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Program and Abstracts

Teaching/Learning Physics:
Integrating Research into Practice

GIREP-MPTL 2014 International Conference

July, 7-12, 2014 - University of Palermo, Italy

Organized by:
Groupe Internationale sur l’Enseignement de la Physique (GIREP)
Multimedia in Physics Teaching and Learning (MPTL)

With the support of:
International Union for Pure and Applied Physics (IUPAP)
European Physical Society - Physics Education Division
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Local Organising Committee
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Welcome to Palermo

Dear Colleagues,

Welcome to the GIREP-MPTL _2014 International Conference.

The University of Palermo is proud to host this important meeting which, we hope will enable you to share your research and teaching practices with an international research community and to engage in discussion about the pressing issues in physics education research.

The theme of the conference Teaching/Learning Physics: Integrating Research into Practice underlines aspects of great relevance in contemporary science education. In fact, during the last few years, evidence based Physics Education Research has provided impressive results concerning ways and strategies to improve student conceptual understanding, interest in Physics, epistemological awareness and insights for the construction of a scientific citizenship. However, Physics teaching practice seems resistant to adapting these findings to teaching contexts and new research based curricula struggle to affirm themselves, both at school and university levels. We hope that our conference will offer an opportunity for in-depth discussions of this apparently widespread issue in order to find ways to improve.

We also hope the conference will be an enjoyable experience for all participants. The University of Palermo, founded in 1806 by Ferdinand III of Bourbon, King of Naples and the Two Sicilies, is a large university hub which developed not only in Palermo, but also in central-western Sicily, as a response to specific needs of training and economic, social and cultural development. It always takes on a social as well as cultural, educational mission, which is typical of a public university, and even more important given the particular geographical and social context in which it operates.

Palermo, the host city, is Sicily's cultural, economic and touristic capital. It attracts many tourists for its nice Mediterranean weather, its Romanesque, Gothic and Baroque churches, palaces and buildings, and its renowned gastronomy and restaurants. During the Conference Excursion we will show you some of the most important sights and we hope that you will get the chance to visit and enjoy the city in your free time.

We realize that all of you made quite an effort to come, contribute and participate and we feel honoured. The scientific program and the breadth of audience which has joined us here today from different countries and continents are exceptional and we hope to meet your expectations about the organization.

The success of the meeting is now in your hands.

Welcome to Palermo

*Rosa Maria Sperandeo Mineo (Chairman of Girep_Mptl_2014)*
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General Information

Home page and e-mail addresses of the Conference

http://www.unipa.it/girep2014/
girep2014@unipa.it girep2014registration@eurocongressi.it

Conference Location

The Conference is held at the Conference and Didactic Centre of the University of Palermo, inside the University Campus, located in Viale delle Scienze (a parallel of Via Ernesto Basile), in buildings no. 7 (edificio 7) and no. 19 (edificio 19) for the general talks and for all the other conference activities, respectively.
Despite of the numbering, the two buildings are one in front of the other. Below there is a map of the Campus, with the location of buildings 7 and 19. Some detail of how to reach the Campus is also reported in the map, but you will find more information in the "Facilities" section of this book, at pages 9-12.

Plan of the Conference and Didactic Centre - Building 19 (Ed.19)
The Parallel and the Poster Sections are held in Sections B and C of Building 19. Rooms 5 - 12 at first floor are used for single oral presentations and symposia. The workshops are held in Aula Seminari B and Aula Seminari C and in Aula Multimediale B, again at first floor of the building. In Aula Multimediale C there are computers connected to the Internet for participants' use.
Poster presentations are given in rooms 7, 8 and 9 and then the exhibition is at second floor, in Section B. It is possible to access the poster exhibition zone directly from the room exits located in the upper parts of the rooms. Lunches and coffee breaks are at second floor, in Section C.
Facilities

The University Campus can be reached by using the AMAT urban busses and the Trinacria Express Metro-type train service, that also connects the Central Railway Station to the Falcone-Borsellino International Airport.

Bus no. 104 connects directly the City Centre (Via Libertà, Piazza Ruggero Settimo/Piazza Politeama, Piazza Massimo, Via Maqueda, Via Vittorio Emanuele) to piazza Indipendenza, that is just 5-10 minutes walking from the entrance of the University Campus.
Busses no. 101 and 102 connect the City Centre (Via Libertà, Piazza Ruggero Settimo/Piazza Politeama, Piazza Massimo, Via Maqueda) to the Central Railway Station. From there you must catch bus no. 234 or bus no. 109 to reach the University Campus (Via Ernesto Basile) or use the Metro-type train service.
Tickets for the bus can be bought in all tobacconist's and newsstands and in the AMAT kiosks in Piazza Ruggero Settimo/Piazza Politeama, Piazza Massimo and at the Central Railway Station. They cost € 1,30 and are valid for 90 minutes after the validation performed in the automatic machines located in each bus.
The Trinacria Express Metro-type train service connects, every 30 minutes, the Central Railway Station to the Punta Raisi, Falcone-Borsellino International Airport, and stops at the "Palazzo Reale-Orleans" station, that is located exactly at the entrance of the University Campus, just 5 minutes walking from the Conference Venue.

The Trinacria Express trains usually leave and arrive at platforms 9 and 10 of the Central Railway Station, but please check the information monitors in the station for more accurate information.

Tickets for the train can be bought in the tobacconist, newsstands and in the ticket office of the Central Railway Station. The urban fare is € 1,30 (while the airport fare is € 5.80) and are valid for 90 minutes after the validation performed in the station automatic machines. Please take into account that you are required to validate the ticket before the train leaves.
Conference Reception - Registration and Information Desk

Conference reception desk and conference office are situated in the Conference and Didactic Centre (Building 19).

Conference reception desk will be opened every day starting from 8:30 and finishing with Conference schedule for the day.

Conference information and updates concerning the organizational and the administrative meetings will be published daily at the main conference board, near the information desk, registration desk and the reception.

The Conference reception staff will be happy to assist you during the Conference with the following services:

- selling tickets for Conference Dinner (50) until Wednesday July 9
- providing tickets
- providing tickets for
- general information, tourist information

Registration

Registration starts on Monday July 7, at 8:30 at the Conference reception (registration desk). Registration fee includes:

- admission to scientific sessions
- book of abstracts with the program of the Conference
- conference bag with promotional material
- refreshments during the coffee breaks
- lunches
Instruction for Poster and Paper Presenters

1) Oral Presentation Sessions
This presentation format allows for 20 minutes of individual presentation time followed by a 4 minute discussion moderated by the session chairperson. Five Oral Presentations will be thematically grouped together and scheduled in a session of 120 minutes.

2) Poster Presentation Sessions
Posters will display the presentation materials in visual form printed in a format smaller than or equal to 90x120 cm$^2$. Posters will also be thematically grouped and presented during the designated poster sessions.
In each of these sessions there will be 7/8 posters. Each session is organized into two parts:

- A brief oral presentations with Power Point slides, of 3 minutes for each poster, is given to an audience gathered as a group and coordinated by a Chairperson.

- After all the authors gave their brief presentations, an in-depth discussion between them and the audience follows in the area of the poster displays, outside the room.

Poster sessions are scheduled for 75 minutes, during which the brief presentations and the poster-centered discussions take place.

Poster Sessions are scheduled on Tuesday 8, Wednesday 9 and Friday 11 morning (11,30 -12,45 ). Each poster board has a number. Please make sure you put your poster on the board assigned to you. The board number of your poster can be found in the Session Schedule. The posters can be displayed for all the afternoon. Please make sure to take down your poster by the end of the day as on the next day there will be a new set of posters.

Papers related to poster presentations are eligible for inclusion in the conference proceedings and the book of selected papers. Instructions for paper preparation are the same as those of Oral Presentations.

3) Workshops
Workshops enable presenters to display, explain and familiarize users with an innovative approach, a teaching or research tool, or some other aspect of research or teaching practices. The Workshop may include a brief presentation of completed research, but the emphasis is on demonstrating an innovation or a tool. Adequate time for reflective discussion is important. These sessions are scheduled for 120 minutes.
4) Symposia
A Symposium is a collection of related papers which examine a topic more broadly and deeply from various points of view. A chairperson (the lead person for organizing the symposium) and a discussant are needed for putting together a symposium proposal. Each symposium will contain at least four individually conducted but closely related studies. The symposium participants must be from at least 3 countries. Each symposium session will be given a 120-minute block of time in the program: 20 minutes for each presentation, 5 minutes for the discussant, and a total of 25 minutes allocated for discussions.

Conference Proceedings
Proceedings of the Conference will be published in electronic form with an ISBN code. The Proceedings will be available in the website; limited number of CD versions may be also produced.

You are required to submit your fulltext paper through the same System for Abstract submission: https://www.easychair.org/conferences/?conf=girepmptl2014

The Deadline for submissions is November 15, 2014. The guidelines for the fulltext paper preparation and templates are published on the web-site of the Conference.

All papers submitted for the GIREP-MPTL 2014 International Conference Proceedings will be blind-reviewed by two reviewers, from countries that are different to those of the authors, according to the criteria described on the web site.
Selected conference papers will be published in printed form, with ISBN code. We plan to publish both the Conference Proceedings and the Book of Selected Papers in spring 2015.
Conference Program
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<td>10:00 - 10:30</td>
<td>Session 7</td>
<td>Lecture 7</td>
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<td>Lecture 12</td>
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<td>11:00 - 11:30</td>
<td>Coffee Break</td>
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<td>11:30 - 11:45</td>
<td>Lunch Break</td>
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<tr>
<td>12:45 - 13:15</td>
<td>SESSION 1</td>
<td>SESSION 2</td>
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<td>14:15 - 14:15</td>
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<td>14:45 - 15:15</td>
<td>SESSION 3</td>
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<td>15:15 - 15:45</td>
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<td>15:45 - 16:15</td>
<td>SESSION 5</td>
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<td>16:15 - 16:45</td>
<td>WORKSHOPS</td>
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<td>16:45 - 17:00</td>
<td>Coffee Break</td>
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<td>18:00</td>
<td>Conference Dinner</td>
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**SESSION 1**
- Oral Sessions
- Symposia
- Workshops

**SESSION 2**
- Oral Sessions
- Symposium
- Workshops

**SESSION 3**
- Oral Sessions
- Symposium
- Workshops

**SESSION 4**
- Oral Sessions
- Symposium
- Workshops

**SESSION 5**
- Oral Sessions
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- Workshops

**SESSION 6**
- Oral Sessions
- Symposium
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**Excursions**
- GIRES General Assembly
- GIRES Representatives Meeting

**Conference Dinner**
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<tr>
<th>Date</th>
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<td></td>
<td>8:30 - 10:00</td>
<td>Registration</td>
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<td>10:00- 11:15</td>
<td>Opening Ceremony</td>
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<td></td>
<td>11:45- 12:45</td>
<td><strong>David Hammer</strong>: Teaching physics as a pursuit</td>
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<td><strong>Tuesday, July 8, 2014</strong></td>
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<tr>
<td>9:00 - 10:00</td>
<td><strong>Chair: Ronald Thornton</strong></td>
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<tr>
<td>Francisco Esquembre:</td>
<td>How can teachers create simulations for tablets (and why should they do so)</td>
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<tr>
<td>10:30 - 11:30</td>
<td><strong>Chair: Marisa Michelini</strong></td>
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<tr>
<td>Eric Mazur:</td>
<td>The scientific approach to teaching: Research as a basis for course design</td>
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<td><strong>Wednesday, July 9, 2014</strong></td>
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<td>9:00 - 10:00</td>
<td><strong>Chair: Ton Ellermeijer</strong></td>
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<tr>
<td>Eilish McLoughlin:</td>
<td>Models for teacher education and assessment of skills in Inquiry Based Science Education</td>
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<tr>
<td>10:30 - 11:30</td>
<td><strong>Chair: Robert Lambourne</strong></td>
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<tr>
<td>Igal Galili:</td>
<td>Considering Physics Knowledge as a Culture - an approach to physics curriculum matching interests and needs of contemporary learners</td>
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<td><strong>Thursday, July 10, 2014</strong></td>
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<tr>
<td>9:00 - 10:00</td>
<td><strong>Chair: Hideo Nitta</strong></td>
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<tr>
<td>Olivia Levrini:</td>
<td>How Can the Learning of Physics Support the Construction of Students' Personal Identities?</td>
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<td>10:30 - 11:30</td>
<td><strong>Chair: Roser Pintò</strong></td>
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<td>Marco Antonio Moreira:</td>
<td>Potentially Meaningful Teaching Units in physics education research</td>
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<td>11:30 - 12:30</td>
<td><strong>Chair: David Sokoloff</strong></td>
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<tr>
<td>Lillian Mc Dermott:</td>
<td>Discipline-based Education Research in a University Physics Department</td>
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<td>9:00 - 10:00</td>
<td><strong>Chair: Dean Zollman</strong></td>
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<td>Costas Constantinou:</td>
<td>An epistemologically informed approach to teaching energy</td>
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<td>10:30 - 11:30</td>
<td><strong>Chair: Mauricio Pietrocola</strong></td>
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<td>Laurence Viennot:</td>
<td>Thinking the content for physics education research and practice</td>
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<td>11:30 - 12:30</td>
<td><strong>Chair: Cesar Eduardo Mora Ley</strong></td>
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<td>Antje Kohnle:</td>
<td>Research-based interactive simulations to support quantum mechanics learning and teaching</td>
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## Parallel Session Schedule: Monday July 7

### SESSION 1 - 14:15 – 16:15

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<td><strong>Chair:</strong> Jenaro Guisasola</td>
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<tr>
<td>1) <em>Graham Rankin</em>: The nature of students’ reasoning processes in tasks involving the concept of angular acceleration</td>
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<td>2) <em>Laurens Bollen, Mieke De Cock and Paul van Kampen</em>: Students’ difficulties with vector calculus in electrodynamics</td>
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<tr>
<td>3) <em>Alexander Mazzolini and Scott Daniel</em>: Improving students’ understanding by using ongoing education research to refine active learning activities in a first-year electronics course</td>
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<tr>
<td>4) <em>JonÁs Torres MontealbÁn and Mario Humberto Ramírez Diaz</em>: Learning for understanding in pre-college level through prototypes of thermal solar energy</td>
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<td>5) <em>Ane Leniz Ereño, Jenaro Guisasola and Kristina Zuza</em>: Investigating university students’ understanding of the mechanism of electric current</td>
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<tr>
<td>1) <em>Renata Holubova</em>: Is it difficult to motivate our students to study physics?</td>
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<td>2) <em>Andreas Lichtenberger, Clemens Wagner and Andreas Vaterlaus</em>: Correlation between Mathematics and Physics Concepts in Kinematics</td>
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<tr>
<td>3) <em>Christiana Th. Nicolaou, Bert Bredeweg, Constantinos P. Constantinou and Jochem Liem</em>: Assessment of Student Constructed Models of Simple Systems in the Topic of Heat and Temperature</td>
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<tr>
<td>4) <em>Diego Ricardo Sabka and Paulo Lima Junior</em>: Role playing game as a tool for the STS approach to science education and physics teaching</td>
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<tr>
<td>5) <em>Silvia Galano, Italo Testa, Luigi Smaldone and Alessandro Zappia</em>: Secondary students’ views about scientific inquiry</td>
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Session 1.3_Oral Presentations : ICT and Multi-Media in Physics Education
Chair: Louis Trudel

1) Miroslava Ožvoldová, Petra Špilíková and František Schauer: Archimedes’ Principle Remote Experiment and buoyancy force elucidation
2) Dorothy Langley and Rami Arieli: Light Sensors and Displays for Student Projects
3) Matthew Hill, Manjula D. Sharma and Helen Johnston: Developing representational fluency in undergraduate physics students through weekly online learning modules
4) Dagmara Sokolowska, Wim Peeters, Job de Meyere, Barbara Rovsek and Elvira Folmer: Are the teachers left alone? The SECURE comparative study across ten European countries
5) Louis Trudel and Abdeljalil Métoui: Study of conceptual change about parabolic motion among high school students in a physics video-based laboratory

Session 1.4_Oral Presentations : In-service and Pre-service Teacher Education
Chair: Marcos Henrique Abreu de Oliveira

2) Ricardo Karam and Terhi Mäntylä: The influence of mathematical representations on students’ conceptualizations of the electrostatic field
3) Verónica Mercedes Javi and Marta Ofelia Chaile: The use of solar devices in an investigative practice in context, developed in Salta, Argentina, helping in the re-significance of what is to “understand energy”
4) Jan van der Veen and Wouter van Joolingen: Practical work revisited: A case study using a lesson study approach
5) Marcos Henrique Abreu de Oliveira, Mara Fernanda Parisoto and Robert Fischer: Project based learning for teacher formation in Brazil’s state with the lowest literacy rate

Session 1.5_INVITED SYMPOSIUM S1): Mathematics in Physics Education -
Chair: Gesche Pospiech

Gesche Pospiech, Marie Geyer, Ulrike Böhm, Yaron Lehavi, Esther Bagno, Bat-Sheva Eylon: The role of mathematics for physics teaching and understanding
Yaron Lehavi, Esther Bagno, Bat-Sheva Eylon, Roni Mualem, Gesche Pospiech, Ulrike Böhm, Olaf Krey and Ricardo Karam: Towards a PCK of Physics and Mathematics: Exploring patterns of the interplay between physics and mathematics
Ricardo Karam, Olaf Krey: Quod erat demonstrandum: Understanding and explaining equations in physics teacher education
Giacomo Zuccarini, Marisa Michelini: Investigating students ideas on the connection between formal structures and conceptual aspects in quantum mechanics
### Session 1.6_Invited Symposium S2) Concepts to initialize learning activities with modern media

**Chairperson:** Raimund Girwidz  
**Discussant:** Pieter Smeets  
**Room:** Aula 12

- Stefano Vercellati & Marisa Michelini: Integrating ICT for new learning goals in a vertical path on electromagnetism
- Stefan Richtberg & Raimund Girwidz: Design, training exercises and feedback in an online learning environment about electrons in electric and magnetic fields
- Victor López & Roser Pintó: Students’ difficulties in the reading of multimedia physics simulations
- Tomek Greczyło & Ewa Dębowska: Formation of Key Competencies through Information and Communication Technology

### Session 1.7_INVITED WORKSHOP W1) Active Learning in optics -

**Chairperson:** David Sokoloff

### Session 1.8_INVITED WORKSHOP W2) Inquiry based teaching and learning in physics education and how to assess it

**Chairperson:** Wim Peeters
## Parallel Session Schedule: Monday July 7

### SESSION 2- 16:45 – 18:45

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**Chair: Enrica Giordano**

1) **Smadar Or**: Junior Physics tutors - 14 years of success story

2) **Kerstin Gedigk, Gesche Pospiech and Michael Kobel**: Development of students’ interest in particle physics as effect of participating in a Masterclass

3) **Barbara Rovšek and Robert Repnik**: Physics competitions for learners of Primary Schools in Slovenia

4) **Giacomo Bozzo, Carme Grimalt-Alvaro and Víctor López**: Classroom interaction with IWB for Physics Education

5) **Enrica Giordano and Sabrina Rossi**: Early childhood science education in an informal learning environment

### Session 2.4 _Oral Presentations : Physics Teaching and Learning at Primary Level
**Chair: Hildegard Urban-Woldron**

1) **María Guadalupe Martínez Borreguero, Francisco Luis Naranjo Correa and Florentina Canada**: Teaching Physics in elementary education: Design and Planning of a Workshop of Recreational Physics

2) **Arantza Rico**: Teaching energy using cooperative learning in a primary teacher training degree

3) **Nora Sánchez-Oussedik, Marina Castells Llavanera and Mercè Izquierdo Aymerich**: Evolution of pre-service primary science teacher’s pedagogical knowledge during reflexive training based on dialogues’ analysis.

4) **Asuncion Menargues, Rafael Colomer, Ruben Limiñana and Joaquin Martinez-Torregrosa**: Effect of problem based teaching about diurnal astronomy (cycles and symmetries of Sun movements and the Sun/Earth model) in knowledge and attitudes of pre-service primary teachers.

5) **Hildegard Urban-Woldron**: Science Teaching Self-Efficacy and Alternative Conceptions of Floating and Sinking in Pre-Service Elementary Teachers
### Session 2.5_Oral Presentations : ICT and Multi-Media in Physics Education

**Chair:** Anna De Ambrosis

| 1) Luisa López-Banet, Álvaro Ortega Retuerta, Enrique Banet Hernández, Francisco Guillermo Díaz Baños and José García de La Torre: Teaching and learning biophysical models in master studies: effect of a protein mutation |
| 2) Nico Rutten, Jan T. van der Veen and Wouter van Joolingen: Inquiry-Based Teaching with Computer Simulations in Physics |
| 3) Juan Pedro Sánchez-Fernández, Carmen Carreras BEjar, Manuel Yuste, Luis de La Torre, Rubén Heradio and Sebastián Dormido: Study of the diffraction of light: A new Optics experiment in UNILabs virtual and remote laboratories network |
| 4) Carmen Carreras, Juan Pedro Sánchez, Manuel Yuste, Luis De La Torre, Ruben Heradio and Sebastian Dormido: The photoelectric effect: A new Physics experiment in UNILabs virtual and remote laboratories network |
| 5) Massimiliano Malgieri, Pasquake Ororato and Anna De Ambrosis: What is light? From optics to quantum physics through the sum over paths approach |

### Session 2.6_INVITED SYMPOSIUM S3): Physics Education Research at University

**Chairperson:** Jenaro Guisasola  
**Discussant:** Mieke De Cook

- **Stephen Kanim:** Student use of proportions in introductory physics courses.
- **Lana Ivanjek, Peter Shaffer, Lillian McDermott and Maja Planinić:** University students’ difficulties with the role of experimental setup in the process of spectra formation.
- **Kristina Zuza, Mieke de Cook, Isabel Garzón, Paul van Kampen and Jenaro Guisasola:** Characterizing university students’ use of electromotive force concept in electromagnetism. A international research in four countries.
- **Paul van Kampen:** International physics education research at advanced university level: a vision.

### Session 2.7_INVITED WORKSHOP W3): Energy teaching and learning

**Chairperson:** Paula Heron

### Session 2.8_WORKSHOP W4): Teacher professional development on the use of technology in student minds-on inquiring and meaning making activities

**Chairperson:** Ton Ellermeijer
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Chair: Dorothy Langley

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1) Nico Rutten, Wouter van Joolingen and Jan T. van der Veen: Measuring The Learning Effects of Inquiry-Based Teaching with Computer Simulations

2) Mara Fernanda Parisoto and Marco Antonio Moreira: Integrating Project Method and Potentially Meaningful Teaching Units to facilitate meaningful learning of concepts of thermodynamics to undergraduate students in Engineering

3) Kübra Eryurt and Ömer Faruk Özdemir: What is the relationship between personal epistemology about physics and scientific epistemology for 9th grade high school students?

