapping their representations the actual situation. This initial phase of collection of students' proposals was followed by a discussion aimed to highlight strengths and weaknesses of each representation and to identify for each of them the level of interpretation. In addition, overlaying multiple layers on the same real situation and grouping the interpretative models with the same level of interpretation in the same layer, the different group of interpretations were analyzed and the key elements in the description of the phenomenon and the core elements of the model of the process were individuated. Indeed, the portability of the developed model was stressed by overlapping it to different experimental situations and by checking how it can be re-used in different contexts.

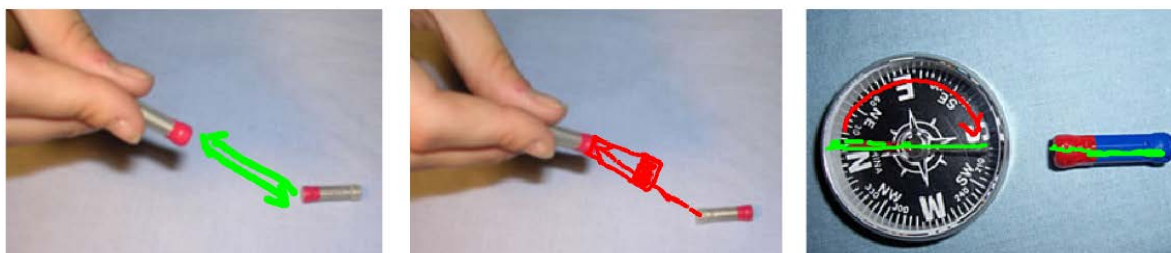


Figure 2: Examples of students' representation of some of the magnetic interaction proposed

Fig.2 shows the proposed solutions with few examples of the students' representations of the interpretive processes. In the left representation, a student has represented the action between the approaching poles as opposite arrows; in the middle, another student, the final situation in which the two magnets are attached. These two representations, very different in terms of interpretative plane, represent two distinctive approaches to the analysis of the phenomenon which overlapping at different levels is essential in order to construct a consistent model. The IWB in fact, offering the context in which students explicit their interpretation, allow students to create a repository of interpretations which enrichment constitute the ground on which construct the interpretative model.

4. Motion

In mechanics, at least three areas are and problematic for student learning and important to construct a functional understanding of the basic concepts (Hestenes 1992): the role of the reference system for the description of motion (Viennot 2002), the graphical representation of the temporal evolution of the kinematic quantities and its connection with the real phenomenon (Thornton and Sokoloff 1999), the representation of an interaction though the concept of force (Michelini, et al., 2002). In all these areas, the IWB can play an important role in creating environments and contexts of active learning for pupils.

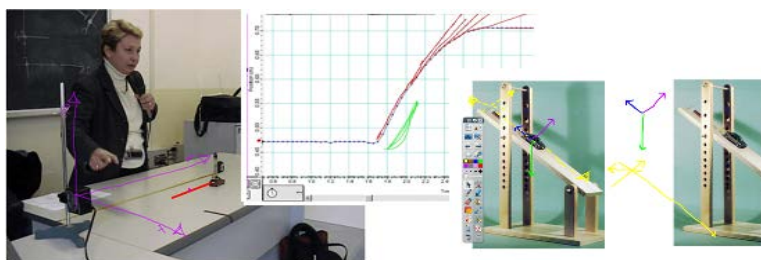


Figure 4: On the left, analysis of a real situation to address the role of reference frame, trajectory, and graph of motion. On the right, the description of the interactions with the forces starting from the real situation

The analysis with the IWB in an experimental situation actually lived (a toy car hit and allowed to move freely on the table in front of a sensor sonar ranger type) allows students to create a structural connection between the image of the phenomenon (the picture of the toy car on the bench) and the different levels of formalized representation of motion: the reference system, the trajectory, the graphical representation of the kinematic motion (Fig. 4). The IWB tools also allow representations on multiple layers, giving the freedom to move, without interruption, from the integrated representation of the different planes (interacting systems, reference system; force representation; motion...) to the separation of each level of representation and analysis (Fig. 4)

5. Conclusions

To have an effective gain by the potentiality of the IWB, its potentiality must be oriented on the disciplinal and educational plane. The connection with the phenomenology by means the use of images drawn on the actual situation using multilayer representation, provides an approach for the construction of formal thinking and the interpretative models. Two goals were attained with the modules of formative intervention regarding electrostatics and magnetic phenomena for prospective primary teachers: forming the involved students to the topics proposed and provide to them ideas for activities in order to be customized and reused in their class work with pupils. The peer cooperation was initially a bit awkward for some students that are reluctance to expose themselves, but it was gradually overcome by the attractive aspect of the IWB and the learning context provided by the increasing peer discussion in the class. The graphic mode and the dynamic visualization of the models and the formal interpretative entities promote an efficient communicative channel between peers. The quality in which students describe their ideas loses of ambiguity as a result of the use of the expressive visual channel, while the verbal sharing of meanings in the group is simplified because communication is encouraged. It is still to analyze how the prospective primary teachers will transpose these activities in their educational design activities and what meanings (disciplinary or models) have been modified through the formalization proposed by the IWB.

6. Acknowledgement

We thank Massimo Faggioli (INDIRE) for the useful discussions and the Promethean Ltd Company for the resources provided and the technical assistance.

References

- Akbas O, e Pektas H M (2011) The effects of using an interactive whiteboard on the academic achievement of university students. *Asia -Pacific Forum on Science Learning and Teaching*, 12, 2, Article13, 1-18.
- Duit R (2007) Science education internationally: Conceptions, research methods, domains of research. *Eurasia Journal of Mathematics, Science & Technology Education*, 3, 1, 3-18.
- Glover D, Miller D, Averis D and Door V (2005) The interactive whiteboard: a literature survey. *Technology, Pedagogy and Education* 14, 2, 155–170.
- Hestenes D (1992) Modelling games in the Newtonian World, *American Journal of Physics*, 60, 732-748.
- Ilyas M A B and Al-Tabtabaie A M (2004) Improving Knowledge Delivery and Information Retention through 'Smarter' Interactive Whiteboards, *Proc. of International Conference on Computers in Education 2004*.
- Jang S J (2010) Integrating the interactive whiteboard and peer coaching to develop the TPACK of secondary science teachers. *Computers & Education* 55,1744-1751.

- Michelini M (2010) Building bridges between common sense ideas and a physics description of phenomena to develop formal thinking, *New Trends in Sci Tech Edu. CLUEB, Bologna 2010*, p.257-274.
- Mossenta A, e Michelini M (2010) Inquiring learning proposals on conceptual knots in electrostatics. *New Trends in Science and Technology Education. Selected Paper, vol. 1*, eds. L.Menabue and G.Santoro, CLUEB Bologna, ISBN 978-88-491-3392-9, p.341-353.
- Michelini M and Vercellati S (2012) Pupils explore magnetic and electromagnetic phenomena in CLOE labs, *Lat. Am. J. Phys. Educ. Vol,1,10,6*.
- Michelini M, Santi L, Sperandeo R M (2002) Proposte didattiche su forze e moti. *Forum: Udine*.
- McDermott L C (1996) *Physics by inquiry*. John Wiley & Sons.
- Otero V (2003) Cognitive Processes and the Learning of Physics Part I: The evolution of knowledge from a Vygotskian perspective, in *Vicentini M. e Redish E.F. (eds) Proc. of the International School of Physics "Enrico Fermi", Varenna, Italy, IOS Press, Amsterdam, 2003, 409-446*.
- Psillos D (1998) Teaching Introductory Electricity in *Tiberghien A., Jossem E., & Barojas J. (eds.), Connecting Research in Physics Education with Teacher Education An I.C.P.E. Book 1997, 4*.
- Robinson A (2008) Easy Implementation of Internet-Based Whiteboard Physics Tutorials. *The Physics Teacher, 46*.
- Stoica D, Paragin F, Paragin S, Mirona C, Jipa A. (2011) D.et al, The interactive whiteboard and the instructional design in teaching physics, *Procedia Social and Behavioral Sciences 15, 3316–3321*.
- Thornton R K, Sokoloff D R (1999) Learning motion concepts using real-time microcomputer-based lab tools, *American Journal of Physics, 58 (9), 1999, 858-867*.
- Viennot L, (2002) *Enseigner la physique*, De Boeck, Brixelles.

‘THE JOURNEY OF ELECTRICAL ENERGY’: AN EDUCATIONAL ANIMATION FILM FOR PROMOTING SCIENTIFIC LITERACY IN PRIMARY AND SECONDARY SCHOOL

Anna Spyrtou, Penelope Papadopoulou, George Malandrakis, Elias Pierrakos,
University of Western Macedonia, Greece

Abstract

Present study concerns an educational animation about the production of electrical energy. The theoretical framework of Science, Technology, Society, Environment education (STSE), as well as the description of the design, and the developmental phases of the film are also discussed. Our guiding goal was the production of a film aiming to enhance students' interest, motivation and knowledge about science. The film discusses four themes: importance of electricity in everyday life, process, occupational experts involved, and environmental impacts. Primary evaluation results indicate that film is a sound educational material for inquiry teaching.

1. Introduction

Childhood has changed rapidly over the past few years – and the methods that we use as teachers of children and young people should reflect these changes. Children learn more and durable when they enjoy what they are doing. Using animation in teaching, aims not only to be fun, but also effective in encouraging and developing children's learning. Underpinning these admissions, the production of this film based on two educational considerations: (i) the perspective of STSE education, (ii) the research results concerning students' interest about science.