4) Roberto Cruz-Hastenreiter: Analogies in High School Classes on Quantum Physics

5) Dorothy Langley, Bat-Sheva Eylon and Rami Arieli: Getting started in Physics Projects: Students’ initial views

Session 3.4_Oral Presentations: In-service and Pre-service Teacher Education

Chair: Mauricio Pietrocola

Room 10 (Aula 10)

1) Greg Lancaster and Rebecca Cooper: Pre-service physics teachers’ development of conceptual understanding and pedagogy through the use of discussion problems and argumentation

2) Vera Montalbano: Exploring sliding friction: an inquiry-based experience for pre-service science teachers

3) Maria Guadalupe Martinez Borreguero and Francisco Luis Naranjo Correa: Developing education tools for teaching Physics and Chemistry in secondary education: Treasure Hunts

4) Fabiana Kneubil and Mauricio Pietrocola: A Teaching-Learning Sequences of the Concept of Mass in Teachers Training Courses

5) Mauricio Pietrocola: Understanding transformative cultural practices in upper secondary physics teachers

Session 3.5_INVITED SYMPOSIUM S4): Multimedia teaching principles and Assessment

Chairperson: Pieter Smeets

Discussant: Ton Ellermeijer

Room 6 (Aula 6)

Pieter Smeets: Making valid assessment of ICT and Multimedia in PhysicsEducation -Experiences from the Netherlands

Lars-Jochem Thoms, Raimund Girwirdz: Training and assessment of experimental competencies from a distance optical spectrometry via the Internet in Munchen (Germany)

André Heck: Experiences with ICT and Multimedia in performance tests
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Roser Pinto, Victor López: Some obstacles when interpreting information from visual representations

Russell Tytler, Karen Murcia, Chao-Ti Hsiung: Coordinating representations in teaching astronomy: a cross-country comparison

Peter Hubber: Teacher change in implementing a research developed representation construction pedagogy

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**Chair:** Paula Heron  
**Room 9 (Aula 9)**

1. **Ivan Ruddock:** Imaging in Gradient Index (GRIN) Fibre
2. **Nilüfer Didiş, Ali Eryılmaz and Şakir Erkoç:** Students' mental models about the quantization of physical observables
3. **Maja Pecar and Mojca Cepic:** Transmission of the light through anisotropic media is not simple
4. **Nikola Poljak, Mirko Planinic and Maja Planinc:** Development of the Conceptual Survey in Nuclear Physics
5. **Paula Heron, Mila Kryjevskaia and Mackenzie Stetzer:** Student ability to measure physical distances in terms of the wavelength of periodic waves

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**Chair:** Hendrik Ferdinande  
**Room 10 (Aula 10)**

1. **Maria Parappilly and Lisa Schmidt:** Ready to Learn Physics: Team Based Learning in First Year University
2. **Ricardo Trumper:** Guiding principles for a vertical teaching of energy
3. **Jolien De Meester, Jan Thielemans, Mieke De Cock, Greet Langie and Wim Dehaene:** Integrated STEM in secondary education: a case study
4. **Eugenio Bertozzi and Olivia Levrini:** Recasting particle physics by entangling physics, history and philosophy
5. **Hendrik Ferdinande:** How can future European physics studies lead to innovative competences and stimulate entrepreneurial behaviour?

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**Chair:** Matteo Leone  
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1. **Valbona Tahiri and Jorgo Mandili:** The problem of recognizing objectives in physics
2. **Jiyeon Park and Junehee Yoo:** Exploration of Korean elementary students’ science related experiences and career aspiration
3. **Marina Castells Llavanera, Aikaterini Konstantinidou and Josep Maria Cerveró:** A teaching proposal on Electrostatics based on the History of Science through the reading of historical texts and argumentative discussions
4. **Michael Pohlig:** What has happened to mass
5. **Francesco Guerra, Matteo Leone and Nadia Robotti:** The discovery of X-rays diffraction from crystals to DNA: a case-study to promote understanding of the nature of science and of its interdisciplinary character
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- **David Hammer:** An account of elementary teachers’ epistemological progress in science
- **Josip Slisko:** Physics concepts and processes in Mexican primary school textbooks: An analysis from inquiry-based learning perspective and implications for teachers’ education
- **Nikos Papadouris & Costas P. Constantinou:** Utilizing physics as a medium for promoting integrated learning in elementary science: an example in the context of energy
- **Marisa Michelini, Alberto Stefanel:** Research based activities and school-university cooperation in teacher professional development on optics

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- **Eilish Mc Loughlin:** An ESTABLISH approach to Inquiry Based Science Education for second level students
- **Zuzana Ješková, Marián Kireš, EilishMcLoughlin, Odilla Finlayson, Christina Ottander, Margareta Ekborg:** In-service and pre-service teacher education in IBSE – the ESTABLISH approach
- **Claudio Fazio:** The development process of the ESTABLISH Teaching-Learning Units
- **Dean Zollman:** An Outsiders view of the Impact of ESTABLISH

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**Chair: Marta F. Barroso**  
**Room 9 (Aula 9)**

1. *Francesco Scerbo, Elena Scordo and Laura Vero*: Good Italian taste: a multidisciplinary approach to pasta cooking
2. *Paulo Simeão Carvalho and Marcelo Rodrigues*: Teaching physics with Angry Birds: momentum and energy conservation laws
3. *Barbara Rovšek, Dagmara Sokolowska, Wim Peeters and Job de Meyere*: SECURE results on differentiation
4. *Paul Logman, Wolter Kaper and Ton Ellermeijer*: Guiding students to combine partial laws of energy conservation within a scientific context
5. *Marta F. Barroso, Marcelo S.O. Massunaga, José Christian Lopes and Gustavo Rubini*: ENEM and physics learning in Brazilian high school

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**Chair: Sebastian Gröber**  
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1. *Tetyana Antimirova*: Video-Based lecture demonstrations and activities in Introductory Physics
3. *Sebastian Gröber, Pascal Klein and Jochen Kuhn*: Video problems in recitations of experimental mechanics and electrodynamics courses
5. *Sebastian Gröber, Pascal Klein and Jochen Kuhn*: Non-relativistic moving frames of reference - Building a bridge between mathematics and physics with video analysis problems in experimental physics

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Ewa Debowska: Report and Recommendations on Available Multimedia Material for Quantum Physics and Quantum Mechanics  
Luis de la Torre, Ruben Heradio, and Sebastián Dormido: Using Moodle to design physics online courses with virtual and remote laboratories based on EJS  
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### Session 6.1: Oral Presentations: Physics Teaching and Learning at Secondary Level

**Chair:** Roser Pintó  
**Room:** Room 7 (Aula 7)

1. **Giuliano Zendri, Stefano Oss, Luigi Gratton and Matteo Valdan:** The speed of sound in singing pipes.
2. **Giuliano Zendri, Stefano Oss and Luigi Gratton:** LED lamps and energy consumption: where is the power factor?
3. **Tomas Franc:** The Results of a Questionnaire about Spacecraft Flights and Tidal Phenomena
4. **Maria Rita Otero, Marcelo Arlego and Fabiana Prodanoff:** Teaching the basic concepts of the Special Relativity in the secondary school in the framework of the Theory of Conceptual Fields of Vergnaud
5. **María Isabel Hernández, Raquel Ríos and Roser Pintó:** How students conceptualize absorption of infrared radiation when interacting with matter? Findings from a research study and implications for an instructional design

### Session 6.2: Oral Presentations: Physics Teaching and Learning at University Level

**Chair:** Hideo Nitta  
**Room:** Room 8 (Aula 8)

1. **Daniela Marocchi and Marina Serio:** Laboratory activities and the perception of the students
2. **Marion Birch and Niels Walet:** An investigation of contextual gender bias of FCI questions
3. **Mackenzie R. Stetzer, Christos P. Papanikolaou and George S. Tombras:** Investigating student understanding of operational-amplifier circuits in upper-division analogue electronics courses*
4. **Ivica Aviani, Nataša Erceg and Vanes Mešić:** Probing the influence of the teaching method on students’ ability to identify real forces in diagrams
5. **Hideo Nitta:** Gender Differences in the Peer Instruction
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<td>2) Nataly Rodríguez, Iván Sánchez and Ivo Fustos: Influence of Peer Method and IBSE in science competence in Chilean secondary students.</td>
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<td>3) Vera Montalbano, Simone Di Renzone, Serena Frati, Emilio Mariotti and Antonella Porrì: Exploring the physics of senses</td>
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<td>4) Mustafa Şahin Bülbül: Nature of Science Fiction Education with a Blind Student</td>
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<td>5) Claudia Haagen: Development of teaching materials: a course for geometrical optics for lower secondary students</td>
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<td>2) Ramon Lopez, Gregory Hale, Ann Cavallo and Karen Jo Matsler: Preparing Future Physics Teachers in the UTeach Model</td>
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<td>3) Olga Gioka: Revisiting derivatives in physics with pre-service physics teachers</td>
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<td>4) Alessandro Zappia, Silvia Galano, Luigi Smaldone and Italo Testa: Science teachers’ transformations when implementing inquiry-based teaching-learning sequences</td>
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<td>5) Assunta Bonanno, Giacomo Bozzo, Federica Napoli and Peppino Sapia: Interactive Whiteboard (IWB) and Classroom Response System (CRS): how can teachers use these resources?</td>
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<td>Onofrio Rosario Battaglia: The Boltzmann Probability to Explain Different Phenomena: Some Experiments and Simulations</td>
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<td>Michele D’Anna and Georg Job: An Alternative Approach to the Boltzmann Distribution through the Chemical Potential</td>
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### Session 6.6_Symposium S11): Aspects of Integration of ICT to enable more Inquiry in the Teaching of Physics

**Chairperson:** Ton Ellermeijer   
**Discussant:** Ronald Thornton

Room 12 (Aula 12)

- Onne van Buuren, Andre Heck and Ton Ellermeijer: A modelling learning path for lower secondary physics education
- Zuzana Ješková, Trinh-Ba Tran, Marian Kires, Ewa Kedzierska, Ton Ellermeijer: Implementation of an in-service course on integration of ICT into Inquiry Based Science Education: A case study in Slovakia
- Trinh-Ba Tran, Ed van den Berg, Ton Ellermeijer, Jos Beishuizen: Preparing pre-service teachers to integrate ICT into Inquiry-Based Science Education: Outcomes of case studies in the Netherlands
- Pieter Smeets: Use of Coach in The Central Exams: Assessment of higher level skills in interactive environments

### Session 6.7_INVITED WORKSHOP W13): Can research support innovations in teaching physics?

**Chairperson:** Wim Peeters

Aula Multimediale B

### Session 6.8_WORKSHOP W14): Tips and tricks to make traditional laboratory more minds-on and inquiry

**Chairperson:** Ed van den Berg

Aula Seminari B

### Session 6.9_WORKSHOP W15): Chaos theory and its manifestations: an informal educational activity to explain the chaos to students

**Chairpersons:** Salvatore Spagnolo and Valeria Greco

Aula Seminari C

### Session 6.10_Oral Presentations: In-service and Pre-service Teacher Education

**Chair:** Mauricio Pietrocola

Room 6 (Aula 6)

1) Jeongwoo Park and Junehee Yoo: The Roles of Visual Perception and Interpretation of Interference Fringe Image in Pre-service Physics Teachers’ Model Development of Standing Waves in a Pipe

2) Marcelo Alves Barros and Marina Valentim Barros: Interactive methodologies in the training of physics teachers in a context of curriculum innovation: the Peer Instruction method

3) Valentina De Renzi, Annamaria Lisotti and Guido Goldoni: The NANOLAB Project: Educational Nanoscience for high school
4) *María Elena Truyol and Maurício Pietrocola:* Do teachers’ conceptualization of key aspects of quantum mechanics really help to overcome the comprehension difficulties students have?

**Parallel Session Schedule: Saturday July 12**

### SESSION 7- 09:00- 11:00

**Session 7.1_Oral Presentations : Physics Teaching and Learning at secondary Level**  
*Chair:* Marco Giliberti  
*Room 7 (Aula 7)*

1) *Petr Kácovský:* Students’ misconceptions regarding everyday thermal phenomena  
2) *Marta Rinaudo, Daniela Marocchi and Antonio Amoroso:* Vacuum: its meaning and its effects throughout experimental activities  
3) *Godwin Augustine Ballah and Okoronka Ugwumba Augustine:* Integration of Historical Vignettes into Physics Instruction at the Secondary School Level in Nigeria.  
4) *Sara Barbieri and Marco Giliberti:* High school students face the magnetic vector potential: some relapses in their learning

### Session 7.2_Oral Presentations : Physics Teaching and Learning at university Level  
*Chair:* Olivia Levrini  
*Room 8 (Aula 8)*

1) *Assunta Bonanno, Giacomo Bozzo, Federica Napoli and Peppino Sapia:* Playing with (super)hydrophobicity: An interdisciplinary learning path on physical properties of water through high-speed visualization and software modeling.  
2) *Sergej Faletič:* The braced string - a simple system to discuss dispersion and elliptical polarization  
3) *Sergej Faletič:* How close can we get waves to wavefunctions, including potential  
4) *Özlem Eryilmaz and Ahmet İlhan Şen:* Reflection of the changes in modern physics curriculum on School Textbooks and Evaluation of these changes by pre service teachers: Turkey Sample
### Session 7.4_Oral Presentations: Pedagogical Methods and Strategies

**Chair:** Eliane Angela Veit  
**Room:** 10 (Aula 10)

1. **Manuel Eusebio:** Investigating the implementation of Hands-on Introductory Physics Curriculum at Abu Dhabi Men's College

2. **Maja Poklinek Cancula, Maja Pecar and Majca Cepic:** Using existing inquiry based learning materials: Is it really straight-forward?

3. **Marta Maximo Pereira:** Some tasks to develop metacognition and evaluate students in Physics classroom

4. **Vagner Oliveira, Ives Araujo and Eliane Angela Veit:** Just-in-Time Teaching and Peer Instruction methods in the learning of Electromagnetism in a Brazilian high school

### Session 7.5_Oral Presentations: Physics Teaching and Learning at Primary Level and pre-service teacher education

**Chair:** Cesar Eduardo Mora Ley  
**Room:** 11 (Aula 11)

1. **Jerneja Pavlin and Mojca Cepic:** Education of pre-service primary school teachers for teaching the physics part of science in Slovenia

2. **Abdeljalil Métiou and Louis Trudel:** The persistence of the alternative conceptions: the case of the unipolar model

3. **Ana Rita Lopes Mota:** Floating rules and Archimedes’ principle in middle school: Where to start?

4. **Maeve Liston:** Using digital teaching and learning tools with pre-service teachers for our modern primary science classrooms.

5. **Angel Antonio Rojas Garcia, Gustavo Alberto Atehortua Rico, Cesar Eduardo Mora Ley and Sonia Yaneth Lopez Rios:** The use of avatar animations in teaching physics to elementary school children.
### Session 7.6: Oral Presentations: Physics Curriculum and Content Organization
**Chair**: Ivan Ruddock

1. **Agata Długosz**: Teaching physics with context in Polish schools – mission impossible or mission accomplished?
2. **Andre F. P. Martins and Jim Ryder**: Nature of Science in science education: from ‘tenets’ to ‘themes’
3. **Margareta Enghag and Clare Christensen**: Methodology for a new project - Teaching and learning nanoscience and nanotechnology in Swedish secondary school with a risk education perspective
4. **Ivan Ruddock**: HOPE: Horizons of Physics Education

### Session 7.7: Oral Presentations: ICT and Multi-Media in Physics Education
**Chair**: Leoš Dvořák

1. **Medardo Fonseca, Arjuna Castrillón C. and Roger A. Hurtado M**: An apparently simple exercise of Newtonian mechanics, to be solved claims aids of ICT
2. **Loo Kang Lawrence Wee and Tze Kwang Leong**: Performance Task using Video Analysis and Modelling to promote K12 eight practices of science
3. **Marcus Stefan Brodeur, Nicholas Braithwaite, Ulrich Kolb and Shailey Minocha**: Enhancing the effectiveness of remote and virtual experiments for teaching undergraduate physics: lessons learned from students
4. **Pasquale Onorato, Massimiliano Malgieri and Anna De Ambrosis**: Rolling motion: experiments, simulations and concepts focussing on sliding friction forces
5. **Zdeňka Koupilová and Leoš Dvořák**: Physics Teachers’ Inventions Fair – a long-time source of teaching ideas
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Abstract of Plenary Lectures
Teaching physics as a pursuit

David Hammer, Tufts University, USA

The assumption remains pervasive that the core objective of science instruction is a body of canonical knowledge. It underlies instructional practices, assessments of learning, and even progressive "inquiry-based" curricula. Meanwhile, for many students, physics class is still disconnected from genuine pursuit of understanding. The assumption, I suggest, is a "misconception" of the community as a system. If "physics is what physicists do," then physics is a pursuit of understanding. But, like a student who keeps thinking force causes motion, the physics education community keeps thinking the goal is a particular set of concepts. I will argue for concerted effort to address the misconception, of research as well as of design and politics. The point is not to eliminate the canon but genuinely to prioritize students' learning physics as a pursuit. I will discuss challenges and possibilities for curriculum, assessment, and responsive teaching, with examples from primary and tertiary education.

How can teachers create simulations for tablets (and why should they do so)

Francisco Esquembre, University of Murcia, Spain

We introduce a new major version of the Easy Java Simulation (EJS) modeling tool that enables teachers (and advanced students) to create Java simulations for computers (existing feature) and Javascript simulations for computers, tablets, and smart phones (new feature). The simulations can be adapted from existing models in Digital Libraries such as comPADRE, or created from scratch, by using the simplified structure and utilities provided by EJS. The simulations created with EJS can be run in HTML pages served by remote computers, or can be downloaded to a Reader App (for Android and iOS) for local use. EJS is free for non-commercial use, including any teacher who wants to use the tool and the simulations created with it for her own teaching in her lectures. We also discuss why and how should a teacher want to use EJS simulations on. More on EJS can be found at http://www.um.es/fem/EjsWiki.
The scientific approach to teaching: Research as a basis for course design

Eric Mazur, Harvard University, Cambridge, USA

Discussions of teaching -- even some publications -- abound with anecdotal evidence. Our intuition often supplants a systematic, scientific approach to finding out what works and what doesn't work. Yet, research is increasingly demonstrating that our gut feelings about teaching are often wrong. In this talk I will discuss some research my group has done on gender issues in science courses and on the effectiveness of classroom demonstrations.

Models for teacher education and assessment of skills in Inquiry Based Science Education

Eilish McLoughli, Dublin City University, Ireland

Inquiry-Based Science Education (IBSE) has been the focus of many national and international programmes and projects in recent years as Inquiry based teaching methods have been suggested as a way to encourage and motivate students in science. The pan-European FP7-funded project ESTABLISH collaboration has led to the development and adoption of the project's framework for teacher education in IBSE across eleven European countries, which is supported by the consortium's development of IBSE teaching and learning materials. The effect of the implementation of IBSE teacher education programmes with pre-service and in-service teachers and the impact on these teacher's attitudes and understanding of IBSE, as well as their integration into classroom practice will be discussed. In addition, strategies and instruments for the assessment of skills developed by students through IBSE will be reported on based on the experiences of the 14 partners involved in the SAILS project.
Considering Physics Knowledge as a Culture - an approach to physics curriculum matching interests and needs of contemporary learners

Igal Galili, The Hebrew University of Jerusalem, Israel

Common physics curricula present the subject of physics as a scientific discipline - clearly and univocally. This presentation usually leaves in shade several aspects of this knowledge which are especially important for the contemporary culture in a wider sense. Those emphasize plurality and polyphonic discourse taking place in physics as a living body producing knowledge in the process of construction, debate and refutation in the ongoing practice and across the time. In structuring physics curriculum we suggest to emphasize its basing on a few fundamental theories which comprise a conceptual dialogue, specify the difference among them as well as their commonality (family resemblance). This goal can be reached through structuring the contents of each theory according to triadic affiliation: nucleus, body, and periphery. Such approach may frame the inclusion of history and philosophy of science in school curriculum. It creates appropriate space of meaningful learning by providing three options of emphasis addressing particular populations of students. All three options share, however, the big picture of physics. We have probed inclusion of this agenda into physics teaching in the form of a summative lecture which reviewed the optics knowledge after it was taught in high school of scientific orientation (Levrini et al. 2013). The applied lecture illustrated physics knowledge as an unfolding dialogue of four optical theories of which three - rays, waves and photons - are normally taught in physics classes. Our findings inform about enthusiastic perception on behalf of the students and teachers involved in the experiment indicating a resonance with their interests and preferences in a wider than disciplinary span.

How Can the Learning of Physics Support the Construction of Students' Personal Identities?

Olivia Levrini, University of Bologna, Italy

In public perception, the humanities (history, philosophy, art, and literature) still have a privileged role as subjects that can encourage students to develop their personal orientations and aesthetics. In contrast, physics and mathematics are school subjects that have been shown to put off many young people because of the strong image of authority they still maintain where there is no place for arguments and personal views. In this talk, we will consider the following questions: How can the learning of physics content support students in constructing their personal identities (in the sense of
their personal narratives of self)? Conversely, How does the search for a personal self-narrative influence students' approaches to learning disciplinary content? The presentation will be based on an extended design experience on the topic of thermodynamics in a secondary school physics class (grade 11). This case is notable for investigating our questions since the students in this class came to appropriate the discourse of thermodynamics. That is, their conceptual understanding and disciplinary engagement were accomplished by a reflexive process of populating scientific discourse with personal intentions, purposes and tastes. With respect to this case, we will discuss possible connections between the specific model of educational reconstruction we used to design the teaching materials and the type of productive learning that sits at the nexus of disciplinary engagement and identity and that we termed appropriation.

Thursday, July 10, 10:30 – 11:30  General Talk Hall

Potentially Meaningful Teaching Units in physics education research

Marco Antonio Moreira, Federal University of Rio Grande do Sul, Brasil

Potentially Meaningful Teaching Units are didactic sequences based on learning theories, specially on the meaningful learning one. Steps for its construction are suggested and examples as well as research findings are provided in their applications to Particle Physics, Quantum Mechanics, and Electromagnetism at high school and introductory college levels.

Thursday, July 10, 11:30 – 12:30  General Talk Hall

Discipline-based Education Research in a University Physics Department

Lillian Christie McDermott, Department of Physics, University of Washington, Seattle, WA, U.S.A.

Student learning in university science courses is a relatively new area for investigation by science faculty. The Physics Education Group in the Physics Department at the University of Washington began conducting research in physics education in the 1970s in courses to strengthen the preparation of prospective and experienced elementary and secondary school teachers to teach physics by inquiry. Our research soon expanded to include undergraduates in the standard
university physics courses required for majors in physics, other sciences, mathematics, and engineering. Later, we included students in more advanced physics courses. The emphasis has been on determining whether students develop a functional understanding of important physical concepts, which includes the ability to do the reasoning required to apply them to simple physical phenomena. Examples from introductory physics will be used to illustrate the nature of our research in physics education and our application of the results in the development of instructional materials that are both research-based and research-validated.