STSE education highlights the idea of teaching science in an integrated manner linking the scientific, technological, societal and environmental aspects of an issue. Literature strongly indicates that science would become more meaningful to students through the STSE approach (Pedretti & Nazir 2001, Zeidler et al. 2005). Furthermore, diverse pedagogical methods and educational materials have already produced in order to support the initial idea of Jim Gallagher (1971): 'For future citizens in a democratic society, understanding the interrelationships of science, technology and society may be as important as understanding the concepts and processes of science' (p. 337). In line with this consideration, three years ago a new science curriculum for primary school was developed in Greece, aiming to constitute students able to negotiate social issues related to scientific, environmental and technological aspects of their daily life (Plakitsi et al., 2013). The film discussed in this paper is included to the educational material suggested for the New Greek science curriculum⁸.

The second driving force in developing the animation film is the well-documented decline of students' interest in studying science subjects coupled with their negative attitudes towards scientific careers (Christidou 2011, Osborne et al. 2003). International studies record unsatisfactory results concerning students' achievement on science literacy, fostering the need to improve science curricula, teaching and teacher education (Eurydice, 2011, OECD 2009). Furthermore, the role of school to encourage students for future science professions has recently asserted to be a stronger factor than the family background (Basl 2011). As a result, in a country troubled by a severe economic crisis, like Greece, the development of innovative educational materials for science teaching is crucial for changing students' negative attitudes towards related professions and, consequently, for fostering nation's future economic competitiveness.

Taking into account the above two considerations, in the present paper we focus on the introduction of digital storytelling in teaching environments. Looking across recent educational proposals for promoting students' meaningful learning, as well as on interest about science, we realize that digital storytelling is considered as a powerful technological tool (Sadik 2008, Robin 2008). Teachers could use digital stories integrating visual pictures, audio and written texts in order to enhance students' imagination about a topic, to link the specific with the general knowledge, to realize how the whole gives meaning to the part (Bryan 2011, Robin 2008). To frame our work in

⁸ Science Curriculum for Primary School, 5th grade, pg 83, <http://ebooks.edu.gr/2013/newps.php>, Accessed February 28, 2014.

Greek educational reality, a recent study showed that Greek primary teachers emphasize the need for using multiple information sources to teach science (Plakitsi et al. 2013). However, teachers face great difficulties in incorporating such material in their teaching, as the available Greek digital science stories are still rare, and from the other hand, the abundant electronic media is available mostly in foreign languages.

Based on the above, we decided to produce an animation film about the production of energy, which is an important and traditional science topic, contributing in such way to the enrichment of Greek digital educational science stories. Moreover, following the perspective of STSE education we anticipate that our film can positively contribute in changing students' interest about science. Last but not least, by translating this film in English, we expect to gain a better understanding of its educational impact, through its dissemination in many other countries.

2. Characteristics of the educational animation film

The energy topic is a constituent part of the Greek science curriculum (grades 5th to 11th) and the animation is an attempt for its teaching transformation. It incorporates characteristics of informal learning and it was developed to be entertaining in nature and attractive for students.

It focuses in four themes: (i) importance of electricity in everyday life, (ii) production process, (iii) occupational experts involved, and (iv) environmental impacts. In the first theme, our aim was to help students understand, through a digital storytelling, that although electricity is a daily-used and fundamental commodity, however a complicated and highly demanding process is needed for its production. The second theme deals in detail with the production of electrical energy into a thermo-electric power plant, organized in six main steps. The highly-trained and expert personnel involved in every stage of the production process was the third theme covered by the film, putting emphasis to the most dangerous and difficult posts, such as welders and linesmen. In the last theme, the main environmental impacts of lignite-produced electricity are highlighted, along with the use of renewable energy sources.

The animation is composed in a widescreen format (16:9), with 1280 by 720 resolution (HDTV standard) and it runs at 24 frames/second. An original soundtrack follows the narration in accordance with the theme area. The film developed using various techniques, mainly cut-out and tradigital animation, while a variety of professional software was also applied (i.e., 'Adobe's Photoshop', 'After Effects', 'Premiere', 'TVPaint Animation', and 'Preonus Studio One').

The animation has already won the 3th prize to the Pan-Hellenic Competition of 'Learning and Technology' in 2011 and it is available online⁹.

The aim of this first educational implementation of the film was to reveal students' general impression about the animation, as well as their self-evaluation about the knowledge they gained.

3. Methodology

Sixty-five students of Grade 10 (38 females, 27 males) attending a suburban high school in Central Macedonia, Northern Greece, participated in the study with the majority of them to inhabit in the surrounding suburban (n=43) and rural (n=22) areas. This geographic area adjoins Western Macedonia, where the main lignite mines and thermo-electric power plants of Greece are located, producing over half of country's electricity.

Participants watched the educational animation during the study of the respective curriculum topic in physics classes. A pre/post research design was used for the assessment of animation-triggered students' learning and motivation in science.

A questionnaire with nine open and one closed-form questions was administered, before and immediately after, to all students who watched the animation. The pre-test questionnaire items were focused on students' pre-existed knowledge on the topic of energy production and on their learning interests on the topic. The post-test questionnaire items were aiming to reveal students' general impression about the animation, as well as their self-evaluation about the knowledge they gained. In the present study, data obtained from five post-test questions (four open, and one closed-form) are presented.

⁹ <https://www.youtube.com/watch?v=coWQ1R2r5MY>.

In open-form questions, students' answers were broken down to units of analysis, which in the particular case, are units of meaning. The latter are a sentence, a phrase or group of words having a clear meaning (Patton 2002). Produced units of meaning were categorized using the pre-defined category scheme of science–technology–society–environment (STSE), which had already been used for the development of the animation. However, in the cases where crucial units of meaning, regarding aspects of students' understanding about the animation, were not fit to any of these STSE categories, new categories were developed using the constant comparison method (Patton 2002). The particular categorization process was extremely successful, as only a slight percentage of original units of meaning were not categorized (2.78%). Finally, for the closed-form question, an ordinal scale of measurement was used ('not at all', 'a bit', 'adequately', 'to a great extend').

4. Results

4.1. Students' general impression about the educational animation

Sixty-two out of 65 students (95%) expressed a positive general impression about the animation and only three of them (5%) made a negative comment. From the analysis of students' answers, 154 expressions (units of meaning) were identified, concerning their first, general impression about the animation (Figure 1). The majority of these expressions were related to the Knowledge gaining category (58.4%), while the remaining was almost equally distributed between Aesthetics (18.8%) and Interest stimulation (22.7%). About half of the Knowledge gaining impressions was associated to Science and Technology (22.7%), with Society (11.7%) and Environment (9.7%) to gain far less percentages.

4.2. Knowledge gaining

- a. *Self-evaluation.* The vast majority of students (94.83%) were either 'adequately' (65.52%) or 'in a great extend' (29.31%) evaluated their knowledge gaining about electricity production as positive.
- b. *Vocabulary gaining.* The analysis of students' answers revealed that their vocabulary related to energy production was enriched by an average of 2.58 terms per student (max=5 terms/student – min =0 terms/student). The total number of new terms learned by students was 11, having the following distribution to the STSE categories:
 - Society (55.76% of students, 4 terms): '*district heating*' (or '*teleheating*'), '*electricity pylons workers*', and '*welder*'.
 - Science and Technology (43.64% of students, 7 terms): '*conveyor belt systems*', '*electricity pylons*', '*electric generator*', '*turbine*', '*electromagnet*', '*boiler*', '*turbine blades*'.
 - Environment (0.61% of students, 1 term): '*lignite*'

During analysis, no words were recorded that clearly fitting to the science category, and only one ('electromagnet') could not be clearly associated with either science or technology categories. As a result, a merged 'science and technology' category was developed containing the words from the technology category, as well as and the ambiguous one.

4.3. Association with previous knowledge

In the third open-ended post-test question, students were asked to associate issues that watched in the film with their previous knowledge. From their answers (54 positive, 1 negative and 10 missing) 82 units of meaning were identified. Their distribution, as well as examples of these associations, to the STSE categories is the following:

- Science – Technology (79.3% of units of meaning): e.g., '*... I knew that a magnet was necessary ...*'; '*I knew about the propeller and now it linked with the rest*', '*I knew for lignite but I had no idea how [electricity] is produced in a plant*'
- Society (10.8% of units of meaning): e.g., '*[I knew about] the lignite plant in Kozani ... but I did not know that is the main source of electricity throughout the country*'
- Environment (9.6% of units of meaning): e.g., '*for example I knew about lignite but did not know that at some time there will not be no more*', '*[I knew about the lignite plant in Kozani] ...*'

and that is harmful to the environment

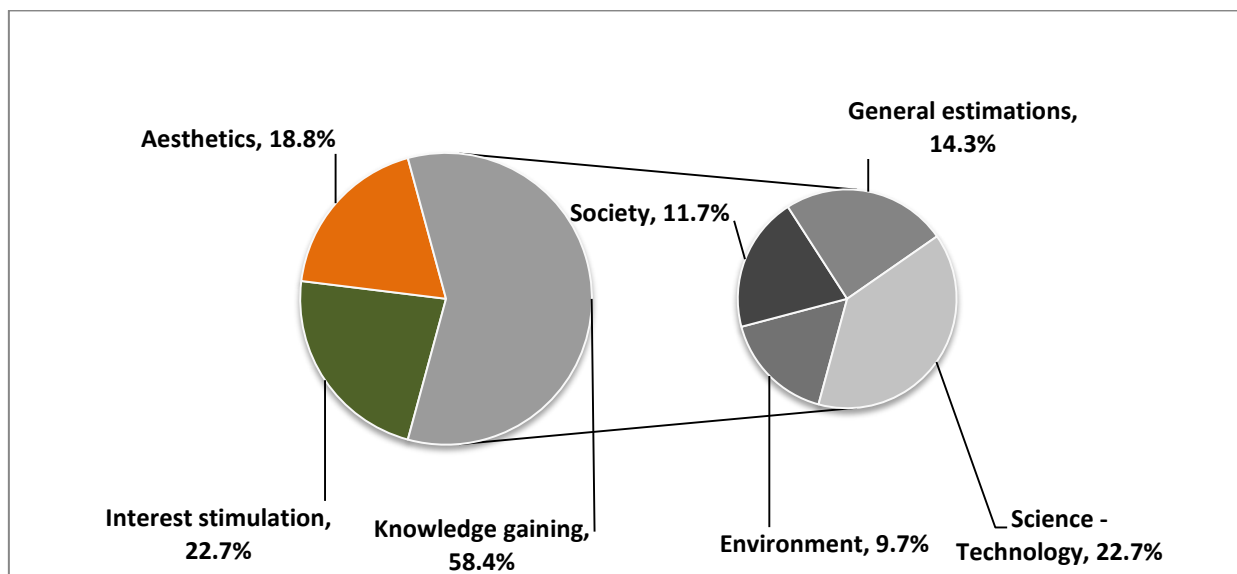


Figure 1. 'My first impression about the animation is...'
 (Total Units of analysis=154)

As in the vocabulary gaining (section 4.2.b) no associations were identified that could be clearly fit to the science category, and another two units of meaning could not be undoubtedly associated with either science or technology categories. As a result, a merged 'science and technology' category was developed again encompassing the units of meaning from the technology category and the two vague associations.

4.4. Questions triggered to students after watching the animation

In the fourth post-test open-ended question, students were asked to note any queries triggered to them by the animation. Fifteen students noted that everything was clear to them, while 14 students did not answer the particular question, which could possibly imply that they have no queries. However, as there no another data to support such claim, these answers categorized as missing. For the remaining students (36), the number of queries they noted coincides with the units of meaning, as each one of them mentioned a single query. Examples of these queries and their distribution the above-used categorization scheme is as follows:

- Science – Technology (77.78% of queries): e.g., 'how we can get energy from sea waves', 'How the magnet helps to produce electricity', 'I would like to know how long is the burning of lignite and how quickly energy is transferred through cables', 'How do they connect cut cables?'
- Society (11.11% of queries): e.g., 'I did not understand this issue related to the district heating', 'I did not understand why the villages that were close to the source have heating and if they pay the same bills with us to PPC¹.'
- Environment (8.33% of queries): e.g., 'Why not trying to replace all these harmful energy sources with other more healthy?' 'With the pylons of PPC to be dangerous within less than 200 meters, why do they place them near to highways?'

5. Discussion

Through this first educational evaluation of the animation film, an effort was made to identify its potential in improving the ways that students learn in science education. Initial results are very encouraging in respect of both the design objectives and the learning outcomes. More specifically, students' self-evaluation data support that the animation triggered students' interest and motivation, while knowledge and terms gaining results indicate enhanced students' learning. Students' knowledge gaining, in some extent, seems to fit in the used curricular theoretical

framework, that of STSE education. Even though that far more Science/Technology terms were gained by students, *Society* terms are more popular among students. Moreover, the traditional and conservative Greek educational setting is revealed, as students seem to link their new knowledge mostly with Scientific/Technological aspects rather than Societal and Environment ones.

It is very encouraging that this film provides opportunities for inquiry-based teaching in science education, as it was recorded through the queries generation. Students' questions and curiosity is a prerequisite for inquiry and the animation seems to be successful in this sense. As a result, it is up to teachers to grasp these opportunities for enhancing connections with societal and environment issues and promote inquiry-based teaching.

Implementation and evaluation process will be continued, and future research is expected to shed light on the educational value of the animation for different age groups.

References

- Basl J (2011) Effect of School on Interest in Natural Sciences: A comparison of the Czech Republic, Germany, Finland, and Norway based on PISA 2006, *International Journal of Science Education*, 33(1), 145-157
- Bryan A (2011) *The new digital storytelling*, Praeger, Santa Barbara, California, USA
- Christidou V (2011) Interest, attitudes and images related to science: Combining students' voices with voices of school science, teachers and popular science, *International Journal of Environmental & Science Education*, 6(2), 141-159
- Eurydice (2011) *Science Education in Europe: National Policies, Practices and Research*. Brussels: Eurydice
- Gallagher J J (1971) A broader base for science teaching, *Science Education*, 55(3), 329 – 338
- OECD (Organisation for Economic Co-operation and Development) (2010) *PISA 2009 Results: What Students Know and Can Do-Student Performance in Reading, Mathematics and Science, (Vol.1)*, Paris
- Osborne J, Simon S, and Collins S (2003) Attitudes towards science: a review of the literature and its implications, *International Journal of Science Education*, 25(9), 1049-1079
- Patton M Q (2002) *Qualitative Evaluation and Research methods*. Sage Publications, California
- Pedretti E, and Nazir J (2011) Currents in STSE Education: Mapping a Complex Field, 40 Years On, *Science Education*, (95), 601 – 626
- Plakitsi K, Spyrtou A, Klonari K, Kalogiannakis M, Malandrakis G, Papadopoulou P, Stamoulis E, Soulios J, Piliouras P, and Kolios N (in press) New Greek Science curriculum for primary education: Promoting educational innovation under hard conditions. Paper accepted for publication in 13th ESERA International Conference, 2- 7 September 2013, Nicosia, Cyprus
- Robin B (2008) Digital Storytelling: A Powerful Technology Tool for the 21st Century Classroom, *Theory into Practice*, (47), 220-228
- Sadik A (2008) Digital Storytelling: a meaningful technology-integrated approach for engaged student learning, *Education Technology Research Development*, (56), 487-506
- Zeidler D, Sadler T, Simmons M, and Howes E (2005) Beyond STS: A Research-Based Framework for Socioscientific Issues Education, *Science Education*, (89), 357-377

THE USE OF COMPUTERS AND MULTIMEDIA IN THE ITALIAN KINDERGARTEN, PRIMARY, AND LOWER SECONDARY SCHOOLS IN RESULTS BY EU PROJECT SECURE RESEARCH ON THE USE OF COMPUTER IN ITALIAN COMPULSORY SCHOOLS

Stefano Vercellati, Marisa Michelini, Lorenzo Santi, *Department of Physics Chemistry and Environment, University of Udine, Italy*

Abstract

The European Project SECURE, investigating the curriculum of mathematics science and technology, provide a relevant set of data related to the actual situation of the scientific education in the base schools. On the base of those data, the actual situation of the use of the ICT technology in the Italian school is analyzed and addressed to highlight the main characteristics and the main critical points.

1. Introduction

The main goals of the SECURE project are to provide relevant and rigorous research data and translate them in recommendations that contribute to the debate among policy makers on mathematics science and technology curricula and their objectives in a way that address the balancing between the needs of training future scientists and the broader social needs.

A total of 11 partners in 10 countries, of which 7 universities and 2 pedagogical institutes are involved in the project: Katholieke Hogeschool Kempen University College, Dienst Katholiek Onderwijs vzw, Universität Graz, University of Cyprus, Technische Universität Dresden, Università degli Studi di Udine,, Nationaal expertisecentrum SLO, Uniwersytet Jagiellonski, Univerza v Ljubljani, University of Gävle, Nottingham Trent University.

The cores of the project are: the analysis and the comparison between the objectives and the contents of the scientific curricula in the involved countries.

In different contexts of the research in education, the definition of “curriculum” has different meaning (Beauchamp, 1986; Pinar et al., 1995; Walker, 2003) which have substantive distinctions between them (Clements, 2007).

As theoretical framework of the research, the van den Akker (2003) theory represented by him as a curricular spider web (Fig. 1) with the addition of the motivational aspect was placed at the ground of the analysis.

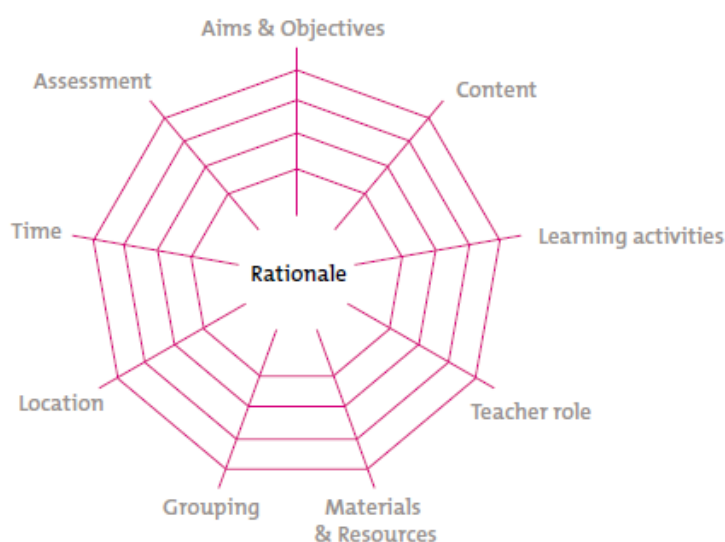


Figure 1: van den Akker's representation of the curricular spiderweb.

The SECURE research was focused on the analysis of the curriculum of mathematics science and technology of 5, 8, 11 and 13 years old learners. This analysis was done at different levels - Supra (international), Macro (national), Meso (school, institute), Micro (classroom, teacher), Nano (individual, pupil) – by using grid for the analysis of the official documents, and questionnaires and interview to investigate pupils and teachers opinions.