An epistemologically informed approach to teaching energy

C. P. Constantinou and N. Papadouris, University of Cyprus, Cyprus.

Understanding energy is widely recognized as a significant learning objective of science teaching. It constitutes a cross-disciplinary concept that spans all domains of science. In addition, energy has been identified as one of a small number of disciplinary core ideas for science learning. Despite this wide recognition of its significance, introducing and elaborating energy in school science continues to pose a significant instructional challenge. We propose a novel teaching approach, for middle school, that could contribute towards addressing this instructional challenge. The main features of this approach include (a) the shift from a purely conceptually-oriented approach towards an epistemologically-informed approach, (b) placing emphasis on energy and its features (transfer, form conversion, conservation and degradation) as a theoretical framework for analyzing system behaviour, (c) utilizing trans-phenomenology for eliciting the added value of introducing energy as an epistemic construct, and (d) distinguishing between forms of energy and energy transfer processes. We have developed teaching and learning materials with variants targeted at either lower middle school students or pre-service elementary teachers. We have carried out a series of implementations of the teaching materials in authentic learning environments and we report data that emerged from empirical studies we have undertaken with the intent to gain insights into what could be achieved by participating students or teachers in terms of learning gains. The results demonstrate the potential of this teaching approach to help students (teachers) construct understanding about energy and develop the facility to employ it for analyzing the operation of simple, unfamiliar physical systems in a coherent manner.
Research-based interactive simulations to support quantum mechanics learning and teaching

Laurence Viennot, Denis Diderot University, Paris, France

Content analysis, it is unanimously agreed, is a fundamental component of physics education research. In this address I will discuss, on the basis of several examples, how various research standpoints resulted in different ways of reexamining - "reconstructing", or "spotlighting" - the content for teaching: student-led, teacher-led, reactive, proactive. In so doing, I will reconsider, in particular, the merits of "simplification". I will plead for a way of spotlighting the content for teaching that leaves room for the search for consistency and conceptual links, making these explicit, while respecting a constraint of accessibility. The examples of color phenomena and the transfer of light will serve to illustrate this objective. The final discussion will bear on how students' intellectual satisfaction might thus be increased, and constitute a powerful incitement for them to engage with physics.

Thinking the content for physics education research and practice

Antje Kohnle, University of St Andrews, UK

Quantum mechanics holds a fascination for many students, but its mathematical complexity can present a major barrier. Traditional approaches to introductory quantum mechanics have been found to decrease student interest. Topics which enthuse students such as quantum information are often only covered in advanced courses. The QuVis Quantum Mechanics Visualization project (www.st-andrews.ac.uk/physics/quvis) aims to overcome these issues through the development and evaluation of interactive simulations with accompanying activities for the learning and teaching of quantum mechanics at university level. Simulations support model-building by reducing complexity, focusing on fundamental ideas and making the invisible visible. They promote engaged exploration, sense-making and linking of multiple representations, and include high levels of interactivity and direct feedback. Some simulations allow students to collect data to see how quantum-mechanical quantities are determined experimentally. Through text explanations, simulations aim to be self-contained instructional tools. Simulations are research-based, and
evaluation with students informs all stages of the development process. Simulations and activities are iteratively refined using individual student observation sessions, where students freely explore a simulation and then work on the associated activity, as well as in-class trials using student surveys, pre- and post-tests and student responses to activities. A recent collection of QuVis simulations is embedded in the Institute of Physics (IOP) New Quantum Curriculum (quantumphysics.iop.org), which consists of freely available resources for an introductory course in quantum mechanics starting from two-level systems. This approach immediately immerses students in quantum phenomena that have no classical analogue, using simpler mathematical tools that allow a greater focus on conceptual understanding. It allows from the start a discussion of interpretative aspects of quantum mechanics and quantum information theory. This presentation will give an overview of the IOP new quantum curriculum, highlight recent work on the QuVis project and outline future plans. It will describe our iterative process of refining simulations and activities and give examples of in-class use. QuVis is supported by the UK Institute of Physics, the UK Higher Education Academy and the University of St Andrews.
Abstracts of Symposia
S1: The Interplay of Mathematics and Physics from a Teaching Perspective

Chairperson: Gesche Pospiech, TU Dresden, Germany
Proposer: GIREP thematic group Mathematics in Physics education

Introduction
The goal of physics education consists in conveying the principles and concepts of physics as insightful as possible to the students. The description of physical processes by mathematical means is one of the most characteristic traits and most powerful tools of physics. Therefore the reality of physics as a science where mathematics and physics are closely intertwined should be reflected especially from a teaching perspective. However, understanding the meaning of different mathematical tools and their interrelation to the physical description of the world is one of the most difficult steps in physics education. In investigating this interrelation from an educational perspective, many questions arise. The overarching question is: Can the domain of mathematical structures improve the understanding of physical concepts and if so, in which way? How can the interplay of mathematics and physics be taught appropriately? In physics lessons teachers, their views and their competences play a central role for the successful learning of students. However, only little is known about the knowledge and views of teachers in this area which is central for physics, especially modern physics. Therefore we want to analyze what teachers are thinking and doing concerning the realization of this interplay. Another important point is how to include those topics into teacher education. The focus of the contributions therefore lies on teachers and teacher education with respect to the interplay of mathematics and physics. The first two contributions are strongly related to each other in that they refer to a bi-national study concerning the views of teachers on this interplay. They ask for related possible patterns within the Pedagogical Content Knowledge (PCK) of physics teaching with teachers from middle school and from high school. Another contribution addresses issues related to understanding and explaining exemplary equations of school physics in physics teacher education. Learning difficulties in the realm of quantum physics in connecting conceptual and formal thinking are addressed on the level of university students in the fourth contribution. All these contributions shed light onto possible improvements in teaching physics and physics teacher education with respect to the interplay of mathematics and physics.

Paper 1: The role of mathematics for physics teaching and understanding

Gesche Pospiech, Marie Geyer, Ulrike Böhm; TU Dresden
Yaron Lehavi, Esther Bagno, Bat-Sheva Eylon; Weizman Institute of Science

Understanding physics is one of the central goals of physics teaching. Generally, physical concepts find their expression in mathematical structures and often are inherently connected to them. Therefore the use of mathematical elements is an intrinsic feature of the method of physics and hence is central for teaching, especially if nature of physics is being addressed. In physics education different mathematical elements such as geometrical objects, graphs or diagrams, algebraic expressions and verbal explanations are used in order to describe exactly and
visualize physical processes. These require mathematical abilities starting from verbalizing functional dependencies and then using the quantitative description with diagrams or algebraic expressions. The next more complex step would be applying techniques of modeling and idealization and interpreting diagrams and formula in terms of physical concepts mirroring the interplay of mathematics and physics. A final, quite advanced step would be the mathematical formulation of physical basic principles in the framework of theories. A suitable model connecting different aspects of understanding and the corresponding steps in the use of mathematics has been developed.

However, the question remains open whether and how teachers use mathematical elements in their daily practice in order to enhance understanding with students and which strategies they are following. Whereas the use of mathematics is mostly analyzed in high school we deem it important to study earlier stages and focus on the interplay of mathematics and physics starting from the very beginning of physics education at school. Therefore we start already in middle school in order to take into view the generation of the connection between mathematics and physics in its first steps.

In an exploratory study interviews with physics teachers from middle school and high school are conducted. The teachers are asked concerning their views on the realization of the interplay between mathematics and physics in their classes. In addition some lessons are described in detail. The focus of the evaluation lies on the relation between the use of function graphs, algebraic expressions and verbal explanations. The results will be related to an earlier study of the views of 8th graders on the role of mathematics in physics lessons. Furthermore patterns will be identified which teachers may use in addressing the interplay of mathematics and physics, the main points of the teachers and some of the problems teachers as well as students encounter. The goal is to develop appropriate ways of addressing the role of mathematics in physics lessons throughout the learning career of students.

**Paper 2: Towards a PCK of Physics and Mathematics: Exploring patterns of the interplay between physics and mathematics**

_Yaron Lehavi, Esther Bagno, Bat-Sheva Eylon, Roni Mualem, Gesche Pospiech, Ulrike Böhm, Olaf Krey and Ricardo Karam_

_a) Weizmann Institute of Science; b) The David Yellin Academic College of Education; c) Technische Universität Dresden_

In the past, mathematics within the physics education context was mainly examined through its use in problem solving (Bagno et al., 2007; Redish & Smith, 2008). Some researchers pointed out that there is blending of conceptual and formal mathematical reasoning during the mathematical processing stage (Kuo et al., 2013, Hull et al., 2013). Recently, a broader view has been suggested, according to which the context of physics teaching invites interplay between physics and mathematics (Eylon et al., 2010).

The present study explores possible patterns within the Pedagogical Content Knowledge (PCK) of physics teaching, related to the interplay between physics and mathematics. The existence of such patterns was suggested earlier (Lehavi et al., 2013). Here we report on a bi-national study in which we have studied the views of expert high school physics teachers with regard to the “Phys-Math” interplay and the ways by which they implement it. We employed open Interviews in which we asked the teachers how they construct the Phys-Math interrelation in their classroom and how they use it to enhance students’ understanding of physics. The teachers provided us with examples from their own experience and also pointed out challenges that arise in constructing this interplay.

Our preliminary analysis of the interviews suggests that the Math-to-Physics part of the interplay is manifested by challenging the students' mathematical thinking through the examination of physical models on aspects such as boarders of validity and approximation, extreme cases, similarities between different physical phenomena, and the deductive derivation of physics statements. The
Physics-to-Math part is manifested when physical considerations are used for simplification of mathematical constructs involving analysis, construction of mathematical tools and an inductive construction (from measurement) of mathematical descriptions. We observed that the teachers’ strategies for introducing the Phys-Math interplay follow different patterns. All patterns begin with a physical description of a phenomenon, continue with mathematical manipulations and end in seeking new physical insights. However, the patterns differ by the number of steps going back and forth between the domains of physics and mathematics and within each domain and by the nature of these steps. These differences may indicate that each pattern is employed to serve different teaching goals.

REFERENCES


http://www.fisica.uniud.it/~ffp12/proceedings.html


Paper 3: Quod erat demonstrandum: Understanding and explaining equations in physics teacher education

Ricardo Karam - Physics Education, University of Hamburg, Germany
Olaf Krey - Physics Education, University of Potsdam, Germany

Fundamental laws and concepts of physics are usually represented by equations. Therefore, explaining the meaning of equations is a routine task performed in physics lessons. But what characterizes a meaningful understanding of physics equations and how does this influence the quality of explanations given by physics teachers? When attempting to answer this question, first of all it seems necessary to be more specific. Thus, we start by considering an overall epistemological categorization of equations, which involves different views on their epistemological nature. This categorization allows classifying one’s conception about the origin of a particular equation, based on his/her answers to questions like: Where does the equation come from? What does it represent? Why is it expressed in this way? We propose a set of four categories for this classification: 1) principles (e.g. \( \sum \mathbf{F} = \mathbf{0} \) and \( \delta \mathbf{S} = \mathbf{0} \)); 2) definitions (e.g. \( \mathbf{\dot{v}} = \frac{d\mathbf{v}}{dt} \) and \( \mathbf{p} = m \cdot \mathbf{v} \)); 3) empirical regularities (e.g. Balmer’s formula) and 4) relations logically derived from definitions and principles (e.g.
\( a_c = \frac{v^2}{r} \) and \( E = m \cdot c^2 \). Being aware of this distinction seems crucial, since possible ways to explain a certain equation and to structure lessons depend strongly on its epistemological character. Principles may be treated as plausible truths confirmed by observations and experiments; definitions need to be somehow justified concerning the needs to conceive physical quantities; empirical regularities are normally justified by performing experiments; whereas equations belonging to the latter group tend to demand a formal deductions showing how they can be obtained from general principles and/or definitions. Nevertheless, this is not to be thought as a strict and mutually exclusive categorization, due to both the intrinsic flexibility of theoretical constructs and the changes in the epistemological status of equations through history. Snell’s law, for instance, was first identified as an empirical regularity and later formally derived from principles (e.g. Huygens’ or Fermat’s).

In this work, we are particularly interested addressing issues related to understanding and explaining equations of the latter group in physics teacher education. For this purpose, a semester course was given to 11 pre-service physics teachers at the Technical University of Dresden. Besides lessons dedicated to general historical and epistemological reflections on the interplay between physics and mathematics, four equations traditionally taught in high school level, namely
\[ y = g \cdot \frac{t^2}{2} \]  \( a_c = \frac{v^2}{r} \) \[ T = 2\pi \sqrt{\frac{r}{g}} \] and \( \sin\theta_1 \cdot n_1 = \sin\theta_2 \cdot n_2 \), were approached in the course. During instruction, the students were presented with different ways of deriving these equations and were given the task to explain each of them to the whole class. Using multiple data sources, which include pre/post-instruction questionnaires, association maps and explanations’ repertoire to each equation, interviews with selected students and the recording of the lessons, we were able to identify several factors that influence students’ understanding of these equations, as well as their views on how to explain them in classroom situations, which we consider to be an important part of their pedagogical content knowledge. The main findings of this study will be presented and discussed.

**Paper 4: Investigating students ideas on the connection between formal structures and conceptual aspects in quantum mechanics**

*Giacomo Zuccarini, Marisa Michelini - University of Udine*

The contribution of mathematics to the construction of a physical knowledge of the world can hardly be overestimated. Much more controversial is the role of mathematics in student understanding of physics. Difficulties in transfer of mathematical knowledge in a physics context have been highlighted by research [1], as well as the fact that good performances in math do not assure student success in physics [2]. At the same time, as the construction of physical concepts and of their interconnections is embedded in the formal entities representing them, an understanding of the structural role of math in physics is required for a deep understanding of the laws of nature [3]. This is particularly evident in quantum mechanics (QM), whose basic concepts are non-intuitive, their physical meaning being strongly related to the formal structure of the theory. As a consequence, students experience a greater need of developing structural skills [4,5], in order to get a solid grasp of the scientific content and to build theoretical thinking. This makes of QM an ideal ground to explore advanced university student understanding of the interplay between mathematics and physics.
Therefore, we designed an inquiry on 3rd year physics students after completing their first QM course. Primary focus of the inquiry is the exploration of student ideas on the concept of state and the physical meaning of the properties of its formal representations. Among other aspects, we studied how students identify physical behaviors requiring the use of wavefunction/state vector; how they transpose pattern of experimental data into the elements of state formalism; how they interpret pure state vector expressions and base change equations.

Data-gathering instruments consist of a written questionnaire and an interview protocol. The questionnaire is organized on three levels: cultural, qualitative-conceptual and formal. Individual interviews were scheduled on student answers to each questionnaire item. Qualitative data analysis was employed to identify emerging element clusters and coherence elements in student reasoning, as well as concepts operating as cognitive organizers.

The questionnaire was administered to six 3rd year physics students enrolled in different Italian universities who had just passed QM exam (4/6). A subset of them was interviewed. The study shows that half of the students link the use of quantum state formalism to interference between particles, the others to specific physical contexts (such as potential well) or indeterminacy. All but one find difficulties in transposing information provided by experimental outcomes in state formalism, some neglecting phase’s role, some other trying to reconstruct the phenomenology on qualitative terms. Half of answering students interpret base change relations as containing information on the state of the system, thus showing difficulties with operator structure of observables. Implications for QM teaching at university level include discussing the structural role of Hilbert space constructs in the theory, as concerns the way in which information is encoded in quantum state formal representations and operator structure of observables.

S2: Concepts to initialize learning activities with modern media

Chairperson: Raimund Girwidz, University Munich, Germany
Discussant: Pieter Smeets, CITO, Arnhem, The Netherlands
Proposer: MPTL Committee

Multimedia applications not only offer various kinds of knowledge representation but also can initialize different cognitive activities to support learning in Physics. Computer and nowadays smartphones and tablets make it easier for everybody to set up experiments, to collect data and to test models and conceptual understanding.

The presentations of this symposium concretize concepts for designing applications with modern media and show how to initialize adequate cognitive activities. The theoretical background for these applications will be discussed as well as empirical evidence that they stimulate productive cognitive activities for learning.

The presentations in this symposium will be:

Vercellati, Stefano & Michelini Marisa, Udine: Integrating ICT for new learning goals in a vertical path on electromagnetism

Richtberg, Stefan & Girwidz, Raimund, Munich: Design, training exercises and feedback in an online learning environment about electrons in electric and magnetic fields

López, Víctor & Pintó, Roser, Barcelona: Students' difficulties in the reading of multimedia physics simulations

Greczyło, Tomek & Dębowska, Ewa, Wrocław: Formation of Key Competencies through Information and Communication Technology

Paper 1: Integrating ICT for new learning goals in a vertical path on electromagnetism

Stefano Vercellati, Marisa Michelini, University of Udine, Italy

Introduction and theory
ICT offer new learning goals for physics education in conceptual learning by means Real Time Laboratories (RTL) and simulations (SIM) for experimental exploration and modelling. The great portability of the new tools promote personalization, enlarge the diffusion in school and enrich the teachers’ employ opportunities in school. RTL provided contexts for quantitative phenomenological explorations comparable with research-like laboratories work; new teaching methods integrate large group activities involving personal interpretive challenges in the context of Interactive Lecture Demonstrations (ILD) (Sokoloff et al., 2007). SIM had evolved becoming micro-tools that are integrable in many learning paths becoming useful for parametric model analysis offering support for interpretation in experimental explorations (Trundle & Bell, 2010). The specific learning contribution of mono-conceptual SIM encourage critical thinking when they are used in the context of conceptual learning path to support structures and strengthen the connection with the science content (de Jong et al., 1999).
In this frame, the IWB adds new potentialities and learning strategies related to conceptual changes and the social interactionist approach and provide the context for the sharing of educational potentiality of the RTL and SIM.

**Concept and implementation**

Research literature widely addressed the main learning knots related magnetism and electromagnetism. In particular the field representation (Guisasola et al., 1999), the field as a superposition, the sources of field and the role of relative motion in the electromagnetic induction (Maloney et al., 2001) were some of the main addressed. In the Framework of the Model of Educational Reconstruction a Design Based Research was carried out integrating ILD and SIM by means the use of the IWB to overcome conceptual knots in the exploration of the formal nature of the magnetic field and the construction of the operative definition of magnetic flux.

The role of the IWB as a promoter of cooperative activities is proposed as an ideal tool to support the modelling process in association with the use of RTL and SIM providing a learning environment where students have the opportunity to explicit personal reasoning and conceptual trajectories and to perform a peer review interpretative process to reach agreements on the physical description of the phenomena.

**Objectives and assessment**

An empirical research in engaging students’ reasoning in the developing formal thinking was carried out to investigate: 1) the contribution of the RTL in IDL in activating interpretative reasoning; 2) the gain in conceptual re-use of SIM when integrated in a conceptual path focused on overcoming conceptual knots; 3) the social constructivist role of the IWB in sharing local and global interpretative ideas; 4) the contribution of the integration of RTL, SIM, IWB, in ILD to the peer review process of reasoning. The activity was held in four secondary schools using inquiry-based carts, questionnaires, audio recording of the discussions and screen recording of the IWB screen.

**References**


**Paper 2: Design, training exercises and feedback in an online learning environment about electrons in electric and magnetic fields**

*Richtberg, Stefan & Girwidz, Raimund, Ludwig-Maximilians-University Munich, Germany*

**Introduction and theory**

General features of multimedia learning were studied in many setting. Fundamental rules for the design of applications were derived, especially applying multicoding, multimodality and avoiding cognitive overload (e.g. Mayer, 2009).

One outstanding feature of modern digital media is that they can provide an interactive learning environment, which offers case sensitive feedback on inducted learners’ activities. This is also attractive for laboratory experiments which can be realized as remote controlled laboratories or
virtual experiments, in order to combine realistic settings with theoretical considerations. Immediate feedback can reduce uncertainty, or indicate a gap between the current performance and perspectives for development. Formative feedback can reduce cognitive load, and help to realize a goal directed working. Furthermore, in multimedia applications the mode of feedback is not limited to text, and can easily be combined with different types of visualization. Thoseseillustrations can be dynamic, integrated and linked to further explanations to promote a deeper understanding. Above all, the multimedia design need to be matched to the intended learning activities and the learning goals.

**Concept and implementation**

Based on the theoretical considerations and guidelines we developed a web-environment¹ which students can use to perform realistic experiments with an electron beam in an electric field or in the magnetic field generated by two Helmholtz coils. Students can modify the acceleration voltage of the electron beam gun and the voltage between the deflection plates respectively the electric current in the coils. Depending on the experimental settings the reaction is displayed on the screen. The students have to accomplish exercises that scaffold learning according to a scientific inquiry process. At the beginning the experimental setup is shown and hypotheses must be generated. After that users can test their ideas and concepts. The mathematical equations for the electron trajectory can be evolved step by step. For that, the acceleration in horizontal and in vertical direction have to be derived as well as the equation of the trajectory y(x). The results are superposed over the image of the real experiment, offering an inherent feedback.

**Objectives and assessment**

Declarative knowledge about the experimental setup and the fundamental laws as well as procedural skills like data acquisition and hypothesis testing belong to the learning objectives. A study with grade 11 students (age 16-18) was performed, to analyze strengths and weaknesses of design, tasks and feedback. Prior knowledge was examined in a pre-test, as well as computer self-efficacy. In an intervention study the students worked autonomously for 45 minutes on the deflection of an electron beam in an electric field. All their activities were logged in a database. Thus it is possible to track their individual learning paths. An additional paper and pencil post-test enclosed different tasks: Declarative knowledge about the experimental setup and technical terms were tested, as well as procedural skills. Effects of a modification of certain parameters were to describe and also arithmetic problems had to be solved. First results indicate that students have no problem to use the environment, to modify the experimental settings, and to test different y(x)-functions for the path of the electron beam. They can also process the different kinds of feedback, and in general they only proceed to the next task after a positive feedback. Even the training exercises on technical terms were highly attractive, not influenced by mistakes or negative feedback. However the learning outcomes and learning objectives have to be discussed thoroughly.

**References:**

¹www.didaktik.physik.uni-muenchen.de/elektronenbahnen

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**Paper 3: Students' difficulties in the reading of multimedia physics simulations**

López, Víctor & Pintó, Roser, Barcelona, Spain

Even simulations are a very spread multimedia tools in physics education, their effectiveness as educational tools cannot be given for granted, since previous researches have shown that both a lack of knowledge of the visual language or a lack of previous knowledge in the represented scientific topics may hinder the interpretation of an image. In this context, we have investigated how a group of secondary school students read and understand the visual representations displayed in two multimedia physics simulations obtained in PhET
repository, concerning the friction between surfaces [1] and the electromagnetic induction [2]. In this research, we carried out individual 14 semi-structured individual interviews and several classroom observations from which we identified the reading difficulties that take place in these reading processes. The students’ difficulties identified concerns to the compositional structure of the visual representations, the relevance that students give to each visual element, the semantics meaning of the displayed elements, the coexistence of multiple external representations, the dynamic information represented and the communicative nature of the displayed information. Our findings allow us to conclude that visualisation of simulations doesn't imply a good comprehension of the content of scientific simulations. We have found that a good reading process requires a set of skills, previous knowledge and external supports, and if those conditions are not given, a good interpretation of the simulation is not possible. Therefore, despite the communicational and educational opportunities provided by simulations and other ICT tools based on visual communication, science teachers should bear in mind these issues in order to help students read images to take benefit of their educational potential.