To investigate the national documents a specific grid based on the Bloom's taxonomy was developed and all of the curricular documents of the involved countries were analyzed. To investigate pupils opinions, two different version of the questionnaires were developed: one for the 8 year old pupils and one for the 11 and 13 years old and semi-structured protocol of interview. The two versions of the questionnaires differ for the number of questions (97 and 108, respectively) and the number of options available for the close replies (3 and 4 respectively).

Questionnaires and interviews were also performed with teachers by preparing questionnaires and protocols of interviews depending on the subject matter taught. In this paper will be presented the results emerging from the investigation of the technology curriculum in Italy (Michellini & Vercellati, 2012).

2. The investigation of the Italian official ICT in school curriculum

Two documents were analyzed: the curricular indication of the 2004 and the one of the 2007.

In the former, emerges how there is not an explicit mention of ICT as regard the 5 y.o. pupils (kindergarten), while it is explicitly mentioned for the 6 y.o. pupils (first year of primary school) where are mentioned elements related to the earlier approach to the use of the computers: i.e. know the main component of computers, be able to turn on/off the computer, begin to use internet, perform simple educational games. At 8 y.o. – third year of primary school – word processing and web search activities are introduced and developed in the following two years of education, where are also reported the capability to create simple web pages and the use of didactic software concerning elemental calculus and geometry. The 11 and 12 y.o. represents the first two years of lower secondary school. At the end of those, pupils had to know the functioning of the operative systems and to be able to use real time communication network and “translate” algorithm in a program by means of the use of simple programming language. The organization of information in information structures, the capability to ménage at distance and remote activities (i.e. automation, telecommunication, teleworking...) and the knowledge of the first useful element needed to obtain the European Computer Driving License (ECDL), are the final goals for the base school in Italy.

In the 2007 Curricular indication, specific ICT goals are related only to the 10 and 13 y.o. pupils (i.e. at the end of the primary and lower secondary education. At the end of the primary school, pupils had to be able to use computer tools and communication in situations of games and relationship with others and to use new technologies and languages to develop multimedia works across disciplines to present the results and to enhance the

communication skills. For the 13 years old, instead, they must be able to use the new technologies and multimedia languages to support their work, advancing hypotheses and validating them to evaluate themselves and to present the results of the work and ad to be able to look for information by selecting and synthesizing them, developing their ideas to be able to share them with others.

3. Pupils' and teachers' perceptions of the ICT in Italian curriculum

In Fig.2 are reported the distribution of use of the learning materials during the class of mathematics, science and technology.

For all of the subjects matter and for all of the pupils, but the technology class for 8 y.o., the most used learning materials is the textbook. In detail, as regards mathematics, computers are only occasionally used, while video are almost never used with the exception of the 8 y.o. pupils, where the use of such learning materials is more frequent even if also in an occasionally way.

In science the situation is similar to the ne reported for mathematics, even if the use of videos is more often. For technology, as for the other subjects, the distribution of the use of the material for the 8 y.o. pupils differs from the other. Here, it happens in more manifest way, because in the Italian primary schools the technology is often seen as coincident with the use of computers, while

in lower secondary it is a wider subject.

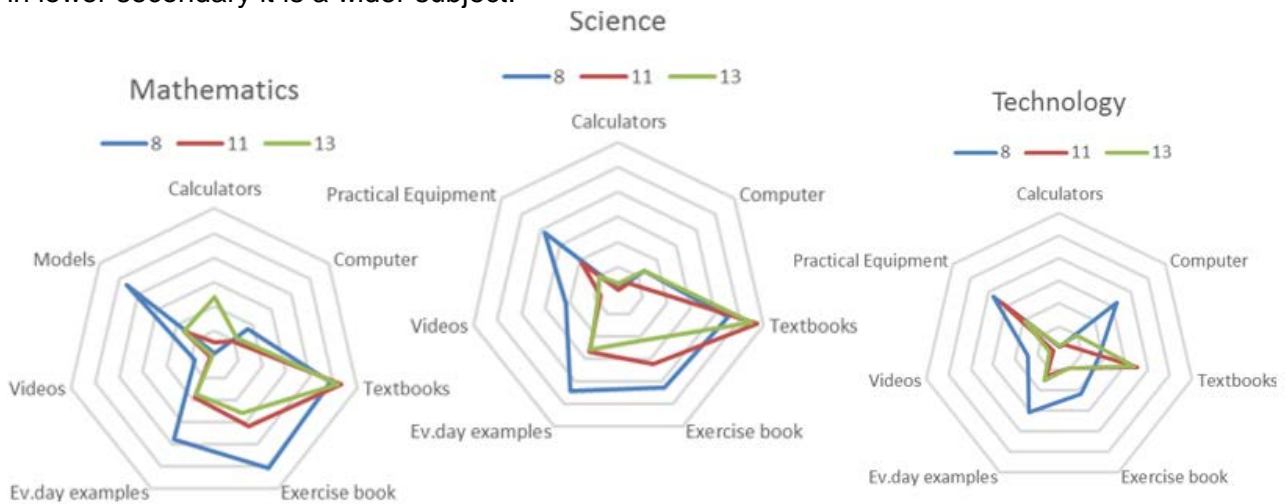


Figure 2: Pupils' use of learning materials during their class of mathematics, science and technology

From the teachers point of view this picture is confirmed: the two ages in which the use of the computer is more often are 8 and 13 y.o. Generally it is more use in relation to activity of science and technology, while for mathematics it is as an occasional role; Fig. 3.

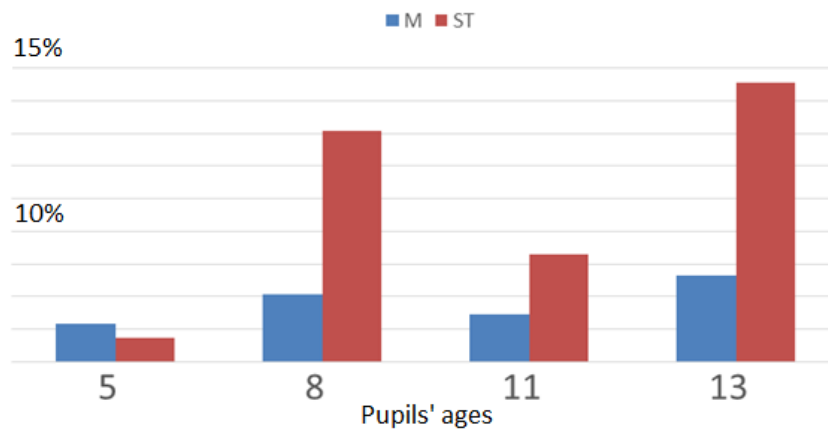


Figure 3: teachers' replies about the use of computer in class.

This low use of computer in the school practices was investigated among three factors: the lack of hardware, software and support in the use of the ICT devices. As could be noticed by the distribution of replies reported in Fig.4, the main limitation factor is the lack of support. It is highlighted in all of the involved ages, while the lack of hardware and software are more peaked in secondary schools becoming the main factor for the 11 y.o. pupils.

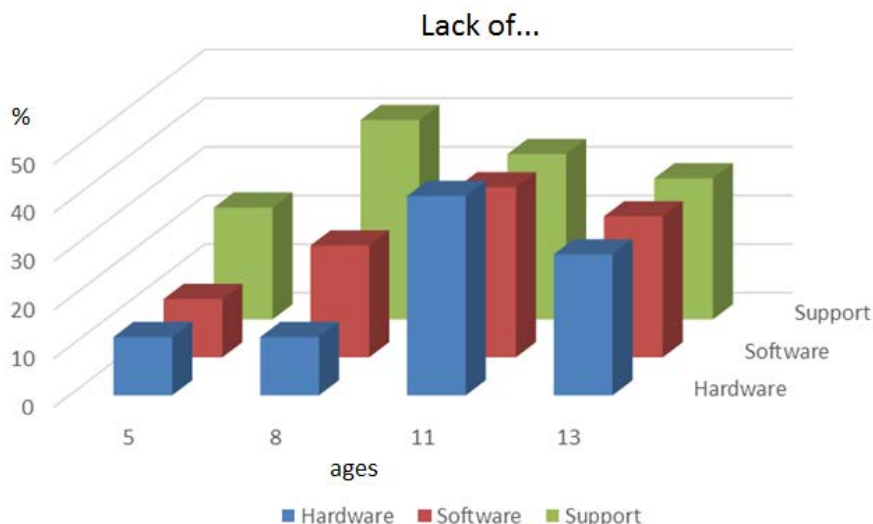


Figure 4: distribution of the limitation factors for the use of ICT in class.

From the analysis of the interviews, 2 on 6 of the 11yo teachers of mathematics and science used the IWB to show video and picture (mainly in science) and to do better geometric drawings (mainly in Mathematics). During the use of computers in class, pupils work mainly alone even if peer cooperation activities are allowed and promoted. Almost all of the teacher of 5 and 8 y.o. denoted a lack of textbooks and proposals of activities for children of that ages, while emerge a big work of designing and preparation of the leaning material by some teachers (mainly in primary) who do a big amount of work of design and develop by their own learning path for their students.