Paper 4: Formation of Key Competencies through Information and Communication Technology

Greczyło, Tomek&Dębowska, Ewa, Wrocław, Poland

In the rapidly evolving world the Information and Communication Technology (ICT) is playing an important role, both as a tool and as an engine of changes in education [1], [2]. Such a great impact is especially visible in educational processes taking place in physics teaching and learning. Moreover it is accompanied by actions leading to the formation of Key Competencies, understood as a combination of knowledge, skills and attitudes appropriate to the context [3], [4].

Different kinds of activities undertaken inter alia by Multimedia in Physics Teaching and Learning Group are in line with efforts to support development of eight Key Competencies: communication in the mother tongue, communication in foreign languages, mathematical competence and basic competences in science and technology, digital competence, learning to learn, social and civic competences, sense of initiative and entrepreneurship, cultural awareness and expression [5].

The main aim of the presentation is to portray the essential knowledge, skills and attitudes related to each of the Key Competences in a framework of modeling the competence in the educational process of the student [6]. Different aspects of learning processes such as: ethics, emotional intelligence, attitude, socialization, knowledge, understanding etc. will be presented as a complementary elements of the model. The model is going to be enriched with certain examples of the use of ICT tools and procedures namely web services, educational environments and electronic resources. In authors opinion these tools and procedures play an important role in formation of the Key Competencies in the nowadays educational institutions and their environments. The findings will be illustrated with examples from authors experience gathered during European Educational Projects e.g. “School of Key Competences”. Special attention will be devoted to emphasizing that such tools and activities are particularly necessary for personal fulfillment and development, social inclusion, active citizenship and employability.

References

[2] Learning while we are connected, Proceedings of WCCE 2013, Toruń, Poland
S3: Investigating physics teaching and learning at university

Chairperson: Jenaro Guisasola. University of Basque Country, Spain
Discussant: Mieke De Cook. University of Leuven- KU Leuven, Belgium
Proposer: GIREP thematic group PERU (Physics Education Research Group at University)

Most of the initiatives taken by the European Community and by other international countries in the area of science education refer to the educational levels of Elementary and Secondary, but few reports analyse the state of science education in Higher Education. However, research in science education, and in particular in physics education, has shown repeatedly that the way teachers teach elementary and secondary school is strongly influenced by its prior instruction in the University. The education that future professionals, such as scientists, engineers and science teachers, receive in University is a very effective, for its duration as to take place in a period of full maturity. Under this situation, it seems appropriate detecting, analysing and providing solutions to the problems of teaching and learning related to university physics curriculum.

The symposium aims to describe and discuss some studies about analysing the current state of the teaching and learning on a specific topic at university level such as limitations of learning achieved by students, teaching strategies or problem solving. In particular, two of the presentations will be about the students learning on conceptual knowledge in topics of electromagnetism or modern physics. The other presentations research on students’ procedimental abilities for making meaning physics equations.

Paper 1: Student use of proportions in introductory physics courses

Stephen Kanim. New Mexico State University, USA.

Recent studies have shown that the mathematics preparation of students is correlated to their success in introductory physics courses, as instructors might expect. Yet the mathematical difficulties exhibited are often with elementary material that students should have well in hand. As part of an ongoing study funded by the National Science Foundation, I have been working with Suzanne Brahmia and Andrew Boudreaux to try to understand why students in introductory courses struggle with use and interpretation of proportions even though they have used ratios and proportions for many years in their mathematics courses. We take the view that proportional reasoning is not a monolithic skill, and that fluency with use of proportions involves learning specific interpretations of ratios as well as procedural skills. Based primarily on previous research, we have attempted to identify the components of proportional reasoning that we believe contribute to this fluency: (1) Recognizing ratio as an appropriate measure; (2) Verbal interpretation of a ratio; (3) Construction of a ratio to characterize a physical system or phenomenon; (4) Applying a ratio to make quantitative predictions about novel situations; (5) Translating between different representations of direct proportions; and (6) Reasoning about situations where relationships are not direct proportions. We have developed a suite of diagnostic questions that we are using to try to
measure the degree to which various student populations have developed fluency with these categories. I will describe some of the questions we have asked and report on student performance on these questions.

We have found that even within these categories, students may be successful with some questions and unsuccessful with others. For example, when we ask for an expression of a useful ratio, students are more likely to answer correctly if the question is asked in an everyday context than in a more scientific one. In addition, students tend to be more successful when the question requires reasoning about numbers than when a variable is substituted for one of the numbers. The development of fluency might therefore require repeated exposure in the various categories at increasing levels of abstraction.

At times it seems that the difficulties we are observing have less to do with the proportions themselves than with fundamental differences between how students and physics instructors think about the purposes of mathematics and about the meanings of mathematical expressions. This in turn has led us to look for ways that mathematics as it is taught in mathematics classes is different from mathematics as it is used in introductory physics classes. In addition, we are beginning to try to account for variations in student fluency as measured by our diagnostic questions by looking at the differences in how mathematics is taught from one school to another. In this talk I will describe some of these differences.

**Paper 2: University students' difficulties with the role of experimental setup in the process of spectra formation**

*Lana Ivanjek¹, Peter Shaffer², Lillian McDermott² and Maja Planinić¹*

¹University of Zagreb, Croatia; ²University of Washington, USA

Physics education research is still mostly focused on student understanding of basic topics from classical physics, with less emphasis on topics from modern physics. Examples of such a topic are line spectra. It is important that students develop good understanding of spectra as a prerequisite for understanding of quantum mechanics, as well as astrophysics. The structure and formation of spectra are a part of university and secondary school curricula both in Croatia and in the United States. Systematic investigation of student understanding of atomic spectra was conducted among 1000 science majors in introductory physics courses at University of Zagreb, Croatia and University of Washington, USA. The research had two focuses: 1) to probe the extent to which university students are able to relate the wavelength of spectral lines to the transitions of electrons between energy levels in an atom, and 2) to probe the extent to which students recognize the conditions under which discrete line spectra are (or are not) formed.

The results indicate low student understanding of the process of line spectrum formation. The focus of this talk will be student understanding of the role of the experimental setup in formation of a line spectrum. A question that probed that aspect of student understanding was constructed and administered to students. Only between 20% and 30% of the students recognized that the type of the light source is critical for the formation of a line spectrum. Students were often treating a prism as if it always yielded a continuous spectrum, treating spectral lines as if they were always visible, and most of them were confusing discrete line spectra with diffraction patterns. Identification and analysis of student difficulties guided the design of a set of new instructional materials, tutorials, to supplement instruction in a standard calculus-based physics course. An online spectra application for homework use was also designed. The posttest results showed that some of the student difficulties persisted even after instruction, and that there is more space for the further improvement of instruction materials.

Findings from the research questions will be presented, and students’ most frequent reasoning difficulties will be discussed. Students’ posttest results and the examples from the tutorial will also be presented and discussed.
**Paper 3: Characterizing university students’ use of electromotive force concept in electromagnetism. A international research in four countries**

Kristina Zuza¹, Mieke de Cook², Isabel Garzón³, Paul van Kampen⁴ and Jenaro Guisasola¹

¹University of Basque Country, Spain; ²University of Leuven- KU Leuven, Belgium; ³National Pedagogical University, Colombia; ⁴Dublin City University, Ireland

Electromotive force is a critical concept that is used in analysing physical phenomena and is often important point in physics problem-solving. It is a transversal concept that appears throughout the physics curriculum in introductory electromagnetism courses at university. The electromotive force (emf) concept is at the heart of description processes when a series of “non-conservative actions” takes place, for example, in the battery of a cc circuits or in electromagnetic induced current, through which energy is delivered to the charge. The emf quantifies these actions as the “work done” per unit charge or the electric energy delivered per unit charge, by a non-coulombian or non-conservative force in the context of classical electromagnetism. So, the electromotive force means transference of energy quantified by work done by non-conservatives forces. Therefore it is important to discuss the topic of emf clearly and effectively in teaching university physics introductory courses and in textbook. However, some research on students’ understanding of the concept of electromotive force in Electricity show that they have confusion about the meaning of emf and, in distinguishing between emf and other different concepts but related epistemologically as the potential difference and electric current. Moreover, the few studies that are on the students’ difficulties in understanding the emf concept in electromagnetic induction also indicate that students do not understand the meaning of it.

Our work deals with categorising the students’ use of electromotive force in two different context such as electricity and electromagnetic induction. The final aim of this study is to identify students’ difficulties in learning the concept of electromotive force in the context of electromagnetism, which could provide a set of guidelines for teaching. In order to investigate students’ difficulties in understanding, a questionnaire based on an analysis of the theoretical and epistemological framework of physics was used. It was put to first course science and engineering students from Spain, Colombia, Belgium and Ireland. The results of the study show that students’ difficulties seem strongly linked to the absence of an analysis of the work carried out on the processes and its energetic balance. In this regard, most university students still do not clearly understand the usefulness of concept of emf as the quantity that measures the work carried out by non-conservative forces to deliver electric energy to system.

**Paper 4: International physics education research at advanced university level: a vision**

Paul van Kampen. Dublin City University, Ireland

Providing state-of-the-art physics education to the next generation of scientists and engineers is an important challenge. In recent years, considerable effort has gone into the development of scientific literacy and frameworks that promote inquiry-based science education at primary and second level. However, it is also crucial to help future scientists and engineers develop a detailed understanding of science and engineering as it is practiced by professionals and as an academic subject. To date, most research into the teaching and learning of physics has been carried out from primary up to introductory university level. One of the next big challenges is to extend this work to more
advanced levels of physics. In this talk I will argue this process will involve more than a simple transfer of existing activities.
The impact of a program of research-informed and research-led physics education will likely stretch beyond the confines of the universities. The education future professionals receive at third level influences the way they view and portray science. As a prime example of this, the way teachers teach at primary and secondary school has repeatedly been shown to be strongly influenced by their prior instruction at university.

I will make the case for an international collaborative research effort and suggest a number of possible approaches that may be fruitful. By coordinating the research in many countries with a wide range of educational and cultural backgrounds, more conclusive and general evidence and a greater impact are achievable than could be achieved in local or national projects. Even where effective international collaboration exists, it is often only translated into actions at the local level. I will give specific examples of cross-border physics education research at advanced university level, and aim to generalise the lessons learnt to instigate discussion on how the scale of such collaborations can be broadened to have an impact at national an transnational levels.

### Session 3.5 Invited Symposium S4

**Aula Multimediale B**

**Tuesday, July 8 14:15-16:15**

**S4: Multimedia teaching principles and Assessment**

*Chairperson: Pieter Smeets*  CITO, Arnhem, The Netherlands  
*Discussant: Ton Ellermeijer* Foundation CMA, Amsterdam- Netherlands er,  
*Proposer: MPTL Committee*

Multimedia and ICT have got an important place in Physics education. Multimedia and ICT give opportunities to teach other things The real life can be brought in the classroom. The student can be more interactive with the software. Calculations can be left over to the software, so there is more time for real thinking about Physics.

Because the education has changed, the assessment has to be changed too. If the student learns using ICT he has to be assessed using the same ICT

We think that The assessment of ICT ears more attention. (We look for partners to cooperate in a project to make a guide for ICT-tests in Physics.)

In this symposium we have

*Pieter Smeets: Making valid assessment of ICT and Multimedia in PhysicsEducation Experiences from the Netherlands*  
*Lars-JochemThoms, RaimundGirwirz: Training and assessment of experimental competencies from a distance optical spectrometry via the Internet in Munchen (Germany)*  
*André Heck: Experiences with ICT and Multimedia in performance tests*
Multimedia and ICT have got an important role in Physics education. In the classroom Animations are available, to many to have an oversight. Software is used to do measurements and to process the data. Video-measurement can give nice projects. And there are a lot of modeling programs. Combining Video-measure and modeling give nice opportunities for the pupils to go through the scientific process: (Question, Hypothesis, Experiment, Data analysis, Theory modeling, Conclusion, New question …..). Nowadays a lot of effort is done to get the existing software working on mobile devices like mobile phones and tablets.

So Multimedia and ICT give opportunities to teach other things. The real life can be brought in the classroom. The student can be more interactive with the software, so there is more opportunity real reasoning in about Physics. Because ICT and Multimedia change the education, the assessment has to be changed to. To incorporate the advantages of ICT in education, the use of ICT should be in the assessment of the students.

The end of the teaching process is the assessment of the students

Because the education has changed, the assessment has to be changed too. If the student learns using ICT he has to be assessed using the same ICT.

In the Netherlands we have Central Exams in Physics These central exams are context based. From 2004 until 2010 we had the COMPEX-project where in the Central Exams Physics (and Biology Mathematics and Economy) and we had a part using the computer. Not as a test device (Computer Based Tests) but as a tool to do experiments and investigations in Physics. On 3 levels, Lower vocational, Higher vocational and Pre-university we used Applets, Excel, Coach data processing, videomeasure and modeling in the tests. Because the students used the same software in their lessons, they had the skills to use the programs.

The idea was that students must be assessed with the same software they work in the classroom in Physics. Because many school use Coach in their lessons, we used Coach in the examination. In the examinations the student cannot do experiments like in the classroom. So we present in the examinations data to process, or a video to measure on. In the classroom the students can design numeric models for their measurements. In the examinations we presented models, the student has to use and to adapt.

But the idea is independent of the software. The same examinations can be made using other software and even mobile devices like tablets.

We developed tests in the format of our examinations. with a marking scheme.

Because not the whole exam was using the computer, we could compare the students in COMPEX with the other students. So even if the computer-questions had a higher level than the not computer question. We can give all students a honest mark.

From this project we conclude that it is possible to construct valid and reliable tests for students at grade 10 11 12. We are convinced that this idea deserves support. Even in these days of mobile devices like phones and tablets.

In this talk I shall present the Starting Principles, The way to construct these Exams, The conclusions of the Exam Analyses and some examples of these Exams.
Paper 2: Training and assessment of experimental competencies from a distance: optical spectrometry via the Internet

Thoms & Girwidz, Ludwig-Maximilians-Universität, Munich, Germany

Introduction and theory
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. Hence, tools are needed that assess both knowledge and skills of knowledge acquisition. Since hands-on experiments are not suitable for large-scale assessment, process-oriented experimental competencies may be assessed in virtual labs. Considering the 2006/7 debate on minimally guided teaching techniques, assessment tools on experimental competencies including process-oriented inquiry techniques should be familiar to students to prevent cognitive overload while assessing competencies. Furthermore, the format of an assessment tool for a particular learning environment should be similar to the format of the learning environment itself. Thus, teachers should introduce these assessment tools in class as instructional tools.

Concept and implementation
Banchi and Bell (2008) proclaimed four levels of inquiry in activities with rising opening and with drawal of predefined structure – confirmation inquiry, structured inquiry, guided inquiry and open inquiry. Based on this classification, we developed a remotely controlled laboratory with predefined set-ups selectable according to the class. This reduces the complexity of the lab activity for students. Students can carry out real experiments via the internet. They can choose from different light bulbs and analyze them with a spectrometer. All user activities are logged by the system without disturbing the students.

Objectives and assessment
Assessment of experimental competencies is not yet well established. We just started with an empirical pilot study, too. This study aimed to examine if undergraduate students may successfully use a predefined remote lab activity to introduce atomic physics to themselves on their own. We evaluated the experimental setup and the accompanying worksheet with groups of two to four students in a laboratory condition. Additionally, the emerged learning material was brought to school and tested as a homework activity with 9th-graders replacing the regular introduction to atomic physics. Since our local curriculum preserves approximately two 45-minute lessons for the introduction to atomic physics especially including the introduction to atomic spectra, excitation, de-excitation, quantized energy radiation, and term-schemata. Even if the school owns a spectrometer, there is not enough time to include a lab activity in class. A homework-based activity in a remote lab can fill this gap and may deliver a new approach to procedural learning. Furthermore, lab activity as homework can foster problem-based, discovery, and inquiry-based learning and support collaborative and cooperative learning as well.

Technical details and the experimental potential are explained as well as some findings from this empirical pilot study about the learning scenario mentioned and its usefulness as assessment tool.

References

André Heck Amsterdam The Netherlands

In Dutch education practical work has an important place. Beside Learning Physics in the classroom by explanations and calculations, there is a role for practical tasks for the pupils. Small practical investigations (4 to 10 hours of work) and one large research or design experiment (80 hours of work) are part of the Dutch examination program of senior secondary education. The main instructional purpose of the small investigation asks is to give students opportunities to (1) build up general competencies such as research skills, ICT skills, communication skills, and so on; (2) deepen or enlarge existing mathematical and scientific knowledge; and (3) become more proficient in applying knowledge and skills in practice.

In The Netherlands every student has to do a final project, usually done in the last year before the final central examination. The project can but a part of two subjects, like physics, chemistry, mathematics, biology, geography. Students must demonstrate their achieved level of knowledge, skills, and attitude by the creation of a masterpiece of independent work on a topic of their own choice. For example, in a research project students must demonstrate their research abilities, ranging from choosing a manageable problem, formulating a good research question, and structuring their work to drawing conclusions and presenting the research results. These projects can be individual, or a cooperation of two or three students.

We discuss assessment of such investigations in which computer-based data logging, video measurement and modeling play a fundamental role. We pay special attention to ICT skills and authenticity of student work, illustrated by examples from student research projects, and to methods used in school practice to manage assessment.

Session 3.6 Symposium S5
Room 12 (Aula 12)
Tuesday, July 8 14:15-16:15

S5: Representations in teaching and learning Physics

Chair: Russell Tytler, Deakin University- Australia
       Peter Hubber, Deakin University- Australia
       Roser Pinto, Universitat Autonome de Barcelona- Spain
       Andreas Redfors, Kristianstad University, Sweden
Discussant: Marisa Michelini, Università di Udine, Italy

There is increasing interest in the role of multiple, multi-modal representations in learning (Lemke, 2004; Ainsworth, 2006; Tytler et al., 2013) across all subjects. The practice of science, and learning science both increasingly involve images, simulations and models, and mathematical symbolic expressions. Problem solving in science involves the development of abilities to generate and coordinate representations (Kozma & Russell, 2005), and meta-representational competence is a key skill that students need to develop to learn science effectively (diSessa, 2004). Difficulties with conceptual change can be characterized as fundamentally representational in nature (Tytler & Prain, 2013)
Much of the research into multiple representations has investigated issues surrounding student interpretation of the representations/models that configure scientific knowledge—the need to understand the conventions underpinning these representations and how they are coordinated to interpret phenomena and develop explanations (Gilbert, 2005). Teachers need to sequence, and coordinate representational work (Ainsworth, 2006). There is a growing interest in the role of representations in inquiry, where teachers guide students to construct and coordinate representations to reason and generate explanations of phenomena in ways that mirror the practices of science (Lehrer & Schauble, 2006).

This symposium includes papers that range across a number of these perspectives: issues for students with representational work, principles of teaching with multiple representations, and teacher professional learning associated with a representation construction approach. Paper 1 explores the relation between theoretical models, mathematical representations and the real world using video based classroom observations and survey. Paper 2 examines difficulties students have in translating physics problems into mathematical form, concluding that the production of graphical representations is a useful intermediate step to generating algebraic representations. Paper 3 examines the ways in which two teachers coordinate and link sequences of representations in explanatory work in astronomy, generating a number of principles underpinning quality practice. Paper 4 examines the professional growth pathways of teachers as they plan and deliver a unit of work in astronomy that uses a representation construction approach.


*Andreas Redfors, Lena Hansson, Örjan Hansson and Kristina Juter*  
*Kristianstad University, Kristianstad, Sweden*

Explanations of physical phenomena are organized through theories and theoretical models (Adúriz-Bravo, 2012). The theoretical models are developed through a cyclic and interactive process of theorizing, discussions, experiments and observations (Giere, 1997), see Figure 1.
Also observations and experiments are by necessity embedded in theory and therefore "Theory laden" (Hanson, 1958), thus there is a complicated relation between what we call a theoretical model with theoretical concepts and representations, and real world referents and real world phenomena.

Mathematical representations are often used in physics models of events in the real world. In physics studies students have been found to struggle with explanations and the solving of physics problems when they need to relate theoretical models to real world phenomena, especially while using mathematics, i.e. combining mathematical representations and operations with conceptual reasoning about physical phenomena – realising that equations can express a supreme meaning (Kuo et al., 2012; Uhden et al., 2012).

The purpose of this project is to further explore the role of mathematics for physics teaching and learning in upper-secondary school through investigating links made during physics lessons (lectures, problem solving and lab-work) between the constructs The real world – Theoretical models – Mathematics. The research questions are:

1. How are links between The real world, Theoretical models and Mathematics made during physics lessons?
2. How does the occurrence of links differ for different organisational forms (e.g. lectures, problem solving, lab-work)?

The study uses video-based classroom observations (lectures, problem-solving sessions and lab-work) and written surveys. A written instrument has been developed to complement the video recordings in giving students a possibility to express individual experiences after a lecture. One teacher and students in three classes in the science programme in an upper-secondary school have been studied during sequences of lectures, problem solving in groups, and lab-work. Three to four lessons (40-80 min) per class.

The data is analysed from a deductive perspective of finding the links shown in the “triangle of analysis” as depicted in Figure 2. The three sides of the triangle represent the different links.
The preliminary analysis indicates that models and concepts are introduced during lessons without links. This pattern is seldom broken. However, there were some situations where the described pattern was broken. The teacher commented on airbags and the length of hoods of cars in relation to the formula \( W = F \cdot s \) thus helping students to link to a real world situation. Hence, there are links made by students and teacher between theories and the real world, but the bulk of the discussion in the classroom is concerning the relation 2 in Figure 2. That is on mathematic representations and manipulations of these. This result is in line with earlier research on problem solving. Surprisingly this result seems to hold true for all three investigated organisational forms, i.e. lectures, problem solving in groups and lab-work. A more detailed analysis will be presented at the conference.


Paper 2: Some obstacles when interpreting information from visual representations

Roser Pintó, Victor López
CRECIM, Universitat Autònoma de Barcelona

Using visual representations in our classes is, naturally, more and more frequent since the exploitation of images is the most common way to communicate at present. If we think the skills that should be boosted in our society, the ability to interpret visual representations will be one of the most relevant ones. That is, our youngster should be able to extract correctly the visual information that arrives to them. In our presentation, we intend to show some obstacles that students have to overcome in order to have acquired such skill. We carried out a piece of research trying to analyse: What are the obstacles that secondary school students have to overcome when faced with some simulations around the phenomena of Electromagnetic induction or around Increasing temperature by rubbing two surfaces? Half an hour interviews where done to 8 students 15-16 years faced in front of a simulation. The below images are a representation of them.