4. Conclusions

The analysis of the collected data allows the reconstruction of the actual situation of the Italian schools as concern ICT, providing information about the frequencies with which the multimedia materials are used during the learning activities. Teachers and pupils vision appear to be in accordance. Even if, with several projects and initiatives, the multimedia materials were introduced in school, they are not frequently used even if pupils appreciate them. Teachers found in the lack of support the main limitation factor in addition to the lack of textbooks and organic proposal for the use of ICT in the subjects the reason of it. Nevertheless, there are several teachers that, by they own, try to overcome this situation providing to their pupils learning materials and self-designed learning path. Indeed what emerges is a gap between the intended goals written in the curricular guidelines and the school practice even if some individual teachers or small groups of teachers are working on this issue, but this is not enough. A focused work on the development of content related proposals has to be done to address systematically this problem providing teachers with clear and effective strategies for the use of the multimedia materials and the ICT in the teaching of their subjects.

5. Acknowledgements

This work is based on the SECURE research project (No SIS-CT-2010-266640), which received funding from the European's Unions Seventh Framework Program for Research and Development.

References

- Akker, J. van den (2003). Curriculum perspectives: An introduction. In J. van den Akker, W. Kuiper & U. Hameyer (Eds.), Curriculum landscapes and trends (pp. 1-10). Dordrecht: Kluwer Academic Publishers.
- Beauchamp, G.A. (1986). Curriculum theory: Meaning, development, and use. *Theory Into Practice*, 21(1), 23-27.
- Clements, D.H. (2007). Curriculum research: Toward a framework for 'research-based curricula'. *Journal for Research in Mathematics Education*, 38, 35-70.
- Michellini M, Vercellati S (2012) SECURE – Science Education CUrriculum REsearch Project under the

MPTL18

Madrid 11-13 September 2013

7th Framework Program, Proceedings of the IOSTE Symposium Hammamet.

Pinar, W. F., Reynolds, W. M., Slattery, P., & Taubman, P. M. (1995). *Understanding curriculum: An introduction to the study of historical and contemporary curriculum discourse*. New York: Peter Lang Publishing

Walker, D.F. (2003). *Fundamentals of curriculum: Passion and professionalism* (2nd edition). Mahwah, NJ: Lawrence Erlbaum Associates.

TOOLS FOR LEARNING PHYSICS AS REGULAR APPLICATIONS TO MID

Konstantin Rogozin, Alexander Kaplinsky, Altay State Technological University,

Sergey Kuznetsov, Tomsk National Research Polytechnic University, Denis Yanyshv, M.V.Lomonosov Moscow State University

Abstract

Two new tendencies in the organization of the teaching process have become obvious now: 1) using of net technologies to deliver and represent teaching content (distant learning); 2) using of specially equipped auditoriums (TEAL) in which all types of classes can be taught (lectures, practical classes and labs). Unification of delivering and representing teaching content for different teaching techniques is an important goal to be reached. One of the possible ways is the use of Learning Management Systems such as MOODLE adapted to MID (Mobil Internet devices).

1. Introduction

Physics education has always been and still is the main engine of human development, including the humanities. We live in a transitional era - an era of constant change in the content and instruments of education. Along with the development of the humanity Physics education passed four stages, each of them had its own physics curriculum and material carrier of knowledge. The first one is the Pre-educational stage (the Ancient East and Egypt, accumulation of basic knowledge about the world, the instrument of education was human communities). The next stage is Initial educational stage (Ancient Greece and Rome). In Russian, we call Annul Domini the "new era". The new era began in the year of 325 BC, in the year of Lyceum of Aristotle. Education, especially physical education, became a social phenomenon. In this stage the main process was scholarization of education, in which the major teaching tool and information carrier was a teacher. University stage (Western Europe) is characterized by bookinization of education. At that time the language of modern science was created.

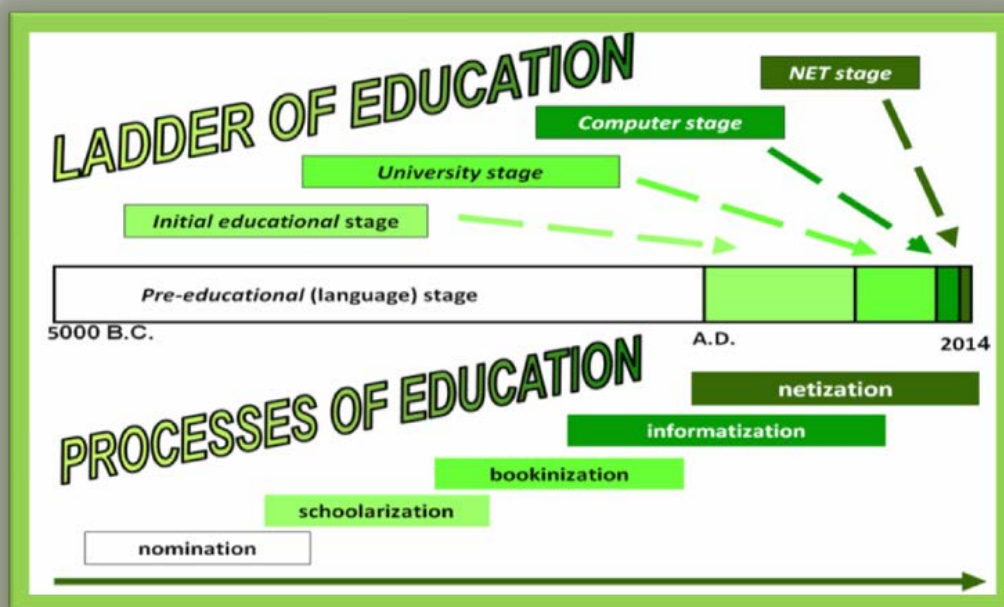


Figure 1: Ladder of Education

It all started with the plus and minus signs (15th century). Descartes suggested the name of the coordinate axes. Newton created his Mechanics and Optics. The code systems for

recording physics laws, tables and graphs were created. Books became a tool of education and universities were becoming its center. In Computer stage (highly developed countries) PCs are a tool of education (informatization of education). The development of physical education is the process of creation and improvement of physical process models. Computer technology enabled us to make these models dynamic. At present, physics education is passing on to the next stage – Net stage (whole world, netization of education). Network instruments for learning physics allow using all the Internet information resources accumulated by the humanity and learning physics using PCs, tablets and mobile phones at any place and at any convenient time. Multimedia network instruments are able to create a special physics learning space where students:

- get a sufficient amount of information;
- are offered up-to-date computer instruments for decision-making;
- get physics competences through the use of new cognitive technologies.

Education has a large inertia associated with the change of instruments, carriers of educational content and especially the teacher community. Our students are already at the highest stage, whilst most of the teachers still have to climb to it. Key competences are a new paradigm of the result of modern education. We agree with the idea that competence is —the ability to apply students outcomes adequately in a defined context (education, work, personal or professional development) (Key Competences 2007). The first and most important part of this definition suggests that competence is the result of learning. It makes us focus our attention primarily on the technique, technology and tools used in the process, as well as the ideology of their use. Another important part of the above definition is "the ability to apply learning outcomes". It means that students should be ready to apply their skills in a real situation. In accordance with the basic principle of cognitive psychology (Sternberg, 2006) competences are formed within the framework of activities that are directed to reach the goal. This means that the learning process should be offered the works in which learners make decisions in situations which are close to real. In our opinion it can be organized as interactive work using MID – devices. In this article, we discuss some theoretical aspects and our experience. Particular examples will be showcased in other publications.

2. Three aspects

The following three aspects of creating physics learning instruments can be singled out:

- **Informational** (knowledge itself);
- **Technical** (software);
- **Technological** (way of using knowledge and software).

2.1. Information aspect

By typing —electromagnetic induction, for example, into one of the search engines on the Internet both in Russian and English, I was able to retrieve more than 2 million answers. In both of these cases the same Internet resource appeared as the first result. It was Wikipedia. According to opinion polls, rarely do students go to the second page of the search engine results. This means that the best information resources are not available to students. Today in the Internet, Wikipedia is the available source of information. We must offer professionally made physics learning instruments to our students. Maybe they will be the second result straight after Wikipedia. In the first phase we have to offer students a minimum amount of specifically organized physics content. This content should be accessible with the help of technical devices used by students.

2.2. Technical aspect

The technical aspect can be subdivided in two parts: **Preparation of knowledge representants** and **Visualization of knowledge representants**.

Preparation of knowledge representants. In our opinion, further development of software has a commercial character, and is not for the users. We can create representants of any complexity with the standard package of Microsoft Office and MO for Mac. With these tools, one can

create any fantasy. This can be done only with the professional knowledge of the aforementioned tools. Then the representants of physics knowledge are built using web technologies for educational tools. **Visualization of knowledge representants.** Effective teaching tools are determined primarily by how well they use the laws of cognitive psychology and psycholinguistics. Redish (2003) said that

—to understand learning, we must understand memory - how information is stored in the brainll (p. 18). Here we have three major stages to consider. Sternberg (2006) stated —Encoding refers to how you transform a physical, sensory input into a kind of representation that can be placed into memory. Storage refers to how you retain encoded information in memory. Retrieval refers to how you gain access to information stored in memoryll (p. 217). We have two input channels of information. Miller (2004) said —Input from the eyes and ears is first stored in the short-term sensory store. As a computer hardware analogy, this memory is like a frame buffer, storing a single frame of perceptionll The analogy of the human brain to a computer makes sense to identify the limit.

(Card 1986), this is due to the ability of perception of visual symbols. First of all, the brain can not actively connect more than seven items at once (Miller 1956). Second important feature is the ability of the brain to forget. Based on the experiments conducted by Ebbinghaus we have built the forgetting curve (Ebbinghaus 1887).

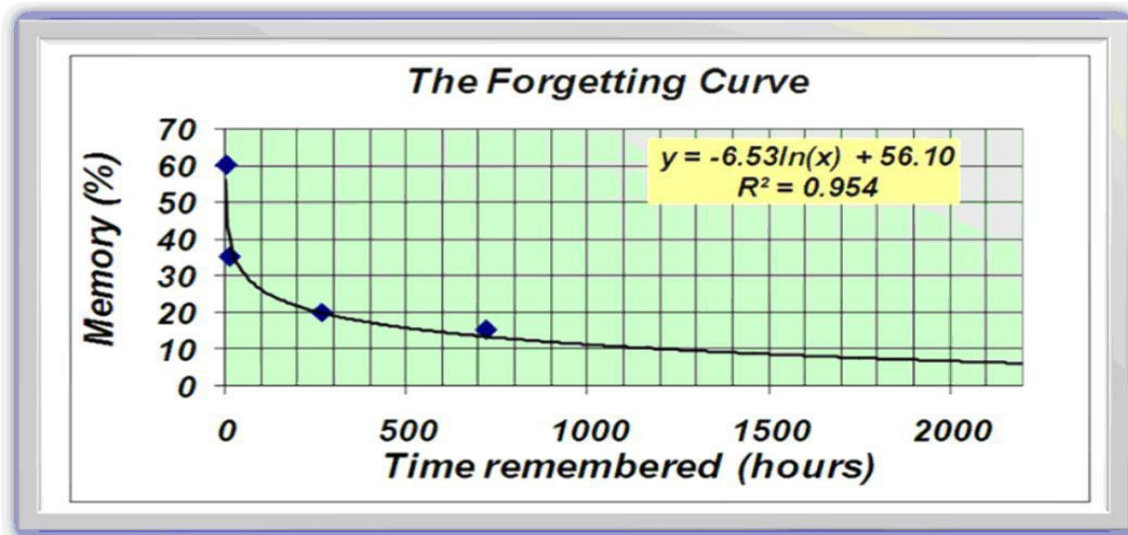


Figure 2: The Forgetting Curve

The **result** shows that a few months later even in the case of simple and coherent mental constructs the memory can store the maximum of 5 percent of the original input information. This explains why (in our opinion) and the experiment carried out by four American professors of physics in the mid-nineties of the last century. They were teaching the same course in the Mechanics using various teaching techniques (problem-solving, experiment, theory and book without any changes and deviations). The mean scores of all the classes were the same within 1% for all the professors. Based on these results, David Hestenes (Taşar 2012) made a seemingly unexpected conclusion: —So, student scores were independent of the professor’s experience, teaching technique, or whatever...ll (p. 148).

Apparently, he's right if the teacher uses only one of these teaching techniques. Modern technical facilities enable students to use all of these techniques for training at any place and at any convenient time. It is the networking opportunities that the Internet provides us. In our opinion by the aforementioned teaching techniques of physics we should add one more technique. It is computer simulations of physical experiments.

Thinking is based on verbal information. Thought expressed in words is the beginning and the end point of the process of decision making. Use of different code systems make integration and organization of verbal information relatively easy (Sternberg 2006). —They

fill in gaps when provided with partial or even distorted information and visualize concrete aspects of verbal information. (p. 244).

The use of different teaching techniques in the consideration of the same physical phenomenon will allow the new connections by integrating the new data into our existing schemas of stored information. Squire (1986) named this process the consolidation. It means a —process (Sternberg 2006) of integrating new information into stored information (p. 578). In humans, the process of consolidating declarative information into memory can continue for many years after the initial experience. This approach allows forming universal research skills as the components of metacognition, our ability to think about and control our own processes of thought and ways of enhancing our thinking (p. 221).

2.3. Technological aspect

There exist only two technologies for learning instrument

- creation: Centric system (—PUSH) technology; Cognitive
- (—PULL) technology.

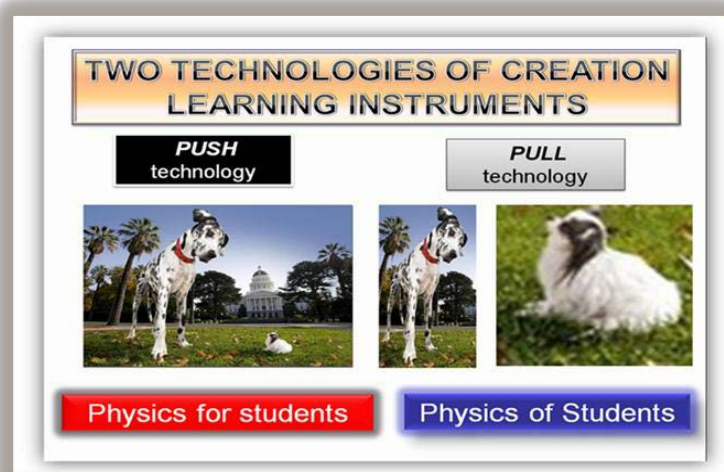


Figure 3. Two technologies of creation learning instruments

In the first one the teacher is central in the learning process. He requires from the students to learn the knowledge which he expects from them. In the second, the students and the teacher are of equal magnitudes. They work together. The students and the teacher form competences acquired in mastering the World. In our opinion, we can not require from the students to keep in mind several hundred formulas, definitions and concepts. But we need to teach our students how to find the necessary information to make informed decisions. Besides, we can teach them the effective ways of using this information, the way of systematic scientific inquiry.

The concept of "modeling cycles" was introduced to the academic community in 1995 by a group of authors, which was composed of the above named David Hestenes with colleagues (Wells 1995). The basis of their approach to teaching physics is the assertion that "in order to improve the quality of your students' physics skills you need them to go through the same path of learning that took physics as the science of the study of physical phenomena".

Modeling cycle involves three successive stages. The first of these is the allocation of the most essential aspects of the physical phenomena (usually physicists describe their physical characteristic), sufficient for its full description. The second stage is the definition of relations between selected parties (physical characteristic) and the definition of the boundaries of their changes. This is the stage to create a model of the physical phenomenon. The last step involves checking the created model of the physical phenomenon in practical action in the experiment. Using such learning algorithm, as the authors wrote in their publication, significantly improved the results of students.

3. Our experience

Modern informational, intellectually saturated with interactive learning instruments and educational technology requires a work of the specialized creative professional teams (in applied mathematics, computer science, psycholinguistics, designers, physics and physics teaching methods) both at the stages of their creation and the operation. This problem is no less complex and important than the construction of an international the Collider and can be solved in an integrated project including technical, technological and organizational solutions. That is why the authors of this article are professors working in three biggest Russian universities. We have teamed up together to achieve a common goal. We decided that the first of these includes: a) Development of software for support invariant to the basic software of the MID-devices; b) Accumulation (and the creation of its own), standardization and adaptation of the best multimedia content to MID-devices and integration its in the educational process; c) Implementation of new tools intended for direct access to educational content and laboratory and classes equipment; d) Rendering methodical assistance and support to teachers. In the second it should be possible to use in MID devices different techniques of teaching physics.

The best way of learning is an active one. Using the Internet is by definition an interactive activity. When we were creating physics learning tools, we used the idea of modeling cycles and cognitive technology for contraction. We have created an educational resource which has a complex layered structure (currently there only exists in the Russian version) and includes: more than 3000 original author tasks; a full university course "General Physics" (in 3 parts); a short course (as a reference); 48 thematic presentations; 45 visual aids for lectures; several hundred files containing additional information. All educational content we put LMS MOODLE deployed on portals of Moscow State University.

The teaching control with the use of MID - devices we organize as cognitive tests (Rogozin, 2014). The cognitive tests are understood as the learning process in which we provide students with access to the content and decision-making tools. The offered content must be organized in a special way, and decision-making tools allow teacher to evaluate the actions committed by students.

It is not possible to create effective learning tools for students without the participation of students themselves. Teachers and students are representatives of different generations only aligned in time. Teachers have the knowledge and experience. Students perceive the world differently. Therefore, it is essential to combine in one resource the skills of teacher with feelings of students. In our workgroup there are 12 volunteers. Volunteers along with teachers created bank of tasks. They changed ways of presentation of tasks themselves adding multimedia emotions and filings (with their faces and jests). They proposed not to make any changes in original applets. Then they also proposed not to explain anything about the tasks. They just decided to integrate pictures of model computing experiments, which they made themselves, into structure of tasks. At the time when other students were taking the test volunteers were working as tutors and were sending messages with comments about the tasks as well as writing blogs in different socials nets and communicating directly with learners.

We conducted a survey of several hundred school students (10th and 12th grade in K-12 system) and 1st, 2nd year university students. One of the questions was: "would you like it if physics

learning tools were available to you at the MID devices?". 99 percent of respondents said "Yes."

They made their choice. We, physics teachers and professors, also need to make our choice. We have to make the tools for learning physics as regular applications to MID.

4. Conclusion

At the moment, two trends are noticeable in the use of digital technology. On one hand, there can be noticed a rapid replacement of personal computers by mobile devices. On the other hand, they become more powerful and increase their interactivity. We believe in a few years MID devices will be the primary means for getting information and decision-making. Students will be no

exception to this. That is why my group is working on a project in which the best resources (content, video, computer models and so on) may be delivered to mobile devices.