Students descriptions, when reading such “dynamic images” and interpreting its meaning, were analysed and conceptual requirements were carefully defined. (It is no matter of this presentation). What we would like to highlight in this symposium is that the extracted information doesn’t correspond to the intended to be represented. We could realise that some mechanisms of reasoning
seems to intervene on the distortion. Particularly, we will intend to describe two found mechanisms used by our students:

**The elimination mechanism.** Students “eliminate” parts of the images in the sense that they seem transparent to them. Some information conveyed for the simulation is not taken into account. In some cases, this “removal” of information is unnoticed and comes from not properly perceiving the information that simulation is intended to convey. This is, for example, the case when students do not identify the irregular arrangement of particles in simulation A.

In other cases the participants perceive the visual elements but do not establish any relationship between them. For example, when students do not establish any relationship between particle vibration and temperature in this simulation A. That is, a central piece of the represented information is not captured for the participant making the simulation useless. When in this simulation, students do not catch the relation between rubbing the surfaces of the books and increasing the collisions of the particles (or increasing the temperature), the work around the simulation becomes negligible.

Another type of mechanism of reasoning seems to appear when student change the information offered for the images to another one more close to their minds. We called them replacement mechanisms. The information conveyed for the simulation is replaced for another one more accessible in their memory long term. According the heuristic of Tversky and Kahneman (1974), there is a tendency to attribute to each effect a cause that is more easily accessible. It may be some recent information that is retrieved effortlessly and is applied in different situations.

We refer to situations in which participants replace the phenomenon presented in a simulation by another phenomenon recently studied in class. Students who have just studied electrical circuits interpret the magnetic field lines of simulation B as “the way of the electrons” and, participants of another school that had just been taught about “changes of state” interpret certain movement of particles in the simulation A as evaporation.

During the presentation on this symposium, details about such mechanisms appearing when secondary schools use simulations will be discussed.

**References**

--Lopez, V. Les dificultats dels estudiants de secundària en la lectura d’imatges científiques representades en simulacions de física. Ph Doctoral thesis unpublished


--http://www.jstor.org/stable/1738360

**Paper 3: Coordinating representations in teaching astronomy: a cross---country comparison**

*Russell Tytler, Deakin University*

*Karen Murcia, Edith Cowan University*

*Chao-Ti Hsiung, National Taipei University of Education.*

Over the last two decades there has been increasing recognition of the central role played by multi-modal representational practices as part of the disciplinary literacies through which students reason and learn in science (Ainsworth, 2006; Kress et al., 2001; Tytler et al., 2013). While there is recognition of the need for teachers to use, interpret and coordinate representational work in science classrooms there has been little research into the specific ways in which such work occurs to support quality learning, or how effective representational practices might be situated within different pedagogical traditions. This paper draws on close video ethnographic analysis of
astronomy lessons in two countries – Taiwan and Australia – as part of a wider crosscultural comparative video study of competent elementary school teachers of science. The sequences were respectively 15 and 6 lessons long, each supported by significant digital and other representational resources. This representational work occurred within very different classroom organizational contexts, with disparate presumptions concerning the roles of teacher and students in constructing knowledge, different emphasis in assessment with Taiwan having a strong tradition of centralized competitive testing, and the greater focus on open group tasks in Australia. The Taiwanese teacher was a specialist science teacher while the Australian teacher was a science-enthusiastic generalist. The study aimed to identify whether within this contextual diversity there are transcendent principles governing the way representations and models are established and coordinated. One lesson was chosen from each sequence, that included a series of models and representations, concerning moon phases (Taiwan), and the day/night cycle (Australia). The analysis shows the deliberate ways that these competent teachers 1) coordinate sequences of representations in a logical narrative, 2) transform representations across modes, and across dimensions (3D to 4D to 2D) in ways established for practice in science (Gooding, 2004), 3) explicitly focus students’ attention on their salient features using gesture and metaphorical talk, 4) use deliberate strategies to link these partial representations in a sequence, and 5) monitor students’ interpretation and use of representations. The Taiwanese teacher established coordination of earth and space perspectives as the key element of the modeling, through role-play, and metaphorical reference to ‘earthlings’ and ‘astronauts’ that persisted through and coordinated the successive representations. The Australian teacher made similar moves, but used open modeling tasks to challenge and monitor students’ understandings. The study demonstrates the centrality of representational coordination as part of expert practice, and specific principles through which such coordination occurs, at the same time acknowledging variation due to cultural context. It also establishes important aspects of the nature and role of representations in learning science –that representations are partial, and that they do not ‘speak for themselves’ but need to be interpreted through negotiation of language and embodied experience. A framework is developed aimed at identifying and guiding effective representational work in the classroom to support quality learning.

References

Paper 4: Teacher change in implementing a research developed representation construction pedagogy

Peter Hubber, Gail Chittleborough, Deakin University

This paper explores the issues in scaling up a research led pedagogical innovation which involved the development of a ‘representation construction’ approach to teaching and learning science. The research program, Representations in Learning Science (RILS 2007-10), developed the representation construction approach working closely with a small number of teachers to plan and implement units of work. This approach involves challenging students to generate and negotiate the representations (text, graphs, models, diagrams) that constitute the discursive practices of science. The representation construction approach is based on sequences of representational challenges which involve students constructing representations to actively explore and make claims about
phenomena. RILS has successfully demonstrated enhanced outcomes for students, in terms of sustained engagement with ideas, and quality learning, and for teachers’ enhanced pedagogical knowledge, and understanding of how knowledge in science is developed and communicated (Tytler et al 2013).

Following RILS research the representation construction approach was translated into wider scale implementation within a current research program, Constructing Representations in Science Pedagogy (CRISP 2012-14), working with new teachers in a range of schools, investigating the issues and factors that determine the quality of uptake. This paper focuses on one of the CRISP schools which involved four Year 8 teachers who implemented the representation-construction approach to the topic of astronomy. The research question: What are issues that confronted four Year 8 teachers in implementing a representation construction approach to teaching and learning astronomy?

Data was generated from teacher interviews, video capture of selected classrooms, field notes taken of researcher-teacher interactions, pre and post-testing of students and student work. The Interconnected Model of Teacher Growth (IMTPG) (Clarke & Hollingworth, 2002) was used to analyse the teachers’ experience in planning and delivering the teaching sequence. There was a range of issues that confronted the teachers and conditions that proved significant for successful implementation for them included: preparedness of the teacher in terms of epistemological positioning and positioning as a learner; significant support for planning and modeling by the university expert; and a team ethos where teachers share ideas and plan jointly.

The IMTPG consists of four domains: the personal domain, the domain of practice, the domain of consequence, and the external domain. The model suggests that a change in one domain is translated into another domain through the mediating process of enactment and reflection. We found IMTPG to be flexible in identifying the experiences of the teachers in different situations and demonstrating the complexity and the multifaceted nature of teacher change. We found that the domain external to a teacher is highly complex, consisting in our case of university experts, curriculum resources, and also the community of teachers involved. Two major characteristics of the external domain are central to our current concerns that are a relative silence in the model. First, the shaping and coordination of the resources exemplifying the innovation is critical for successful implementation. An important challenge we face is how to characterize the central aspects of the approach, in a way that is understandable and attractive to teachers, provides a basis for successful classroom experimentation, and is consistent with its deeper theoretical underpinnings. Second, the importance of peer collaboration is apparent in our data, such that input and feedback from colleagues acts as a critical supplement to the input provided by the researchers. Thus, we recommend that the model can be fruitfully extended or further interpreted to clarify the different dimensions of the external domain in particular.

References
Paper 1: An account of elementary teachers’ epistemological progress in science

David Hammer - Tufts University-USA

We examine elementary teachers’ inquiries in science in summer professional development (PD) workshops, as part of Responsive Teaching in Science, a three-year project supported by the National Science Foundation. The data, in broad view, shows significant progress in most teachers’ disciplinary engagement. Our purpose here is to study epistemological aspects of that progress. Motivated by accounts of epistemological resources and framing, we consider evidence of local dynamics by studying teachers’ work during the first summer workshop and the third. The analysis shows moments in the first summer that resemble the more extensive disciplinary engagement of the third. These moments were uncommon and short-lived, during the first summer, but they evidence intuitive epistemologies consistent with disciplinary epistemologies. We thus characterize teachers’ progress in terms of expanding stabilities of emergent patterns of engagement.

Paper 2: Physics concepts and processes in Mexican primary school textbooks: An analysis from inquiry-based learning perspective and implications for teachers’ education

Josip Slisko - Benemérita Universidad Autónoma de Puebla-México

Inquiry-based science learning (IBSL) is the current world trend in science education. Its fundamental idea, well supported by educational theory and experiments, is that students best learn science by doing science. Doing school science means that students are actively engaged in observing, describing, measuring, explaining and predicting scientific phenomena. The recent curricular reforms in Mexico, at least at the level of official declarations, moved science education towards the paradigm of IBSL. Similar intentions can be noted in re-education of in-service science teachers.

Knowing that teachers’ classroom behavior depends very much on how something is pedagogically treated in students’ textbooks, it is important to analyze how adequate these educational resources are for implementing IBSL.

In this work I analyze how physics concepts and processes are presented in Mexican primary school students’ textbooks for «Natural sciences», an obligatory matter taught from third to sixth grade. All suggested students’ activities related to physics are categorized according to the presence
of basic scientific procedures (observing, describing, measuring, explaining and predicting), in order to find out how well they reflect and potentially implement the philosophy of IBSL. The results show that the big majority of students' activities are not in resonance with IBSL. In too many cases, the narrative text, which follows a students’ activity, describes what students were supposed to observe or learn. In addition, there aren't activities that are designed to reveal and challenge many known students’ alternative conceptions and make possible conceptual change. Being so, the design of learning activities, related to physical concepts and processes, is not cognitively adequate and can hardly lead to transferable school science knowledge and ideas about the nature of science. It is also alarming that even revised textbooks still contain conceptual and representational errors. Namely, in the latest edition of science textbooks only some of the most obvious errors of previous editions were corrected. It means that official reviewers and in-service teachers who use the textbooks in their daily teaching do not possess necessary science and pedagogical knowledge to correct all errors. Solutions of these difficult problems would imply two related lines of action. First, it would be crucially important to get research-based evidence that cognitively inadequate learning activities and textbook errors lead to low-quality and/or erroneous students’ knowledge. Second, having such evidence in hand, it would be much easier to advocate for a more intense participation of domestic and international science and physics education experts in all phases of curriculum design and textbook revision, both for primary school and teacher education institutions. As is the case for many other countries, for a better social and economic future Mexico needs a new generation of science teachers with solid pedagogical content knowledge who will be able to implement authentic IBSL in primary schools.

Paper 3: Utilizing physics as a medium for promoting integrated learning in elementary science: an example in the context of energy

Nikos Papadouris & Costas P. Constantinou - University of Cyprus - Nicosia Cyprus

Learning in science constitutes a multifaceted construct. It involves, among others, (a) conceptual understanding, in terms of the conceptual resources that one could draw on to analyze, and account for, the operation of physical systems and processes, (b) appreciation of fundamental aspects of how science operates and how scientific knowledge is produced, elaborated, justified and organized, and, (c) reasoning strategies related to the design and implementation of valid experiments, the collection and processing of reliable data and formulating evidence-based knowledge claims. We suggest that the disciplinary knowledge in Physics could play an important role as a medium for organizing powerful learning environments that could usefully promote the integration of these learning objectives. At the same time, we also argue that in the elementary grade levels (K-6) it would be reasonable to place the emphasis mostly on the last two components and take a rather modest perspective in terms of what could be reasonably expected from students as a conceptual learning outcome. Even though it is important to also address conceptually oriented learning objectives, it is essential that care be taken to ensure, on the one hand, consistency between the complexity of the targeted learning objectives and students’ existing resources and relevant experiences and, on the other hand, compatibility with the more formal representation of these ideas in the domain of physics, so as to allow shifting to more powerful accounts in subsequent grade levels, through appropriate teaching sequences. In this paper, we undertake to illustrate the idea of utilizing the disciplinary knowledge of physics as a medium for promoting integrated learning in science, taking the concept of energy as an example. In particular, we seek to illustrate how energy could serve as a productive context for organizing a learning environment that could facilitate holistic learning, by promoting, in an integrated manner, objectives referring to conceptual understanding, appreciation of the nature of
science and reasoning strategies. In particular, we discuss a specific example of teaching/learning materials for upper elementary students (12 year-olds) that could enable integrating *conceptual understanding* (use of energy as a framework for analyzing the operation of systems) *appreciation of certain aspects of the nature of science* (e.g., understanding of the distinction between interpretation and observation and the role of human invention in the production and elaboration of scientific knowledge) and the *development of reasoning skills* (optimization as a reasoning strategy for processing data in decision-making situations relevant to topical energy-related socio-scientific issues). In the last part of the paper, we report empirical results from trial implementations of these teaching materials in authentic classroom environments, so as to offer insights into what could be achieved by upper elementary students, in terms of learning gains.

**Paper 4: Research based activities and school-university cooperation in teacher professional development on optics**

*Marisa Michelini, Alberto Stefanel DCFA, University of Udine-Italy*

A knowledge society and its rapid change require professionals with new skills. Teachers are among the professionals needing the greatest changes [1-4]. However, teachers tend to reproduce school practice, styles, and traditional methods [8-9]. Teacher professional development must support teachers in changing their practices in spite of this inertia [5-7]. A wide research literature shows that it is not sufficient for teachers to be told to promote active learning for students [7, 10-13]. Instead, teacher professional development must take into account differences in teachers' formative experiences [14-15] and what they have learned from practice [5, 16] to create communities of practitioners, relating to content [17-18] and differentiating by context [2-3, 5]. In primary school the preparation of teachers should include not only substantial science content but also how that content can be proposed to children in the form of games, including explorations based on conceptual challenges [19-23]. In this way, teachers may foster learning environments in which children have an active role in the construction of their own scientific knowledge.

We seek to understand how teachers take ownership of the content offered in teacher professional development and transform that content into instructional practice. A formative module on optics has been designed for this purpose and proposed to a group of 18 kindergarten, primary and lower secondary school teachers of the same Institute. The module begins with a history of conceptualizations of light and vision and integrates meta cultural, experiential and school-situated phases of learning. Simple experiments and problem solving tasks enable reflection on both specific conceptual problems and how they may be addressed with students.

Design and implementation of microteaching activities were interspersed with formative sessions, to ensure teachers’ active role in the construction of their conceptual understanding and to engage their experience with students as science learners.

The present study investigates teachers’ conceptual difficulties with light and the mechanism of vision, and how and how much they use the historical module, experiments, and problems in their classes. Data was gathered using classroom observations, written assessments of teachers, and exercises in which teachers analyzed student responses to instructional tasks.

Our results show that teachers tend to appropriate activities that they themselves find most challenging, including activities relating to the formation of images by plane mirrors and the propagation of light in refraction. The steps that have primarily triggered this process of appropriation have been the collaborative review written assessments and the collective discussion of student responses to instructional tasks.
S7: The results of the EC-project ESTABLISH

Chairperson: Ton Ellermeijer, Foundation CMA, Amsterdam, Netherlands
Discussant: Rosa Maria Sperandeo Mineo, Università di Palermo, Italy

Introduction

Based on the Rocard report, EC funded several larger projects on Science Education during the period 2008–2014. One of these projects was the Establish project, that ran from January 2010 – April 2014, 4 years and 3 months. All these projects aimed at the introduction and broader use of Inquiry Based Science Education (IBSE) through enriching the skills of teachers, as well as through programs during initial teacher training and further professional development. Special in the approach of the Establish project has been the attention given to the links with Industry and involving all stakeholders.
This Symposium will present the main results of the Establish project, and will address several of the aspects of such a large project.

Eilish McLoughlin, the coordinator of the project, will present the overall approach of the project, and will discuss the engagement with stakeholders and in particular the industrial links.

Zuzana Ješková will present on the models for pre-service and in-service teacher training programs, and especially the way it has been implemented in Slovakia.

Claudio Fazio will present an overview on the 18 Units that have been developed by the consortium for use in teacher education and in the classroom, with a focus on the Physics Unit: Heating and Cooling: Designing a Low Energy House.

Dean Zollman will present his views on the impact and overall results of the project from his viewpoint as an external evaluator on the ESTABLISH project.

Paper 1: An ESTABLISH approach to Inquiry Based Science Education for second level students

Eilish Mc Loughlin, Dublin City University, Ireland

The pan-European FP7-funded project ESTABLISH (2010-2014) collaboration has led to the development of the project’s teaching and learning materials as well as educational supports for both in-service and pre-service teachers designed to promote the use of Inquiry based approach at second level. This paper will share the approach adopted across 11 countries (Ireland, Germany, Sweden, Cyprus, Czech Republic, Poland, Slovakia, Malta, Netherlands, Estonia and Italy) to engage second level students in science through inquiry based learning.
To achieve its goals, the ESTABLISH project consortium have adopted a common understanding of inquiry as the “intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments” (Linn,
Davis E.A. et al. 2004). Using this definition and arising from extended group discussions, the individual elements of inquiry were identified and operationalized to represent the role of the student in an IBSE classroom. An agreed framework for the development of these IBSE units has been developed by the consortium, and each unit describes: (1) Unit/science topic, (2) IBSE character, (3) Pedagogical Content Knowledge, (4) Industrial Content Knowledge, (5) Learning Path(s) and (6) Student Learning Activities and Classroom Materials. Using this framework, central IBSE units have been developed and piloted in several countries by the consortium members working with local science teachers. The central unit is then adapted for implementation in each country, taking into account cultural and curriculum differences.

The specific aim of ESTABLISH is to promote innovation in classroom practice by bringing together and involving all the key communities in second level science education, including science teachers and educators, the scientific and industrial communities, the young people and their parents, the policy makers and the science education research community. In fact the relationship between the stakeholders is quite complex given the varying strengths of each relationship and the many societal demands placed on science education. In particular, to promote education-industry links, ESTABLISH IBSE activities are described on a five levels of engagement scaling. I- The activity is linked to industry or everyday context; II- An industry or a product is studied, preferable by a site visit. The challenges in that industry are used to introduce science activities; III- Analyzing an industry’s main product or process based on a site visit and study of both the science content and the design process; IV- An activity where the students need to follow all steps in a design process and during the process they will learn science and do experiments; and V- Contacts with industry lead to a design task with a customer.

**Paper 2: In-service and pre-service teacher education in IBSE – the ESTABLISH approach**

Zuzana Ješková¹, Marián Kireš¹, Eilish McLoughlin², Odilla Finlayson², Christina Ottander³, Margareta Ekborg⁴

¹ Pavol Jozef Šafárik University in Košice, Slovakia
² Dublin City University, Ireland
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One of the main goals of the ESTABLISH 7fp project (http://www.establish-fp7.eu/) was the development and implementation of the professional development teacher education programmes (TEP) to support teachers in adopting inquiry-based strategies in their teaching. Within the project there was a model for in-service and pre-service teacher training in IBSE designed and implemented across 12 participating countries. The programme is based on 4 core elements and 4 additional elements that are built around the IBSE teaching units developed within the project. As accepted by ESTABLISH partners, all teacher training programmes includes the minimum of the four elements, i.e. introduction to IBSE, industrial content knowledge, teacher as implementer and teacher as developer of IBSE teaching materials. There are also four additional elements designed in detail, i.e. ICT for IBSE, argumentation in the classroom, research and design projects for students, assessment of IBSE. These can be added to the programme optionally with regard to the level of teachers` IBSE skills and current situation in education and teachers` professional development within the country.

This ESTABLISH model of TEP was followed in participating countries in order to change teachers` attitudes from traditional ways of teaching towards adopting inquiry strategies and their successful implementation in the classroom. Within the face-to-face workshops teachers
experienced and developed their inquiry based teaching strategies using specifically developed materials. In addition, the e-platform has been developed to provide on-line support. This platform provides educators and teachers with all the necessary materials for the training and IBSE teaching units and other teaching materials for teachers’ ongoing help.

The teacher training programme was successfully implemented in Slovakia. There were two runs of teacher training workshops on IBSE already carried out. Moreover, the additional element ICT in IBSE was developed more deeply designing a separate teacher training course for it. The contribution discusses in more details the success and problems of implementation in the context of Slovak educational environment.

Acknowledgement
This work is supported by the ESTABLISH project (FP7/2007-2013 under grant agreement n° 244749), which received funding from the European’s Unions Seventh Framework Programme.

Paper 3: The development process of the ESTABLISH Teaching-Learning Units

Claudio Fazio, Dipartimento di Fisica e Chimica, Università di Palermo, Italy

In the framework of the ESTABLISH project, 18 Teaching-Learning Units focusing on several aspects of Physics, Chemistry, Biology, Natural Sciences and Integrated Sciences relevant for Science Education at Secondary level have been developed.

The Units were built according to a format agreed by the consortium partners, and reported in the Framework for IBSE Teaching and Learning Units (Deliverable D.1.1 of the Project), and by following the lines sketched in the Guide for developing ESTABLISH Teaching and Learning Units (D.3.0).

The ESTABLISH Units have been designed mainly to serve as exemplary material for teachers during the professional development track developed during the four years of the Project. They have been thought to provide materials for a broad range of pedagogical situation, to be representative of Inquiry Based Science Education (IBSE) methods and to show teachers the benefits of IBSE in classroom practice, inspiring them to generate their own IBSE materials. Therefore a typical ESTABLISH Unit is designed to:

• highlight the role of IBSE methods, and their importance of the development of the Unit;
• provide a science background for both students and teachers;
• highlight the Pedagogical Content Knowledge that should be used or that can be developed by the teacher during the use of the Unit in his/her class;
• link the discussed subjects to real world/industrial applications, also in order to catch the interest of students (and teachers);
• include Student Learning Activities based on IBSE and aimed at encouraging and facilitating students to be the leading actor of his/her own learning;
• be structured according the requirements of secondary school students and teachers;
• explicitly show different levels of IBSE, starting from the simplest ones, suited for complete beginners in IBSE, and possibly getting to the most demanding (for both students and teachers), open inquiry-based, ones;
• give specific attention on gender issues ensuring that all materials are suited to both genders.
• allow adaptation to take into account cultural differences and particular circumstances in each beneficiary country.

After an introduction of the general framework followed for the ESTABLISH Unit preparation, we will focus on the Physics Units and, in particular, on a Unit developed by University of Palermo and oriented to the IBSE that can be developed when projecting an energy efficient house.
The Unit was jointly designed by the researchers of the University of Palermo Physics Education Research Group and 22 lower and upper secondary school teachers, that worked together for all the four years of the ESTABLISH Project. We will discuss the development of the Unit and some relevant results of its trialing, first with the teachers, during the teacher training activities, and then with their students, in real schools classes.

**Paper 4: An Outsiders view of the Impact of ESTABLISH**

*Dean Zollman, Kansas State University, Manhattan, KS USA*

To help assess the impact of ESTABLISH I reviewed the products and research completed during the four-year effort. ESTABLISH set for itself very high level goals. Given our current understanding of how students learn and how they are motivated, the goals would be appropriate for any effort that is attempting to improve the teaching of science and/or to increase the number of secondary students who are interested in science as a career. However, reaching this goal is difficult under any circumstances. Attaining it over a large number of countries and cultures is extremely difficult, and the partners in the ESTABLISH project faced significant challenges. Yet, ESTABLISH has succeeded admirably. Overall, ESTABLISH has developed programs, learning activities, frameworks and models that have significantly impacted inquiry-based science education in Europe. These impacts are well documented in the many deliverable reports created during the past four years. The results of ESTABLISH are likely to influence science education in Europe and beyond for many years to come.

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**Session 5.5 Invited Symposium S8) Aula Multimediale B**

**Wednesday, July 9 14:15-16:15**

**S8: Uses of Multimedia in Physics Teaching**

*Chairperson: Francisco Esquembre, Universidad de Murcia, Spain*

*Proposer: MPTL Committee*

**Introduction:** This symposium is sponsored by the MPTL (Multimedia in Physics Teaching and Learning) group and includes four talks that highlight important trends in uses of multimedia (software) in teaching Physics. The Symposium starts with the 2013 winner of the MPTL Honorific Award for his outstanding online resources. We then report the results of the 2014 Evaluation of Online Multimedia Resources. The other two presentations deal with two ways of dissemination educational multimedia material: Learning Management Systems, namely Moodle, and electronic publishing in the form of ePub books. With these four talks we aim to give an overview of both already available interesting material and ways of deploying it for actual Physics teaching.
Paper 1: Using Technology to Provide an Interactive Learning Experience

Kyle Forinash, Indiana University Southeast, Indiana, USA

Most pedagogical material found on the Internet today is still very passive; pdf versions of books, notes and other traditional learning material, much of which has been around since before the Internet. In this talk I will describe two interactive, online text books I have written that use simulations to engage students in active learning. I will also briefly describe other work I have done with colleagues involving real (as opposed to virtual) online laboratories and student laboratory experiences outside the classroom using mobile devices such as tablets and cell phones.

Paper 2: Report and Recommendations on Available Multimedia Material for Quantum Physics and Quantum Mechanics

Ewa Debowska, University of Wroclaw, Poland

This presentation will report the findings of a joint evaluation of multimedia educational resources for quantum physics and quantum mechanics by the European working group “Multimedia in Physics Teaching and Learning” and the MERLOT/Physics Editorial Board. This work promotes, through discovery and review, the use of valuable and freely accessible information technology materials for different levels of teaching, mostly higher education. The authors will briefly discuss the process of selecting resources and the rubrics used in the rating process. The reviews of highly quality learning resources will be presented along with descriptions of valuable didactical features.

Paper 3: Using Moodle to design physics online courses with virtual and remote laboratories based on EJS.

Luis de la Torre, Ruben Heradio, and Sebastián Dormido

The EJSApp add-ons gather together EJS and Moodle, offering the possibility to build and prepare e-learning programs based on: 1) experimentation (thanks to the use of the virtual and remote laboratories) and 2) theory documentation provision, social interactivity and easy management (thanks to the use of the LMS). Thanks to the EJSApp tools, not only all the EJS laboratories are added and integrated into Moodle in a very easy and natural way, but they also acquire special functionalities they lack when used outside this LMS. One of these functionalities, for example, is the capability of saving and/or loading files to/from the private files repository in Moodle. The newest EJSApp plugin allows to easily access, search and pick EJS simulations from the OSP ComPADRE digital library and to add them in a Moodle course. EJS labs in Moodle are administrated exactly in the same way as any other Moodle resource or activity, meaning they can be updated or deleted; their access can be restricted under certain conditions; security copies are automatically performed during Moodle’s system backups, etc.
Paper 4: Writing Electronic Books with Interactive Curricular Material

Wolfgang Christian, Mario Belloni, and Kristen Thompson, Davidson College, North Carolina, USA

Abstract: With the rise of tablets, such as the iPad, the past few years has seen an increase in the demand for quality electronic textbooks. Unfortunately most of the current offerings do not exploit the accessibility and interactivity that electronic books can deliver. For astronomy and physics electronic textbooks, support for typesetting of equations (MathML) and interactive simulations (JavaScript) are necessary. In this talk we will discuss how our curriculum development projects (Physlets, Easy Java/JavaScript Simulations, and Open Source Physics) are merging with the EPUB electronic book format. Specifically we will discuss the EPUB format and how we are taking an iterative approach to producing interactive electronic books for astronomy and physics. This work was supported in part by Davidson College and the Bacca Foundation.

Session 5.6 Invited Symposium S9
Room 12 (Aula 12)
Wednesday, July 9 14:15-16:15

S9: Strategies for Assessment of Inquiry-based Learning in Science (SAILS)

Chairperson: Eilish McLoughlin, CASTeL, Dublin City University, Ireland.
Discussant: Wim Peeters, Pegdagogical advisor for PBDKO vzw, Belgium

Paper 1: Strategies for Assessment of Inquiry-based Learning in Science (SAILS)

Eilish McLoughlin, Paul van Kampen, Deirdre McCabe, Odilla Finlayson, Centre for the Advancement of Science and Mathematics Teaching and Learning, Dublin City University, Ireland,

The Strategies for Assessment of Inquiry-based Learning in Science (SAILS) project (2012-2015) has been funded by EU 7th Framework Program to support teachers in adopting inquiry-based science education (IBSE) at second level (www.sails-project.eu). This project is focused on improving science classroom practice with students aged 12-18 years, in twelve European countries, by providing teachers with inquiry-based teaching and learning and assessment materials supplemented with teacher education programs. Many IBSE resources and models for teacher education in IBSE have been developed through projects arising from national and international programs, including EC FP7 program for Science in Society, for both pre-service and in-service teachers. These resources will be further developed and enhanced by the SAILS project, specifically through the addition of further elements and implementation of teacher education programs. In particular, the SAILS project will develop appropriate strategies and frameworks for the assessment of IBSE skills and competences and prepare teachers not only to be able to teach through IBSE, but also to be confident and competent in the assessment of their students’ learning. Through this unified approach of implementing these multiple components for transforming...
classroom practice, i.e. teacher education, curriculum and assessment around IBSE pedagogy, a sustainable model for IBSE will be achieved. The recent trend across the EU towards competence-based teaching and learning and a learning outcome approach, has resulted in significant changes occurring at school curricula level in traditional subject areas such as science. These curricula are now being treated in more engaging cross-curricular ways, with greater emphasis being placed on developing skills and positive attitudes towards science alongside knowledge. There is also an emphasis on use of “real-life” applications to provide appealing learning contexts. The IBSE pedagogy is considered to be appropriate in development of these skills and competencies. Therefore, a key starting point for the SAILS project was to review the key skills and competencies desirable for young people in the 21st Century as identified by different international sources and to map these against those developed through IBSE. The Framework for 21st Century learning was used as a basis for identifying key 21st century skills and competencies and those that can be developed through scientific inquiry and the mapping of these inquiry skills under this framework’s learning and innovation skills, Creativity and Innovation, Critical Thinking and Problem Solving and Communication and Collaboration, will be presented.

For many students and teachers, assessment drives classroom activities. Most current assessment methods place a strong emphasis on knowledge recall and do not sufficiently capture the skills and attitudes dimension of key competencies. The result is that current models of assessment are typically at odds with the high-level skills, knowledge, attitudes and characteristics increasingly necessary in our fast-changing world. Furthermore, if something is assessed, then it is often more highly valued by both teachers and students. It is essential that teachers must also be properly prepared for this IBSE approach and hence development of good resources and programs for teacher education is necessary. The SAILS project will address challenge by enhancing existing IBSE approaches through the development of assessment strategies that supports student learning and key skills through IBSE, and developing resources and programs that are both culturally and educationally appropriate.

Acknowledgement - This work is supported by the SAILS research project (SIS.2011.2.2.1-1, grant agreement 289085), which received funding from the European’s Unions Seventh Framework Program.

**Paper 2 - Assessment opportunities in inquiry-based learning**

_Dagmara Sokolowska^1, Eilish McLoughlin^2, Paul van Kampen^2, Odilla Finlayson^2, Deirdre McCabe^2, Christine Harrison^3, Beno Csapo^4_  

^1Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland  
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^3 King’s College London, United Kingdom,  
^4University of Szeged, Hungary

The SAILS project has been funded by EU under the 7th Framework Program to support teachers in adopting inquiry-based science education (IBSE) at second level (students aged 12-18 years) across Europe by providing them with inquiry-base teaching and learning material supplemented with the assessment instruments. To achieve this goal existing resources (e.g. EU projects, like ESTABLISH, Primas and Fibonacci) containing inquiry-based learning units in biology, chemistry and physics, have been examined and twenty two units have been selected or developed in this current work. Each unit is utilized to develop specific inquiry skills through a suggested learning sequence and to give an opportunity for practitioners to use suggested instruments for formative assessment. A uniform structure for these units has developed to present each unit in 7 sections: (1)
One of the most sought-after skills, naturally developed through inquiry, are reasoning skills (formulation of research questions, formulation of hypotheses, planning investigation, presenting and explaining ideas, overcoming difficulties) and practical abilities (conducting the experiments, cooperating). Moreover, during inquiry lessons students are engaged in brainstorming and discussions, as well as in use of different representations. All of these actions provide teachers with opportunities to assess the students individually or in groups, and provide immediate feedback during the activities or through a written assessment after lessons.

This paper will present the SAILS approach to the development of IBSE units and highlight the range of assessment tools and strategies adopted. The method of rubrics (German and Aram, 1996) have been utilized with descriptors and criteria tailored to the specific skills and actions in the selected unit. The frequency chart has been proposed as a method to evaluate student engagement in discussions. The use of different representations (graphs, diagrams, tables, schemes, pictures), and graphical information outlines (e.g. mind maps) has been strongly recommended for use in implementing IBSE as an alternative to assessment of written work (Wright, 2006). In addition, Lawson (1978) test items for scientific reasoning have been incorporated into the assessment strategy of learners’ performance.

References


Paper 3: Assessment opportunities in inquiry-based learning: report on case studies

Paul van Kampen\(^1\), Eilish McLoughlin\(^1\), Dagmara Sokolowska\(^2\), Odilla Finlayson\(^1\), Deirdre McCabe\(^1\), Christine Harrison\(^3\), Benő Csapó\(^4\)

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SAILS Inquiry and Assessment materials (Units) will be used as exemplars for using with teachers during teacher education workshops. Units will be used by teacher educators with both in-service teachers and pre-service teachers in order to help classroom teachers broaden assessment opportunities and to cater for a broad range of teachers/contexts/cultures materials suitable for a variety of subjects and educational levels. In particular, SAILS materials highlight how assessment practices can link in with the inquiry lesson and show teachers the benefits of inquiry in classroom practice and also illustrate the variety of assessment opportunities/processes available to them. In particular, these Units provide clear examples for teachers of how inquiry skills can be assessed, alongside content knowledge, scientific literacy and scientific reasoning and illustrate the benefits of varied types of assessments. More specifically, they illustrate how evidence of student learning can be collected and evaluated using a variety of methods, e.g. student discussion, written evidence, diagnostic questions etc.
A core aspect of each unit is the inclusion of case studies—narratives written by teachers that describe their experiences of using IBSE and assessment items in their own classroom. This presentation will report on a number of case studies collected from the implementation of the SAILS project, with particular focus on physics topics, including gravity, speed and motion, collisions and forces, UV absorption.

A section of inquiry-based learning sequences that incorporate the indication of assessment opportunities of selected key skills and competencies for a variety of age groups within the 12-18 year range will be discussed. The experiences gained in using these learning sequences on the same topics from a variety of countries will be shared. In particular, details of how the learning sequence was adapted to encourage students to adopt inquiry strategies and teachers to carry out assessment before, during, and after the learning sequence, will be presented along with details of how the evidence collected was used. Examples of student artefacts and how teachers were able to use these for formative evaluation are presented.

Acknowledgement
This work is supported by the SAILS research project (SIS.2011.2.2.1-1, grant agreement 289085), which received funding from the European’s Unions Seventh Framework Program.

**Paper 4. Teacher professional development in IBSE and assessment**

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Within the ESTABLISH FP7 project (www.establish-fp7.eu) a teacher professional development framework for IBSE was developed and implemented in the consortium of 12 partners’ countries. Effective models for in-service and pre-service science teacher training in IBSE have been proposed that encompass approaches collectively developed by the consortium and successfully adopted in each country. The ESTABLISH teacher education program (TEP) consists of four core (that were intended to be included in all training programs) elements and four supporting elements (that could be used as required, depending on the experiences of teachers). One of the supporting elements selected was the Assessment of IBSE, as main objectives of ESTABLISH were focused on supporting teachers to firstly use IBSE in the classroom.

The context of the FP7 project SAILS (www.sails-project.eu) is more deeply focused on TEP in assessment and IBSE. A phased approach for TEPs was developed with three different teachers’ cohorts. The first teacher cohort consisted of teachers from each country that had diverse experiences of IBSE and hence the first workshops focused on the IBSE pedagogy itself and on implementing inquiry based activities in the classroom. Partners selected suitable teacher education materials (IBSE Units) from those already developed in each country for use in their teacher education workshops. A review of the implementation of these workshops has revealed a number of common components across them. The first component discusses scientific inquiry, the different interpretations of inquiry and provides a range of activities to allow teachers to experience inquiry as a student. Teachers then critique and discuss implementation and adaption of particular resources to meet the needs of their curriculum. Further components support teachers in developing and trialling their own inquiry lesson. In some cases, where teachers are already experienced in inquiry practices, workshops focused on developing inquiry resources.
Workshops for the second teacher cohort were focused on IBSE and incorporating assessment of IBSE, based on assessment strategies and items developed by the SAILS consortium. The final model for SAILS TEPs will involve teacher cohorts engaged with IBSE units that have fully integrated assessment frameworks, developed and piloted by previous teacher cohorts. The SAILS partners collaborate with pre-service and in-service teachers in parallel and the observed behaviour of these teacher groups can be typified based on these experiences. The pre-service students are without routine habits, more flexible to innovation, more like students than teachers. On the other hand, in-service teachers are strongly focused on content and knowledge, they have own approach to teaching science topics and innovation must be provoked through strong argumentation and the provision of case studies of experiences in classroom practice. The needs for both of these groups are important for developing and implementing effective TEPs. In this contribution, the SAILS approach to TEP will be presented along with examples of assessment tools that can be used in classroom practice for formative assessment of student learning and teachers’ role within this evaluation process.

Acknowledgement
This work is supported by the SAILS research project (SIS.2011.2.2.1-1, grant agreement 289085), which received funding from the European’s Unions Seventh Framework Program.

References:

Session 6.5 Symposium S10
Room 11 (Aula 11)
Friday, July 11 14:15-16:15

S10: Data, Probability and Entropy: an Approach for Physics Education

Chairperson: Corrado Agnes. Polytechnic of Turin, Italy
Discussant: Rosa Maria Sperandeo Mineo. University of Palermo, Italy.

The seminal works of Gibbs, Boltzmann, Shannon gave rise to wide cultural and research areas: the last world conference on statistical mechanics had thousands of participants and informatics is becoming almost a bureaucratic burden of our everyday life. But Gibbs and Shannon are almost forgotten, a part the hagiographical tribute which T. Kuhn explains with the idea of “invisibility of scientific revolutions”, a circumstance most evident in the case of Boltzmann. This is the way science evolves, so that the astonishing consequence for education is that “The Book of Science” cannot be unitary and coherent, because the paradigm shift in actual teaching becomes a contradiction, sometimes difficult to explain. Therefore the basic task of science education is to elaborate the corpus of the discipline in the form of an unified theory. It has to interface different paradigms and restore the continuity and coherence necessary for a successful teaching. And why not, spare the students the tortuous path that actually led to scientific knowledge. What we’ll show is that the area where the cultural and disciplinary heritage of Gibbs,
Boltzmann, Shannon, is most needed and most missing is science education; and the main aim of the symposium is a step toward the conceptual unification of such different topics from mathematics, physics and chemistry, as a first look to the names could suggest. But there is the ambition to look for a deeper level of unification, which can be achieved only in education: because only in the school we can hope to recover a unified theoretical view from the separation and specialization of disciplines, in order to build the common house of science and technology.

The planned symposium begins with the introduction of the Shannon measure of information, reasonably considered an important physical quantity, and its implementation into basic science teaching. What the use of universally recognized units, the bit and the bit/s, if the corresponding quantities remain in the shadow of vagueness? Moreover learning to compute the amount of data from everyday life examples could realize the Maxwell insight that “the calculus of probability is the true logic of this world”. Then the relation between the physical entropy and the amount of data is investigated, so that the “microscopic” meaning of entropy comes from the analysis of physical systems from the point of view of the amount of data, that is enumerating their states, and that leads to the formal identification of the two quantities.

The obvious role of computer simulations and modeling is the subject of the third contribution, and in a way an indirect confirmation of the main thesis that entropy and amount of data are two manifestations of the same quantity.

In the following two contributions the symposium concentrates on the Boltzmann distribution, from the theoretical and from the experimental point of view.

Experiments on the Boltzmann distribution come from all areas of physics, but examples from chemical reactions are particularly welcome, because the theoretical derivation of the Boltzmann distribution is based on the idea by G. Job to represent statistical physics events as reactions. The simplicity of the approach shows that the traditional barriers between physics and chemistry are indeed bureaucratic, as well as the special position of mathematics within the natural sciences: so that all these hints give hope for the unified approach we are proposing.

**Paper 1: The Missing Quantity in Physics Education - Twenty Years Later**

*Corrado Agnes. Polytechnic of Turin, Italy.*

At the 1993 Girep conference held in Braga, I presented a paper with this title, which refers to the quantity introduced by Claude Shannon (1948) as a measure for “information”. The main thesis remains actual and valid, and it is the need to introduce the quantity in science education. Notwithstanding almost everybody knows the name of the unit “bit”, very few associate to it a way to quantify a physical property of objects from the real world; say nothing of the wide misinformation concerning the unit “bit/s”, happily mixed up with the capacity of the communication channel, and surrounded by fancy words, the least wrong being “velocity”.

So the first step is to proof its being a legitimate physical quantity according to the following simplified definition: a physical quantity is a relation between physical systems, which becomes a property of the physical system. As shown by the prototypical example of length as the relation of things with the stab in Paris. Applying this procedure to the missing quantity, we begin with two hypothetical physical systems, one Emitter and one Receiver, which exchange news: the most reduced type of news, consisting of one out of two equally possible signs. A reasonable mathematical measure is shown to be $H = \log_2 N$ bit, where $\log_2$ is the base 2 logarithm of the number $N$ of exchanged news. Beginners are introduced to this simplified version of the Shannon measure.

Let me remind that all we are speaking about are abstract ideas, included the stab in Paris which has been recently substituted with the theoretical universal nature constant $c$. So that a name is a most needed necessity for a physical quantity, for theoretical and practical, that is didactical reasons. In our case we are lucky because the name of the unit is well known: compare for example with the difficulties related with the missing name of the unit of entropy. But the mediatic
established name for the quantity, “information”, carries, in our opinion, undesired extra information causing unnecessary obstacles for the understanding process; therefore we propose to rename the missing quantity, for teaching purposes, “Quantity or Amount of Data”.

Next comes the true obstacle, the introduction of the generalized Shannon measure, where two didactical problems seem to be intertwined in a perplexing way. On one side we need the theoretical concept of probability, but the manageable examples come from the artificial world of cards and games; on the other side we put the computation of the amount of data from meaningful everyday life examples as the main reason for introducing this quantity in the science curriculum. Universal physical quantities, the ones independent of particular physical systems, are invented so that following quantitatively their flow into and out of physical systems, we gain insight about natural phenomena. The maximal hope is that following the flow of data is the way of understanding the “logic of this world” and, as a collateral benefit, the calculus of probability. Which is to be considered the minimal hope of our proposal? Let me call it the eulogy of logarithms. They symbolize all along the heavy and tough side of mathematics, and now they give the key to understand the world, in the words of the already quoted Maxwell.

The Quantity of Data, a physical quantity so soaked with uncertainty and probability, is fit to quantify the least quantifiable properties of the real world. To confine it within specialized boundaries is a collateral damage both for education and culture.

Paper 2: Entropy and the Amount of Data

Friedrich Herrmann, Michael Pohlig. KIT Karlsruhe, Germany

The equation that is used to calculate the entropy statistically,

\[ S = k_B \sum p_i \ln p_i \]

has the same mathematical structure as Shannon’s equation which allows for the calculation of an amount of data, the so-called information:

\[ H = f \sum p_i \ln p_i \text{ bit} \]

In both cases the quantities \( p_i \) are probabilities. Is the similarity of these equations only the expression of a formal analogy, such as that between the equations for the kinetic energy and the energy of a spring, or between Fourier’s heat equation and the Schrödinger equation, or is there more behind it?

It will be shown that the reason for the coincidence has a deeper cause: The thermodynamical quantity Entropy and Shannon’s amount of data are the very same physical quantity, measured in different units. It follows that the bit can be expressed in thermodynamical units:

\[ 1 \text{ bit} = k_B \cdot \ln 2 = 0.96 \cdot 10^{-23} \text{ J/K} \text{ or roughly } 1 \text{ bit} \approx 10^{-23} \text{ J/K} . \]

This statement can be interpreted in two different ways. One can also say it has two kinds of consequences:

1. The thermodynamical entropy can be interpreted as the amount of data that is stored in a microstate of a thermodynamical system.
2. The quantity information, as it is employed by the computer scientists, represents an additive term of the total entropy of a data storage device.

The relation between the two quantities is similar to that between mass and energy. Both were first introduced independently and only much later their identity was discovered. Actually, the relation between the amount of data of computer science to the entropy of thermodynamics is analogue to that between the kinetic energy to the rest energy of a body. Just as the amount of data of a data storage chip is smaller by many orders of magnitude than the thermal entropy (measured in the same units), the kinetic energy of say a car is smaller than the car’s rest energy by many orders of magnitude.
ThermoLab is a software that simulates thermodynamical processes. Its purpose is to help getting an intuitive feeling for the physical quantities entropy, temperature and chemical potential from a statistical point of view. Its distinctive feature is that a physical system is represented by a Gibbs ensemble. The user has the choice between various kinds of systems: From a one-particle two-state system until systems with many particles at different positions which can admit different states of excitation.