References

- Card, S., Moran, T., & Newell, A. (1983). *The Psychology of Human-Computer Interaction*. Hillsdale, NJ: Lawrence Erlbaum.
- Ebbinghaus, H. (1885). *Memory: A Contribution to Experimental Psychology*. Translated by Henry A. Ruger & Clara E. Bussenius (1913). New York, NY: Columbia University. <http://psychclassics.yorku.ca/Ebbinghaus/index.htm>, accessed February 2014
- Miller, G.A., (1956). The Magical Number Seven, Plus or Minus Two. *The Psychological Review*, vol. 63, 81—97, <http://psychclassics.yorku.ca/Miller/>, accessed February 2014
- Miller, Rob. (2004). *User Interface Design and Implementation*. Massachusetts Institute of Technology, <http://ocw.mit.edu/courses/>, accessed February 2014
- Redish, E.F. (2003) *Teaching Physics With the Physics Suite*: John Wiley & Sons, Inc., <http://www2.physics.umd.edu/~redish/Book/>, accessed February 2014
- Rogozin, K.I. (2014) *Physics Learning Instruments of XXI Century*, Proceedings of The World Conference on Physics Education 2012, Pegem Akademi, Ankara, Turkey, <http://www.wcpe2012.org/proceedings.html>, accessed February 2014
- Squire, L. R. (1986). Mechanisms of memory. *Science*, 232, 1612-1619.
- Sternberg, R. J. (2006). *Cognitive psychology* (4th ed.). Belmont, CA: Thompson Wadsworth.
- Taşar, M. F., Bilici S.C., Pınar, F. (2012) An Interview with David Hestenes: His life and achievements. *Eurasia Journal of Mathematics, Science & Technology Education*, 8(2), 139-153.
- The Key Competences for Lifelong Learning – A European Framework (2007), <http://www.alfatrall.eu/>, accessed February 2014
- Wells, M., Hestenes, D. & Swackhamer, G. (1995). A modeling method for high school physics instruction. *American Journal of Physics*, 63, 606–619.

VIRTUAL LABORATORY IN THE TEACHING OF ASTRONOMY AND ASTROPHYSICS IN SLOVAKIA

Mária Csatáryová, *Faculty of Humanities and Natural Sciences, University of Prešov in Prešov*

Štefan Parimucha, *Faculty of Science, Pavol Jozef Šafarík University in Košice*

Abstract

Astronomy and astrophysics are scientific disciplines which are particularly suitable for teaching of natural sciences as they have a non-negligible impact on the increase of pupils' and students' interests in physics and scientific and technical subjects in general. An enormous increase of astronomical measurements that are presently available to the general public opens new possibilities for their use in teaching. There are several all-European projects in the world whose aim is to intensify the teaching of astronomy through modern educational technologies. We have concentrated on astronomical interactive computer programs Stellarium and Aladin which offer the user software tools for the searching, virtualizing and analyzing of data not only for scientific but also teaching purposes. These programs can be deservedly called virtual laboratories. Using them we can observe processes in the night sky in real time, but also in the past and in the future. With help of displayed data we can explain a phenomenon in a historical context of its discovery or process the latest astronomic data. We suggested simple astronomical tasks which had been tested at all levels of education, from pupils of primary schools to University of the third age. This article describes some features of the above mentioned computer programs as applied to enhancing physics lectures or after-school activities.

1. Instructions

Recently, astronomy and astrophysics has reached unprecedented development and the results of its research are appealing not only to the scientific community but also to the general public. Astronomy is also a good example of a branch of science that is closely related to other scientific disciplines and is globally ranked as a suitable motivator for science education. Nevertheless, the astronomy teaching at primary and secondary schools occupies still less space. In curricula of primary and secondary schools in Slovakia, astronomy does not appear as a separate subject. In Slovakia, the interest in studying natural sciences, not only mathematics and physics, is rather low the fact which copies the world-wide trend. The school reform, however, offers teachers ways how to create new subjects that could be included in educational curricula. Observations from the teaching practice, however, reinforce our view that teachers do not use the opportunity of including astronomy under optional subjects. The fundamental question therefore is how to get astronomy to school. One option is to rely on core competencies of graduates with lower secondary education degrees, in particular, familiarity with the application of information - communication technologies. Introducing these computational tools to classroom allows students to work with modern technology, while supporting active research components, and developing students' technical thinking and their interest in science. The inclusion of an optional subject in school astronomy education programs, training of which will be supported by interactive computer programs, is one of the possibilities for implementing the above-mentioned goals.

2. Interactive computer programs and their use in school practice.

The necessity to increase attractiveness of science disciplines in education is presented not only in our work but also by foreign experts. One option is meaningful and effective use of modern technology, including software that supports excellence in teaching. In teaching astronomy we can find efforts to support instruction with interactive programs. We mention a few publicly accessible programs: *Galaxy Zoo*, which is suitable for classification of galaxies; *Solar StormWatch* offers studies eruptions on the Sun and *Planet Hunters* is aimed at finding extrasolar planets of observed data from the Kepler satellite. Listed interactive programs are currently used in the preparation of

future astronomers, as well as science teachers. Skills that students acquire while solving various attractive tasks posed in these computer environments can be applied in their subsequent scientific work and teaching career. Among the many programs available, we focused on astronomical interactive computer programs - products of the European project virtual observatories (EURO VO) - the programs Stellarium and Aladin, which are linked to actual astronomical databases and offer software tools for searching, virtualization and data analysis not only for scientific, but also for educational purposes. These programs can rightly be called virtual laboratories. Their use allows us to demonstrate astronomical objects of the night sky in the present time, or in the past or future. Using the displayed data we can explain a phenomenon in the historical continuity of its discovery or we can work with the latest astronomical data. To use interactive programs Stellarium and Aladin in school practice, we prepared a series of tasks and examples that we have demonstrated in the context of the Children's University and the University of the Third Age. Participants in these events have become familiar with interactive programs and have gained necessary skills in their use. Given that our university educates future science teacher's part of the tasks was included into their teaching process. Our experience has shown that working with these interactive programs get the students very excited about the subject. The results of these events were presented to physics teacher in primary and secondary education in the seminar "Creative teacher" and in workshops for physics teachers of primary and secondary schools. Science teachers have expressed interest in working with these interactive programs, however, they have pointed to the lack of teaching materials on the subject. Based on this observation, we created the project, among other things, which aims to make accessible to the teachers various model examples for working with Stellarium and Aladin. In this paper, we focus on applying some options of these computer programs in physics classes or for working in interest groups.

3. Examples of the use of programs Stellarium and Aladin

For pupils at lower secondary education of primary schools we present examples of how to complement the curriculum about eclipses of Sun and Moon. The example of a solar or lunar eclipse is particularly suitable for working with the interactive computer program Stellarium, which offers various animations of individual eclipses. Furthermore, it can simulate the progress of the eclipse to determine the exact time of the eclipse and the approximate path of the totality. Dates of individual solar eclipse can be found, for example, on the web http://sk.wikipedia.org/wiki/Zatmenie_Slnka. In the toolbar we choose an observer on the Sun and the datum of the selected solar eclipse. We'll observe how the phenomenon takes place in this view. To determine the exact time of the eclipse we are changing in short intervals the menu item "time" in the toolbar. Observing the course of the eclipse it is possible to determine the eclipse time, as well as the band of totality. As an example we chose the date Nov 3, 2013. Simulating the phenomenon we determined the time of the total eclipse - 1.33 pm and the band of totality, which crosses the Atlantic Ocean and the southern parts of Africa, as can be seen in Figure 1.

Among the many other topics we chose the problem of determining distances in the Universe. This topic is not only interesting from the astronomical point of view, but also provides many tasks suitable for practicing trigonometric functions, as well as working with graphic presentation. In the night sky all the stars appear equally far. Stellarium provides a basic astronomical data on each star. After selecting a star we can find its distance from Earth reading the data displayed on the screen. As an example, we look at the stars in the constellation Orion. First, we record different distances of the stars in an auxiliary table and then we plot them either in a simple graph, or in the way we present in Fig 2. This figure shows the position of individual stars in the night sky, depending on their distance to the Earth. The distances of stars from Earth are given in the light years. Introducing conversion for light years allows for practicing other distance units used in astronomy, e.g., the parsec (pc) or kiloparsec (kpc) . We see that the distances of individual stars in the constellation Orion span a large range, about 2000 light years, and thus the stars are developmentally or gravitationally unrelated.

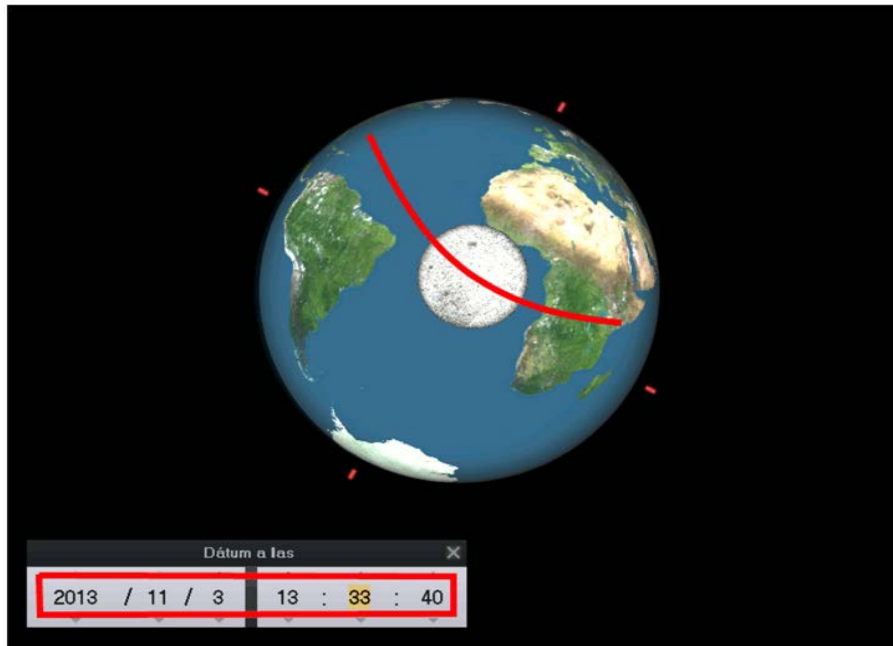


Figure 1: Total solar eclipse- simulation in Stellarium

Developmental proximity of stars we can be demonstrated by determining the distances of stars in an open cluster. Figure 3 shows an example for the open clusters Hyades in the constellation Taurus. The star distances, as can be seen in the figure, span only the range of order 10 light years. This nearest open cluster contains many red giants and therefore it is also interesting from the point of view of stellar evolution. For a better illustration of stellar evolution we can construct a Hertzsprung-Russell (HR) diagram of open clusters. Provided that the stars in the open cluster originated at the same time, it is possible from the shape of the HR diagram monitor their development. A procedure for solving this task was described in the work Csatáryová et al. (2011).