When using the software, the first step is to prepare the ensemble, i.e. the state of the macro-system. There are various options: One can choose an equilibrium energy distribution with a well-defined temperature and a well-defined chemical potential. But one can also choose any other arbitrary energy distribution. In this latter case temperature and chemical potential are not defined. Next the simulation is started. As time runs the quantities characterizing the ensemble members (the micro-systems) are statistically changed, in such a way that the chosen boundary conditions, such as particle number conservation and/or energy conservation, are respected. These changes are done independently for the various (many) micro-systems.

For each instant of time (time step) the values of the macroscopic quantities, i.e. the quantities that refer to the ensemble, are calculated: entropy, particle number, temperature and chemical potential. Their values are plotted over the time.

If the initial state was not a state of thermodynamical equilibrium, the macro-system now runs by itself into such a state, whereby the entropy increases. (The entropy can be calculated for non-equilibrium states, in contrast to temperature and chemical potential.)

In addition, for each time step the energy distribution of the states is compared with a theoretical distribution, optionally the Boltzmann, Fermi-Dirac or Bose-Einstein distribution, and it is indicated how a temperature and a chemical potential emerge, as the system is approaching equilibrium.

An important feature of the software is that several macro-systems can be simulated simultaneously. These systems can be coupled in two different ways: thermally (entropy exchange) or chemically (particle exchange). So it can be seen that for two subsystems that are thermally coupled their temperatures approach one another whereby the entropy increases. If then the particle exchange is switched on, the chemical potentials will also approach and adjust each other whereby again entropy is produced.

The software gives the user an insight into the working of statistical physics without the necessity to follow the involved mathematical derivations. One gets an intuitive feeling about the similarity and the difference of the role of the two intensive quantities temperature and chemical potential in statistical physics. One also learns about entropy: It is a quantity of a more general scope than temperature and chemical potential. One also learns that it is not the movement of the particles that characterizes the values of entropy and temperature.
temperature of the environment. A simple interpretation of the Boltzmann probability can be given by considering a system of particles in thermodynamic equilibrium at temperature T that can exist in two microstates with the energy difference ΔE. In this case, the Boltzmann probability, \( p \propto e^{-\Delta E/kBT} \), where kB is the Boltzmann’s constant, gives the fraction of particles that are in the higher energy state.

Books for undergraduate students use different approaches and arguments for its derivation: most of them, following Feynman, justify it heuristically by referring to the ‘exponential atmosphere’, others analyse the quasi-continuous states of the heat bath or use the method of the most probable distribution.

Some pedagogical experiments directly related to the Boltzmann probability have been published, such as that suggested by Einstein and first performed by Perrin: the sedimentation equilibrium of colloidal suspensions. The experiment analyses the behaviour of small plastic spheres suspended in a liquid slightly denser than water representing a miniature atmosphere. The measure of the sphere concentration at different heights is shown to obey the Boltzmann distribution.

Some commercial equipment illustrates the random motion of molecules by shaking a system of small balls. Such equipment has been used for demonstrations as well as to perform quantitative experiments which measure the velocity and height distribution of the ‘gas’ of shacked balls. More recently, a Boltzmann machine ‘the canonical simulator’ has been constructed as a working model of a two-level quantum system in a temperature bath. This experiment enables one to quantitatively analyse some fundamental principles of statistical mechanics, micro-canonical and canonical statistics.

Here, I would describe an approach to the Boltzmann probability derivation that uses experiments and simulations aimed at the following main objectives:

- to take into account that the object of statistical mechanics is that of deriving macroscopic laws from the underlying microscopic behaviour by providing a theoretical model which could possibly explain how such laws emerge from the microscopic dynamics;
- to apply a pedagogy grounded on visualization and modelling, since we acknowledge their relevant role in pupil physics understanding.

Experiments use easily available apparatuses and regard three different phenomena: flow of viscous liquid, thermionic emission and chemical reaction. Simulations are developed in the Net-Logo environment that, besides having a user-friendly interface, allows an agent-based approach and an easy interaction with the algorithm.

**Paper 5: An Alternative Approach to the Boltzmann Distribution through the Chemical Potential**

*Michele D’Anna¹ and Georg Job².*

¹Liceo Cantonale of Locarno, Switzerland; ²Job Foundation, Hamburg.

The Boltzmann distribution, first derived by Maxwell for the velocities of gas molecules at a given temperature, is one of the most important results of the molecular-kinetic approach, which since has become a cornerstone of statistical physics. Despite its historical and cultural relevance, there are few attempts to introduce suitably this result in high school teaching. Textbooks generally introduce the Boltzmann distribution without deriving it from some basic ideas, stating only the final result with some pictures that illustrate the situation together with a few details about probabilities and mean values. The reason may be that Boltzmann distribution is considered the main result of the theory of statistical physics, well beyond the reach of secondary school ambitions.

This contribution proposes an alternative approach, which can be traced back to an idea expressed by Einstein in a paper dated July 1914 (what a lucky coincidence for the symposium!): we can look at the ideal gas as a mixture of distinct substances, each one characterized by its excitation energy.
Moreover, the description of elementary processes of statistical physics as reactions between free and occupied states allows the use of the chemical potential and its basic dependence on concentration and excitation energy. In this way, the condition for thermodynamical equilibrium makes it possible to derive the Boltzmann distribution.

As a conclusion we shall briefly outline the general validity of this approach, considering some of the many examples from classical situations, and indicating how, introducing the quantum rules of occupation of energy levels, the same approach will lead to the Fermi-Dirac as well as to the Bose-Einstein distribution.

**Session 6.6 Symposium S11**

**Aula Multimediale B**

**Friday, July 11 14:15-16:15**

**S11: Aspects of Integration of ICT to enable more Inquiry in the Teaching of Physics**

*Chairperson: Ton Ellermeijer, Foundation CMA, Amsterdam, Netherland*

*Discussant: Ronald Thornton, Tufts University, USA*

**Introduction**

Since beginning of 1980’s the Physics Education community has widely recognized the possibilities of technology to enrich the Physics teaching and learning process. Firstly tools for gathering data with sensors became available, and also environments for dynamical modelling. Later on the Multimedia power of computers enabled Video-measurement and Simulations/animations.

Although we identified already a 30 years ago the above applications as valuable and fitting as well the nature of today’s physics as well its potential to physics education, we can question how far we are with respect to good practices of integration into the curriculum, and with the implementation in the ‘normal’ teaching. In fact full use of the potentials of technology is still far away. We like to address in this symposium as well a good practice and research project on integration of dynamical modelling, as well the major factors influencing implementation: teacher preparation and exams.

Concerning teacher preparations two case studies will be presented, for pre-service and for in-service. The contributions on the use of ICT in national exams will be based on several years of experience in The Netherlands.

In Europe the Coach Authoring and Learning Environment is used in many countries and available in many languages. This environment, conceptualized in the mid-80’s, integrates all above mentioned tools and offers flexible authoring facilities. The presentations in the Symposium are based on working with the Coach platform, but the experiences and solutions are easily transferrable and valid for other platforms.

The contributors in this Symposium are:

*Onne van Buuren* will present the outcomes of his PhD project: A modelling learning path for lower secondary physics education.

*Zuzana Ješková* will present design and results of an in-service course on integration of ICT into Inquiry Based Science Education.
Trinh Tran will present the results of several case-studies for a pre-service teacher training to integrate ICT into Inquiry-Based Science Education.

Pieter Smeets will report on the experience in the Netherlands with assessment of higher level skills in interactive environments during computer examinations.

Paper 1: A modelling learning path for lower secondary physics education

Onne van Buuren, Andre Heck and Ton Ellermeijer

Problem definition
Because a carefully designed and thoroughly tested modelling learning path did not yet exist in the Netherlands, in the past five years a learning path on modelling integrated in the first two years of the Dutch lower secondary physics curriculum has been developed and tested in school practice (Van Buuren, 2014). In this learning path, modelling has been systematically combined with experimenting and doing measurements. One goal of this learning path is that students can build simple quantitative models themselves at the end of lower level secondary education. The graphical version of Forrester’s system dynamics is used as a modelling approach. Integration of modelling into the physics curriculum may have important consequences for this curriculum.

Research questions
Research questions are
- What are characteristics of an effective learning path on graphical modelling in lower secondary education?
- How is the mathematics and physics content of the lower secondary physics curriculum affected by the modelling learning path?

Research method
The study can be classified as educational design research. Educational materials are designed, tested in classroom and redesigned in several cycles. Observations, audio-recordings and screen recordings have been made of multiple student groups. In addition, written materials and assessments have been collected. As an educational tool, we have used Coach 6, because in this computer learning environment modelling can be combined with measurements.

Results
Important results of this design research project are two of the main design principles that have evolved during the project. The first of these principles is based on the educational similarity we have identified between modelling and practical work. The second principle is the splitting up of the learning path into five partial learning paths, each addressing a specific competency required for modelling. For these partial paths, several student difficulties have been identified and dealt with. The curriculum has been adapted in several way to prepare for modelling and to make use of modelling. Integration of modelling may change the view on physics in secondary education. At the end of lower secondary education, a majority of students was able to build and use a simple graphical model based on known equations independently.

References
Paper 2: Some Implementation of an in-service course on integration of ICT into Inquiry Based Science Education: A case study in Slovakia

Zuzana Jeskova, Trinh-Ba Tran, Marian Kires, Ton Ellermeijer

In the framework of the ESTABLISH project, a variety of support materials for teacher learning about application of ICT tools in inquiry-based science lessons have been developed. These materials are organized in a Moodle platform and meant for blended approach, enabling effective courses with limited life sessions and in different educational contexts. The materials were used in Slovakia for in-service training in the context of an accredited course at University of Kosice. Within the course there were several tools introduced, such like data logging, video measurement and modeling integrated in the Coach learning environment. Before the course, many participants did not have any experience with the modeling tool while with other tools they were just moderately or slightly familiar. Teachers´ theoretical knowledge about the intentions of inquiry-based teaching was good, but they still had problems in carrying out an inquiry lesson. In the case study on implementation of the course, variety of research methods such as observation, questionnaires, and documents were designed and used to collect and analyze data on the teacher learning process and outcomes.

The positive course results proved successful application of the blended setting in which traditional-workshop sessions were extended appropriately with the home assignments and the final defense of teachers' lesson plans, supposedly incorporated what they learnt in life sessions. Teachers became aware of educational benefits of the ICT tools and were motivated to apply the ICT activities in the class. Their familiarity and confidence with the ICT tools increased remarkably. The main goal was attained as 37 participants (out of 39) could develop their own Coach activities and design their inquiry-based lesson plan enhanced by the ICT tools. The main obstacle during the course was that teachers had little experience with the ICT tools. On the one hand, the teacher trainer had to explain concepts and manipulations in detail gradually but always under time constraint. On the other hand, teachers complained of too much new information to follow and remember, especially in the modeling tool. Consequently, some advanced skills were not achieved as expected. The crucial issue was how to keep participants on task and continue when facing ICT problems. In this case, the online platform for the distance learning mode where they could access support materials and receive timely feedback became very helpful. This certainly offers teachers on-going support even after the course completion when using ICT in their classrooms.

Paper 3: Preparing pre-service teachers to integrate ICT into Inquiry-Based Science Education: Outcomes of case studies in the Netherlands

Trinh-Ba Tran, Ed van den Berg, Ton Ellermeijer, Jos Beishuizen

Integration of ICT tools such as measuring with sensors, video measurement, and modeling into science laboratory activities in the school is a need globally recognized. A common problem in using the laboratory for teaching is that practical work is generally effective in getting students to do what is intended with physical objects or software, but much less effective in getting them to use the intended scientific ideas to guide their actions and reflect upon the data they collect (Abrahams and Millar, 2008). Therefore, the preparation of teachers to use the ICT tools should be combined with the issues of minds-on inquiring and meaning-making. From this perspective, we have been developing a course (within the post-graduate teacher education program of universities in the Netherlands) in which pre-service teachers learn not only to master ICT skills but also to design, teach, and evaluate an inquiry-based lesson in which ICT tools are used. The course participants work in a blended setting including three 3-hour life sessions and much individual practice and
preparation with support materials and with assistance through an online platform, e-mail, or telephone.

In two years 2013 and 2014, we have taught and evaluated three iterations of the course which can be considered as case studies within a design-research framework. The ICT tools taught in the course are integrated in a single, open learning and authoring environment, called Coach, which supports student learning in Inquiry-Based Science Education (IBSE) (Heck and Ellermeijer, 2010). Development and delivery of the course have been supported by the ESTABLISH project which has received funding from the European Union’s Seventh Framework Program. The challenges were that the pre-service teachers lacked time for getting over initial hurdles in handling a new ICT tool and for struggling with first-year teaching pressure in addition to other demanding teacher-education assignments. Moreover, the course participants had heterogeneous backgrounds, and their teaching conditions for preparing and trying out an ICT-IBSE lesson were very different as well. In a case study, through qualitative methods such as observation, interviews, questionnaires, and documents we collected data which helped us access pre-service teacher learning processes and results. Data analyses also provided evidence and suggestions for revising the course design, which will be subsequently executed and then assessed again in a following case study.

Our presentation will emphasize the outcomes of the three case studies which can be summarized as follows: within a limited time (3 life sessions spread over 2 – 3 months); the heterogeneous groups of pre-service teachers achieved a reasonable level of competence regarding the use of ICT in IBSE. The blended setting with support materials, especially the Coach activities, contributed to this result under the condition that the course participants really spent considerable time outside the life sessions. There was a need for more time for hands-on, in-group activities in life sessions (e.g. practicing basic ICT skills, preparing ICT-IBSE lesson plans) and more detailed feedback on individual reports of participants. The majority of the pre-service teachers were able to design a lesson plan aimed at a certain inquiry level with integration of ICT, but just a few could implement it faithfully in the classroom. There was still a considerable difference between intended inquiry activities and actual realized inquiry which parallels result from the literature (Abrahams and Millar, 2008). In the classroom, the participants had to struggle with science - ICT conceptual issues, the demand of getting pupils to focus on inquiry and concept learning, in addition to first year teaching problems.

References

Paper 4: Use of Coach in The Central Exams: Assessment of higher level skills in interactive environments

Pieter Smeets, Assessment Expert Science, CITO, Arnhem, The Netherlands

In the Netherlands we have a context based exam curriculum in which specific contexts have been prescribed since the 80s. So schoolbooks, and as a result of that, most of the Physics lessons are context based as well. Because of the principle: "test what you teach", all exam questions are context based too. With the help of ICT (data acquisition, video-analysis modelling, data-analysis or a simulation program) a lot of problems on several subjects are becoming more clear.
Since 2000 there is a lot of attention for computer education in the Dutch schools and in Physics especially. All teachers and students can use software like COACH for doing measurements on film fragments and are allowed to use Systematic as a programme for solving problems in physical computing.

Since 2003 we offer schools besides the paper variant also a computer based assessment in Physics. From 2003 to 2010 we have had the COMPEX-project in the Netherlands. For four subjects and in three levels in the central exam the pupils had to answer questions using software used in the Physics Class. The questions and answers were on paper. The purpose of the project was to assess the skills they learned in the Physics Lessons.

We constructed exams in which about one third of the questions should be answered using the software on the computer. The same software the pupils use in the classroom.

For three levels: lower vocational, higher vocational and pre-University exam we constructed exams where we tested mechanics, electricity, heat, radiation, informatics in Physics, optics. For the lowest level we adapted Coach to Coach-junior, for video-measure and modeling, but also Excel and we constructed our own applet-like applications for assessment purpose.

In all the cases the results of the pupils were saved on the computer. This resulted in high levels of interactivity.

In the talk we shall give examples of tests on the diverse levels. And look at the level of interactivity of the student with the computer. A higher level of interactivity will give assessment of higher level inquiry-skills and in that way very valid tests.
Abstracts of Workshops
W1: Active Learning in Optics

Chairperson: David Sokoloff (University of Oregon, USA)

Widespread physics education research has shown that most introductory physics students have difficulty learning essential optics concepts—even in the best of traditional courses, and that a well-designed active learning approach can remedy this. This workshop will provide direct experience with methods for promoting active involvement of students in the learning process. The focus will be on active learning, hands-on lab activities (1), and Interactive Lecture Demonstrations (ILD) (2,3)—a learning strategy for large (and small) lectures, including the use of special Optics Magic Tricks. Sample materials and instructions on how to do the tricks will be distributed. These materials have been used successfully by the author in his introductory college level physics course, and recently in a series of Active Learning Optics and Photonics (ALOP) (4) workshops in developing countries, sponsored by UNESCO, SPIE and ICTP. Research on the effectiveness of these approaches will be presented


W2: Inquiry based teaching and learning in physics education and how to assess it

Chairperson: Wim Peeters, vice president of GIREP
Proposer: GIREP Committee workshop for teachers

Assessment is crucial in education, both to monitor a learning process and to determine the results of such a process. In this workshop we will focus on assessment of inquiry based learning. What is inquiry based teaching and learning, how to do it as a teacher, and, most important, how to assess both the teaching and the learning? As trigger of discussions we use a Fibonacci outcome booklet “Tools for enhancing inquiry in science education”. Among other topics, this contains a self-reflection tool for teachers on IBL.
Two big FPT EU projects (SAILS and ASSISTME) focus on assessment of IBL. Participants to these projects will be invited to explain what the content is of these projects, the actual status and previewed outcomes. The engagement of the participants will be important when dealing with questions such as:
- how does your educational system deal with assessment?
- what kind of assessment is mentioned in the curriculum
- what kind of assessment do you use in your teaching?
- is your assessment, in practice, focusing at the process or at the result?
- how do you assess IBL? Labs? Collaborative work? Group work?
- self assessment or peer-evaluation: what experiences do you have?
This workshop aims at building a bridge between daily class practice and research and to broaden participating teachers’ horizon by interchanging information and best practices.

Session 2.7 Invited Workshop W3
Monday, July 7 16:45-18:45

W3: Assessing student and teacher understanding of energy

Chairperson: Paula Heron, University of Washington, USA
Proposer: GIREP Thematic Group Energy

The workshop is for members of GIREP WG_Energy (and any others who are interested) to analyze copies of questionnaires, etc., that they would use to assess student and teacher understanding of any aspect of energy. Workshop participants would then form small groups to discuss the merits of the various questionnaires with the goal of reaching some level of agreement on the types of responses that would indicate that learning had taken place.

Session 2.8 Workshop W4
Monday, July 7 16:45-18:45

W4: Teacher professional development on the use of technology in student minds-on inquiring and meaning making activities

Chairpersons: Ton Ellermeijer, Foundation CMA, Amsterdam- Netherlands
Trinh-Ba Tran, VU University Amsterdam- Netherlands
Zuzana Ješkov, Pavol Jozef Šafárik University in Košice- Slovakia
Marián Kireš, Pavol Jozef Šafárik University in Košice- Slovakia
Ed van den Berg VU University Amsterdam- Netherlands
Ewa Kedzierska, Foundation CMA, Amsterdam- Netherlands

ICT tools e.g. data logging, video measurement, and modeling might stimulate and enable student hands-on and minds-on inquiring and meaning making in science education. The challenge to
teachers is how to turn manipulation of equipment and software into manipulation of ideas. With regard to the practical work, the instruction often offers cook-book lists of tasks for students to follow ritualistically, so it does not engage them in thinking about larger purposes of their investigation. Therefore, it is necessary to prepare and support effective teacher learning on how to incorporate ICT into Inquiry-Based Science Education (IBSE). In two years 2013 and 2014, we have developed and provided ICT-IBSE training through an in-service course (1 round in Slovakia) and a pre-service course (3 rounds in the Netherlands). Development and delivery of the ICT-IBSE courses have been supported by the ESTABLISH project which has received funding from the European Union’s Seventh Framework Program under grant agreement no 244749. More detail about settings of these courses will be presented. However, most of the time during the workshop is intended for you to be actively engaged in demonstrations, hands-on sessions, and discussion as a participating teacher of the ICT-IBSE courses.

Through following activities, you will experience part of a teacher learning scenario, aimed at different levels of integration of ICT into IBSE. The first level is related to awareness of the possibilities of using various ICT tools in science lessons; the second level involves technical mastery of the tools; and the third level is addressed to the ability to design, teach, and evaluate an inquiry-based lesson enhanced by the ICT tools.

- First, we will introduce the ICT tools taught in the ICT-IBSE courses i.e. data logging, video measurement, and modeling, which are integrated in a single, open learning and authoring environment, called Coach.
- Second, you will learn in groups or individually to use an ICT tool by choice through practicing a tutorial activity with direct help from the trainers.
- Third, working in groups you will modify a given cookbook instruction related to a Coach activity to become more inquiry. After that, revised instructions will be shared and discussed among the groups.

From case studies in the Netherlands and Slovakia, we found out ICT-science conceptual problems to teachers in learning to use the ICT tools and the gap between intended inquiry activities and actual realized inquiry in the classroom. Some examples of these findings will be presented. Through practical experience with the hands-on activities followed by open discussions, we expect that you will appreciate hurdles in teacher learning of an ICT tool and obstacles for teachers to apply the ICT tool in an inquiry based science lesson. At the close of the two hours will be a reflective discussion in which you as experienced teachers, teacher educators, physics education researchers will share your own experience about preparation and support for teachers to incorporate ICT in IBSE. Perhaps you might give us advice on how to improve our research and development project.

### Session 3.7 Invited Workshop W5

**W5: Adopt and adapt a simulation for your tablet-based teaching**

**Chairpersons:** Wolfgang Christian (Davidson College, USA)  
Francisco Esquembre (University of Murcia, Spain)

**Proposer:** MPTL Committee

The functionality of the Easy Java/JavaScript Simulation (EjsS) modeling tool has recently been expanded to support the creation of JavaScript simulations that run in html pages on all platforms including tablets. In addition, the EJS team has developed Reader apps for Android and iOS tablets.
that allow teachers to download simulations from digital libraries such as ComPADRE. Teachers and students can organize their simulations in folders and can run them at any time, even if an internet connection is unavailable.

This workshop will introduce our new EjsS-based pedagogic tools to participants (freely available at: http://www.um.es/fem/EjsWiki/Main/Download) and lead participants through the process of installing a Reader app and downloading simulations to create a personal collection. We will also discuss the general pedagogical and technical issues in the design and use of interactive simulations and we will show how to download and modify simulation source code into the EjsS modeling tool in order to adapt simulations to local needs. Participants are encouraged to bring tablets to run the Reader app and laptops to install and run the EjsS authoring and modeling tool.