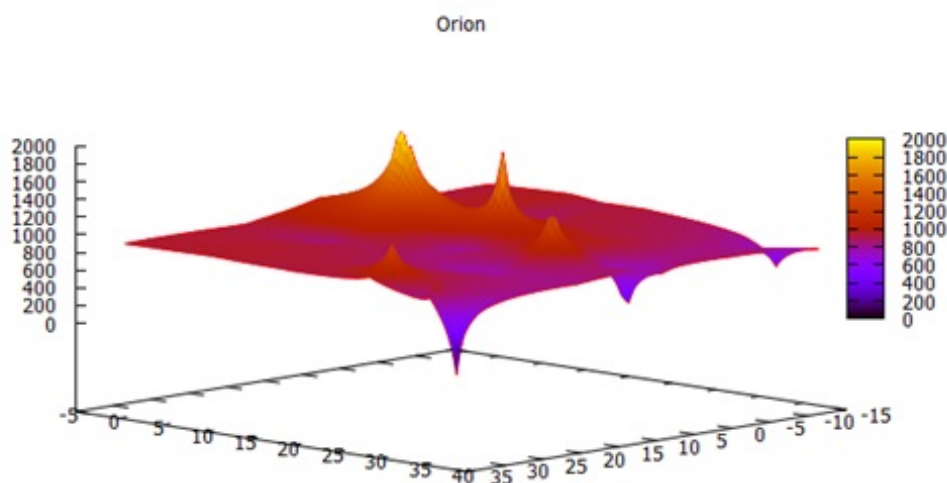


Figure 2: Distance to stars in the Orion constellation

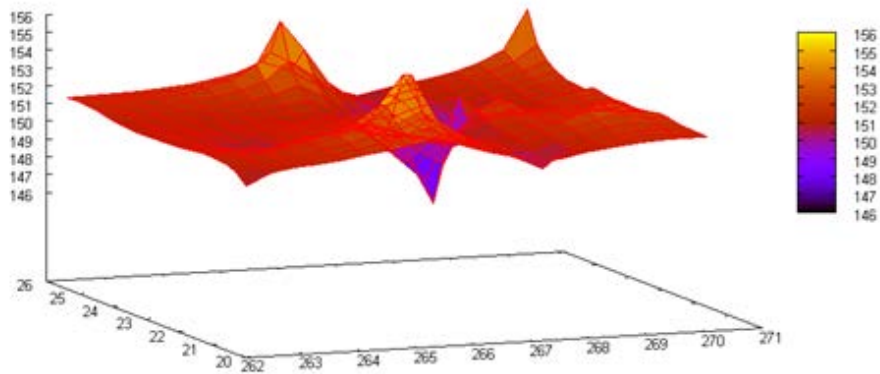


Figure 3: Distance to stars in open clusters Hyades

For classes that include Astronomy as a separate subject, we can extend this example to determining distances of extra-galactic objects. A typical example of determining the distance of galaxies is the method of supernovae. Supernovas are a great indicator for determining the distance of the object, since classifying the supernova type allows us to determine its absolute magnitude. As an example we chose the second brightest supernova of the 20th century, which was discovered on May 13, 1972 in the galaxy NGC 5253 in the constellation Centaurus. To simulate the entire supernova explosion we select in the Stellarium toolbar the date of observation and search for the supernova SN 1972. Moving ahead in time we record the supernova brightness and the changes in brightness are depicted in the displayed light curve. From the light curve we confirm that it is a Type Ia supernova.

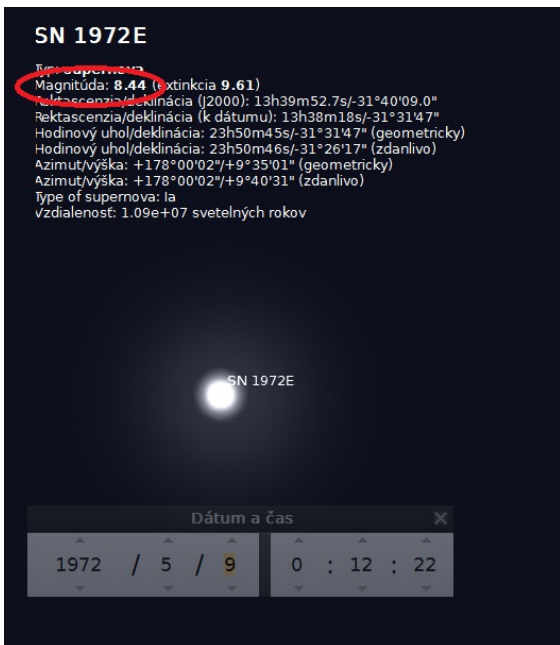


Figure 4: SN 1972 in Stellarium

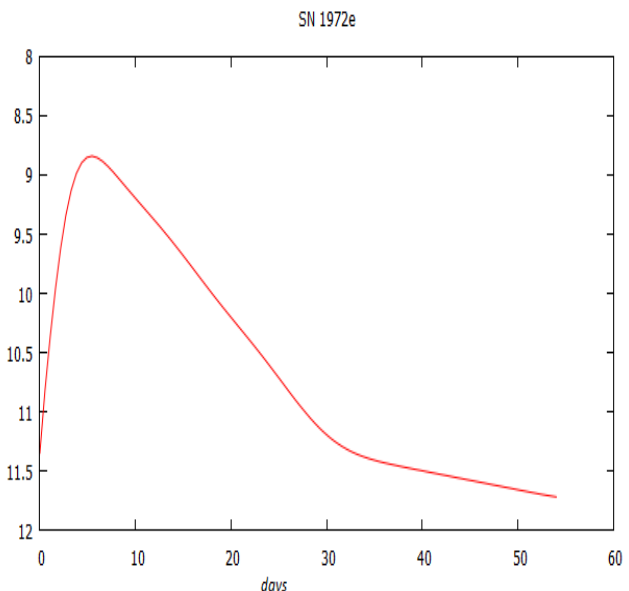


Figure 5: Light curve SN 1972

The absolute brightness of Type Ia supernovae at the time of maximum brightness in the visual domain spectrum is $M_v = -19,3$ mag. If we know object's absolute visual brightness we can determine its distance using the distance modulus. The relation for the distance modulus is given by $m - M = 5 \log r - 5$, where m is the apparent star's brightness and M is the absolute brightness. Thus the distance r in parsecs is given by

$$r = 10^{\frac{m-M+5}{5}} \quad (1)$$

In our example the apparent magnitude of the supernovae at the point of its largest brightness was, according to Stellarium, 8.44 mag. Substituting the absolute magnitude to the distance modulus we obtain the distance of this supernovae to be 3.5 Mpc. This distance agrees, at least to the order of magnitude, with the published value 5.2 ± 0.6 Mpc (Branch et. al., 1994). The difference is mainly caused by the fact that we did not consider the interstellar light absorption.

Conclusion

Recent technologies offer us unpredictable opportunities to make teaching process of astronomy at our schools more attractive. An extent of applying these opportunities depends on teachers' abilities. The authors of this contribution are preparing a set of tasks with astronomical content recommending application of interactive software to solve them. This set will be displayed at the web page <http://astronomy.science.upjs.sk/mtva/> which is in preparation now. We hope it will be an inspiration for teachers teaching natural science courses.

Acknowledgment

The present paper was created with the support of the project Kega no. 007UPJŠ-4/2013 - Modern technology in teaching astronomy and astrophysics.

References

- Branch D. and col. (1994) The distance to the type Ia Supernova 1972 E and its parent Galaxy NGC 5253: A Prediction, THE ASTROPHYSICAL JOURNAL 421, L87 – L90, The American astronomical Society
- Csatáryová M., Šebeň M, Šechný M (2011) Virtuálne laboratórium v astronómii, In: Tvorivý učiteľ IV, Bratislava: Slovenská fyzikálna spoločnosť, 2011, s.44 – 49, ISBN: 978 – 80 – 970625 –3-8
- Ferrares and col. (2000) A Database of Cepheid Distance Moduli and Tip of the Red Giant Branch, Globular Cluster Luminosity Function, Planetary Nebula Luminosity Function, and Surface Brightness Fluctuation Data Useful for Distance Determinations. THE ASTROPHYSICAL JOURNAL Supplement Series 128, 431–459
- Freistetter, F., Iafrate, G., Ramella, M. (2011), The Sky is for Evryone - Outreach and Education with the Virtual Observatory, rXiv:1101.3061v1/ http://arxiv.org/PS_cache/arxiv/pdf/1101/1101.3061v1.pdf