Session 3.8 Workshop W6
Tuesday, July 8  14:15-16:15

W6: "Good vibrations" - A workshop on oscillations and normal modes

Chairpersons: Marco Giliberti, Sara Barbieri, Marina Carpineti, Marco Stellato, Marina Tamborini, Università degli Studi di Milano, Dipartimento di Fisica, Italy
Enrico Rigon, Liceo Scientifico "Grassi", Saronno, Italy

We plan to adopt some theatrical strategies, to show many meaningful experiments and underlying useful ideas to describe a secondary school path on oscillations, developing from harmonic motion to normal modes with the use of video analysis, data logging, slow motions and applet simulations [Tracker 2014, Logger Pro 2014, Falstad 2014, Fisicaondemusica 2014]. In fact, as well known, theatre is an extremely useful tool to stimulate motivation starting from positive emotions. This approach to the presentation of physical themes has been explored by the group “Lo spettacolo della Fisica” [Spettacolodellafisica 2014] of the Physics Department of University of Milano for the last ten years [Carpineti et al. 2011; Carpineti et al. 2006]. A similar approach has been inserted also in the European FP7 Project TEMI (Teaching Enquiry with Mysteries Incorporated) [Temi 2014] which involves 13 different partners coming from 11 European countries among which the Milan group.

The aim of this project is to help transform science and mathematics teaching practise across Europe by giving teachers new skills to engage their students and the extended support needed to effectively introduce inquiry based learning into their classrooms. Following the guide-lines of TEMI, this workshop will be based on the core scientific concepts and emotionally engaging activities of solving mysteries. Participants to the workshop will be involved in some nice and engaging experiments along a path towards oscillations and normal modes which are very useful concepts to describe many physical contexts. In fact normal modes are fundamental in quantum physics [Giliberti 2007, Smith 2010], in electromagnetism (especially in treating coupled oscillating circuits and electromagnetic waves), in acoustics and in mechanical systems. The conceptual and practical importance of normal modes emerges also clearly from the fact that every small and sufficiently smooth oscillation of a complex system is given by a linear superposition of its normal modes [Barbieri 2012, Fitzpatrick 2013]. Furthermore, normal modes give also a way of introducing students to some of the Fourier Transform concepts in a meaningful way within a phenomenological approach. Moreover, normal modes are important conceptual organizers that allow a unifying approach to many different physics topics, giving students a deeper and also faster way to face different contexts.
Nevertheless, in teaching practice (at least in Italy), only short time is devoted to harmonic motion, rarely coupled oscillators are treated while, in secondary school text-books, normal modes are usually not even present.

In our workshop we present the general framework of our educational path on oscillations and harmonic motion, which is intended for students of 11th and 12th grade. It has been derived by a designed based research carried out with about 200 secondary school students. In the path that we have developed, that has been tested and refined three times, the importance of a well suited educational path on harmonic motion, in order to face coupled oscillators and normal modes in a meaningful way, has emerged clearly.

REFERENCES
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Session 3.9 Workshop W7
Tuesday, July 8  14:15-16:15

W7: Inertial and non-inertial frames: only with pieces of paper but in an active way

Chairperson: Leos Dvorak, Charles University in Prague, Faculty of Mathematics and Physics, Czech Republic

In the workshop, the participants will try some activities that can help with their understanding of inertial and non-inertial reference frames. To be specific, the activities can clarify how the same motion is described in different reference frames.

Often, motion with respect to different reference frames is presented and described rather theoretically in textbooks and lectures for future physics teachers. To overcome this formal approach, a set of activities was developed that could enable teachers and students to directly perceive how transformations between different reference frames work. The activities use very simple paper models on which students “construct” various types of motion and their descriptions, with respect to different reference frames step by step. The purpose of these activities is to give
students some concrete experience with how motion is described in different frames, to provide tasks that can stimulate discussions and, in general, to help students to have a better understanding of this area.

Models developed to enable the investigation of various types of motion and reference frames are as follows: a) uniform rectilinear motion with respect to two inertial frames (for example with respect to a train moving with constant speed on rails; the motion could be either in the direction of the rails or in a general direction), b) accelerated motion with respect to two inertial frames, c) motion with respect to an inertial frame and a non-inertial frame moving rectilinearly with constant acceleration (thus, “creating gravity” in an accelerated rocket, whilst on the other hand, weightlessness can be demonstrated and investigated) and d) motion with respect to rotating frames (where effects of Euler, Coriolis and centrifugal forces can be separately studied).

This set of activities was piloted in both pre- and in-service teacher training courses. At the workshop in “Heureka Workshops 2013” conference more than fifty teachers participated at several runs of the workshop, with a positive feedback. Teachers appreciated that the models are very simple and low cost, that they can be easily modified, some of them can even be used at different school levels, from lower secondary to introductory university level and also that they can be used separately. (Piloting proved to teachers it was possible to go through all twelve activities in 90 minutes, though this is a challenging task. In normal classes, teachers can flexibly choose the activity suitable for their teaching in a given moment.) Teachers reflecting on the workshop also stated that although the models and situations are basically simple, some parts of the activities were not so easy and really required them to think more deeply about the tasks and to discuss some aspects – which they, in fact, also appreciated.

At the proposed workshop, the participants will work in pairs, use simple paper models, go through all activities indicated above and also discuss (on a “meta-level”) how these models and activities can help give a better understanding of the area of inertial and non-inertial reference frames.

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**Session 4.8 Invited Workshop W8**

**Tuesday, July 8  16:45-18:45**

**W8: Assessing students’ conceptions and instruction in physics courses**

**Chairperson:** Genaro Zavala (Tecnológico de Monterrey, Monterrey, México)

**Proposer:** GIREP Thematic Group

A great deal of research in physics education research is devoted to alternative conceptions of students. It is very important then to have a good instrument to assess what they think. There are many tools available that are actually very good, as a series of carefully designed open-ended questions in which students must write their reasoning, or an interview in which, following a protocol, the interviewer can fully understand the reasoning of each student. However, these tools are not designed for a large number of students or to standardize assessment. If one wants to assess students' reasoning on a large scale or wants to have a standardized evaluation, multiple-choice question test is an instrument of choice. As with many other evaluation techniques, if multiple-choice questions are carefully designed, they could form a powerful instrument to understand how students think. To analyze the data resulting from multiple-choice questions, there are several techniques available. This workshop will present some not so well known techniques used in the field of Physics Education Research: the item response curves and concentration analysis.
Item response curves (Morris, 2006) have been used in the Physics Education Research field. The technique can be used to test the effectiveness of a question, whether the question is assessing not only whether the students have the correct conception, but also, whether the question is telling us what other conceptions the students have. Once the test is proved to be assessing students’ conceptions, item response curves can be used to assess the result of the instruction by comparing the curves before and after the instruction.

Concentration analysis (Bao&Redish, 2001) is a technique to analyze students’ responses by how concentrated their answers are. It uses the concentration factor of students’ responses. In an evaluation of instruction, normally a pre and post-test is administered to students and the relative gain (Hake, 1998) is calculated. Concentration analysis is more than gain since results include whether an incorrect conceptions is prevalent after instruction. Therefore, the results can be used as feedback to instructors on what specific concepts and topics they have to focus in the following time they teach the course.

REFERENCES

Session 4.9 Workshop W9
Aula Multimediale B
Tuesday, July 8 16:45-18:45

W9: Solving of quantitative physics tasks – selected sub-skills and how to teach them

Chairpersons: Marie Snetinova and Zdenka Koupilova, Department of Physics Education, Charles University Prague, Czech Republic

Solving of quantitative physics tasks is one of the teaching methods used very often not only at Czech high schools. However, students often face many obstacles when solving physics tasks [1]. The previous research [2] shows that equations are the most important thing for students when solving quantitative physics tasks. Thus, the solving of quantitative tasks often turns into nearly mindless manipulation with the equations and the main aim for students is getting a number as a result of the tasks. Unfortunately, with such an approach, the deeper understanding of the physics context as well as the developing of problem solving skills is disappearing.

For this reason, we prepared seven activities oriented on improvement of selected students’ problem solving skills. Each activity consists of methodical materials for teachers (with activity description independent on particular topic) and examples of worksheets for students that were prepared according to needs of teachers participating in the pilot study.

The activities are focused on selected parts of the problem solving process. All activities are listed below together with a short description.

Careful reading – Students are asked to underline parts of task assignment (numeric as well as nonnumeric) significant for solving the tasks.

Conditions of applicability – Students should realize that it is not possible to use each equation in every situation (conditions preventing applicability of some physics principles can be stated in the task assignment).
Principles fitting the solution – In this activity, students select physics principles from a list which are appropriate for solving the given tasks.

Classifying the equations – Students determine how important each equation is and whether it should be memorised.

Reasonableness of the answers – Students comment on reasonableness of the given answers.

Solving aloud – Students solve given task aloud to realize each step in the reasoning.

Creation of own problem solving plan – Group of students create their own plan (or hint list) how to proceed with solving physics tasks.

In our workshop, we would like to present these activities (methodical materials as well as worksheets), offer the opportunity to test them, and discuss their usability.

[2] The research was presented at the ICPE-EPEC 2013 Conference with the title “Students’ Perception of the Problem solving Process in Physics”

Session 5.7 Invited Workshop W10
Aula Seminari B
Wednesday, July 9  14:15-16:15

W10: On the verdict of the German Physical Society against the Karlsruhe Physics Course – A Chronicle of Events

Chairpersons: Friedrich Herrmann and Michael Pohlig - KIT, Karlsruhe, Germany

The Karlsruhe Physics Course (KPC) is a novel approach to the teaching of physics at the secondary school. It was developed more than 30 years ago at a time when courses with similar pretensions were developed by other groups: in England the Nuffield Course, in France Libre parcours, in the US the PSSC. The KPC text books have since been used in a certain, slightly increasing number of German schools. Simultaneously, ideas of the KPC have found their way into the mainstream textbooks. The basic ideas of the course had been published in the European Journal of Physics, the American Journal of Physics and other scientific reviews. Several selected chapters had been presented on previous GIREP-Meetings. The original course is in German, but there are also translations into other languages, such as Italian, English and Chinese.

There are mainly two distinctive features of the KPC:

1. KPC is a unified approach to science teaching, based upon a certain class of quantities, which play a fundamental role in classical and modern physics: the extensive or „substance-like“ quantities.

2. The historical development of physics has taken an intricate path. When learning physics, our students have to follow this path although there are shorter and easier ways to reach the same goals. When developing the KPC we have tried to eliminate such historical burdens from the physics syllabus.

Only recently, the German Physical Society (DPG) got aware of the course. In their opinion the KPC represents a danger to the teaching of physics at school and University. Therefore, the DPG has taken unusual measures to ban the use of the KPC text books and to pursue any spread of KPK ideas.
They nominated an „expert group“ with the assignment of finding scientific errors in the KPK. The group believed to have found such errors. Thereupon the DPG has initiated a campaign with the objective of eliminating not only the KPC textbooks from the market but to eradicate any other manifestation of ideas that might have originated in the KPC work. Some of these measures seem rather off-key in a modern democratic society. DPG did so not only in Germany but worldwide. So, among other things, DPG alerted the European Physical Society, and requested them to notify the appearance of any KPK idea in any European school or university to the board of the German Physical Society. A similar warning was addressed to the Chinese Physical Society. As a result of these measures, a discussion of unusual fierceness arose, first in Germany, but then spreading to other countries. Thereby the physics community got more and more polarized. A chronicle of an eventful year and a brief evaluation will be given from the perspective of the author. The pretended errors in the KPK will be discussed with the participants of the workshop as well as the necessity and the chances of innovations in the teaching of science.

W11: Polarization of Light and Related Phenomena: Experimental Support for Construction of Understanding

Chairpersons: Maja Pecar and Mojca Cepic - Faculty of Education, University of Ljubljana, Slovenia

Teacher usually consider a polarization of light as a very simple optical phenomenon, but debates with students have shown, that several phenomena related to the polarization of light are not conceptually understood well enough. As today linear polarizing sheets are easily accessible, students are mostly familiar with linear polarization, sometimes also with quarter-wave plates. Circularly polarized light is met in some variations of 3D glasses, but the concept of elliptical polarization is often not discussed at all. Therefore also some other phenomena connected to those basics concepts of polarization, as the difference between the light traveling through a birefringent material and an optical active material, are often misinterpreted even in serious publications [1]. A god understanding of basics concept as different polarization states is obligatory for further understanding of other phenomena connected with polarization of light. The first such phenomenon is the interaction of polarized light with the media, especially the anisotropic one. The latter should be also treated as a basic understanding of light polarization and its traveling if one would study more complex situations of this phenomenon or try to find out other information about the material using this phenomenon (as the difference between the birefringent material and an optical active one). The experiences that student get should also be connected with their everyday life. The presented subject is, as we already know, nowadays widely used in different light emitting or receiving technology and other monitors, which is a great benefit and a greater reason to use such materials and instruments in the experiments that clarify those specific problems. But a teacher should have always in mind what is the main aim of every experiment and what he wants to show with it. For this reason, we try to focus more on the problematic of understanding and explaining specific topics of the subject one by one.
The workshop will allow attendees to test a set of experiments that clarify and demonstrate the problems that were recognized in students’ understanding. Furthermore, experiments connect the topic with every day experience of students and devices they often use. The set of experiments includes also experiments that show a difference between the unpolarized, linearly, circularly and elliptically polarized light. We will use mobile phones, different 3D glasses, photographic cameras, transparent plastic foils and other easily accessible materials and instruments for experiments. Experiments will be shown that allow for classification of transparent materials to isotropic, birefringent and optically active. We will also show a wide applicability of LCDs and Pad as sources of polarized light in experiments.

REFERENCES

Session 5.9 Workshop W12
Wednesday, July 9 14:15-16:15

W12: Simple experiments for enhancement of pupils’ curiosity about science - Firefly, the Polish National Contest for primary school

Chairpersons: -*Dagmara Sokolowska, Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland
  -*Mateusz Wojtaszek and Witold Zawadzki, Foundation the Academy of Young Explorers, Krakow, Poland
  -*Grzegorz Brzezinka, Daniel Dziob and Justyna Nowak, Smoluchowski Institute of Physics, Jagiellonian University, Krakow, Poland

The research results show that positive attitude towards mathematics, science and technology school subjects decreases with age and recently it has been indicated that the biggest drop takes place between ages 8 and 11 (Sokolowska et al., 2014). At the same time the evidences have been collected to conclude that more efforts are needed at early stages of schooling for implementation of group work, more practical activities and tasks enhancing the analytical thinking (e.g. de Meyere et al., 2014). On the other hand our experience from a bunch of open events, organized by our Institute of Physics at the Jagiellonian University, shows an enormous increase of children’s interest in all kinds of popular science for the last few years. This strong children’s motivation towards experimentation and interest in scientific knowledge gathered from different resources encouraged us six years ago to start a new national competition in science for primary school (Sokolowska, 2009). The idea was to engage the most open-minded group for experimenting and soaking up the scientific knowledge, meaning children aged 6-13, together with their parents and/or teachers in guided science hands-on and minds-on activities at school or at home. The key role in the competition is played by simple experiments, based on everyday materials. The experimental part is then followed by a multiple-choice test, organized for all participants on a certain day in March and examining their mathematical thinking and scientific thinking and knowledge. This workshop is organized to engage the participants in a collection of simple experiments we have designed for six grades of primary school for the last seven runs of the contest. A selection consists of experiments from different science disciplines: biology, chemistry, physics as well as
technology. Some of them will be shown by the organizers, the others will be prepared for performance in small groups. The idea of the workshop is to share good examples of hands-on simple activities and to exchange similar experience among the audience. During the workshop some time will be also devoted to show the exemplary tasks utilized in the multiple-choice tests, adjusted to the pupils’ age. We would like to share our experiences with the contest organization, done by NGO institution, for as much as twenty-nine thousand pupils’ participating in the contest this year and to invite partners for International Firefly Competition.

REFERENCES.

Session 6.7 Invited Workshop  W13
Friday, July 11  14:15-16:15

W13: Can research support innovations in teaching physics?

Chairperson: Wim Peeters, vice president of GIREP
Proposer: GIREP Committee workshop for teachers

Learners, didactical materials, technical tools, ICT, communication and teachers change rapidly in the 21st century. Dealing with these changes in the class room is a challenge. Innovative methods and ideas are welcome.

The first round of the workshop will be answering the question: what is an innovative teaching method? After that, questions like “How do innovations appear?”, “Who are the innovators: teachers or researchers, or both?”, “What is the role of renewed curricula? “, “Which external factors play a role in changing teaching practice?” might give rise to lively discussions.

Some researchers will come to the workshop and inform the participants on questions like:
- what does research tell us about innovative teaching methods?
- are new ways of teaching efficient and effective?
- how do researchers measure the learning during teaching?

The engagement of the participants will be important when dealing with questions such as
- how do teachers adapt to the change of learners’ skills and attitudes?
- explain good practices of innovative teaching/methods/curricula
- is it based on research or expertise/experience/practice?
- are teachers aware of research in this field?

This workshop aims at building a bridge between daily class practice and research and to broaden participating teachers’ horizon by interchanging information and best practices.
W14: Tips and tricks to make traditional laboratory more minds-on and inquiry

Chairperson: Ed van den Berg, VU University Amsterdam, Netherlands

Thirty-six years ago the first review of research on effectiveness of teaching in the laboratory appeared (Bates, 1978) and concluded that there was no evidence for better conceptual or process skill achievement for students WITH as compared to WITHOUT laboratory experience. Other reviews with similar results followed (Hofstein & Lunetta, 1982, 2004; Lunetta et al, 2007; Hodson, 1993; Dillon, 2008) but were largely ignored until recently. Research has shown that the objectives for laboratory teaching – just as with other teaching methods – are often not achieved and that many laboratory sessions are ineffective and yet expensive in terms of student and teacher time and facilities. In the workshop we practice ways to modify lab instructions, lab teaching, and lab evaluation in order to achieve better teaching outcomes. In the workshop you will encounter at least several generic methods to convert any traditional laboratory activities into more minds-on and inquiry oriented activities. Materials include a review of research literature, a paper with tips and tricks, check lists for evaluating lab activities, and sample lab activities.

W15: Chaos theory and its manifestations: an informal educational activity to explain the chaos to students

Chairpersons: Salvatore Spagnolo and Valeria Greco, PALERMO SCIENZA, Italy

The chaos theory is not present in the Italian school curricula and textbooks in spite of being present in many topics of classical physics and in everyday life. For example, the mechanism of convection to transfer heat or the motion of the planets are arguments which are taught in Italian courses; the dripping of a faucet which keeps people awoken in the night or the thermals which birds use to climb are everyday experiences; or yet, meteorology, traffic, population growth, and so on. Then, chaotic dynamics are involved in phenomena easily accessible to everyone or in events experienced by most people in their lives, but they don’t know it and what chaos really is. Some people think that chaos is synonymous of mess – like in teenagers’ rooms – or at best that it has a relationship with the unpredictable but they are not able to explain how or why. The most important feature of chaos theory is that the descriptive models developed have a strong dependence on the initial conditions, just as the phenomena which aims to describe. The
mathematical models of this field are complicated and typically are based on tools or on a cultural background hardly possessed by the people. Nonetheless, it is possible to find physical systems whose chaotic evolution is easily viewable through computer simulations or through experiences specially designed.

A good starting-point to introduce the theory is beginning from the laboratory that everyday life is. Of course, a significant learning is characterized by the fact that the new concepts or ideas to learn is connected and put into relation with the ones already possessed by each person. So, the new ideas assume a meaning for everyone because people can increase and sometimes restructure their previous knowledge with new concepts.

On the other hand, the transmission of scientific knowledge must use new ways to communicate closer to the citizens and especially young people and recognize the need to create a cultural environment suitable to the development of science and characterized by the fall of barriers between science and society. For years the association PALERMO SCIENZA has moved in this context which aim to promote the growth of scientific communication of young people and the general public outside the formal structures.

In particular, the Association works with students with the idea that the informal educational activities aim to the development of concepts and to the key processes rather than to contents. We believe interaction and confrontation are indeed elements that – if constantly and correctly attended for – lead to individual and collective growth of people in general and students in particular. So, we start from experiments and go on interacting with students in different ways, analyzing an everyday fact or phenomenon to come to understand abstraction. Through this process a significant learning is promoted.

In the workshop we propose, we display a series of experiences related to the chaos theory. In particular, we will present four activities based on the Sinai billiard, a dripping faucet, a double pendulum and on a simple convection example. It is well known from the literature that these physical systems can have chaotic dynamics under certain particular conditions. These systems have the advantage that involve objects or everyday phenomena with which all have or have had something to do; on the other hand, these systems allow some simple visualizations of the concept to be conveyed.

The exposure and the explanation of these phenomena will be conducted in terms of informal learning but the activities, developed to be managed in an informal setting, can be implemented quite simply in schools or in science centers.
Abstracts of Oral Presentations
The nature of students' reasoning processes in tasks involving the concept of angular acceleration

Graham Rankin
Kwantlen Polytechnic University

A large amount of work to date has been done in the field of physics education by researchers primarily interested in students' conceptualizations of physical concepts. These investigations have ranged over such diverse areas as; heat, gravity, statics, electrical circuits, mechanics, sound, vectors, light and quantum mechanics. Studies as these have provided evidence that many students before, during or after instruction hold physical conceptions at variance with accepted scientific views. This study extends this domain of investigations to the kinematic concept of angular acceleration and is an extension of Reif's and Allen's early investigation (1992) of students understanding of acceleration and of the work by Rankin (2013) in his study of students' understanding of angular speed.

In the study reported herein, fifteen first and second year university physics students were interviewed in a variety of task settings. The nature of the reasoning processes employed by these students as they answered questions about an object moving in different paths are described and categorized in terms of mental associations with the words, images, and context experienced by the students during the task setting. These category like descriptions of reasoning parallel the work of Marton & Booth's (1997) approach for analyzing qualitative data, with the caveat that the process of forming such categories are not unique as one can never claim that there are no other ways of seeing or thinking about a phenomenon than the ones we know of (Marton, 2006).

Three forms of associations are described in this study namely; word, symbolic and contextual associations. Word association is a simple or a complex association made by the student to the words angular or acceleration. Symbolic association is an association to a formula (or an incorrect formula) with angular acceleration. And contextual association is an association to an analogous situation by which the student understands or thinks about the angular acceleration of an object in one of several task settings. This latter type of association is consistent with the view that how a person acts and responds in a situation is inherently contextualized.

Being reminded of something as part of our reasoning process, whether or not it occurs by words (as in word association) or by symbols (as in symbolic association) or by surface similarities (as in contextual association) with some aspect of the problem situation which we are contemplating is thought to be an important way in which we frame, think about, or understand a problem. By extension, such reasoning processes as so described provide a powerful way in which to view how students understand and interpret both familiar and novel situations. In some situations described in this study there is evidence of a reliance on special cases of compiled knowledge, knowledge that when retrieved from memory can also be problematic because one needs then to remember (and subsequently also to recall) the validity conditions under which such compiled special-case knowledge is actually correct, as has been noted by Reif (2008).

The implications for instruction arising from these descriptions of student reasoning suggests a new way in which to think about and understand the influence physics textbooks and physics lectures have on student's understanding of angular acceleration. However, while such an understanding may be suggestive of new instructional strategies it does not guarantee the effectiveness of such strategies. It will be for further research to establish their effectiveness in the classroom.
Students’ difficulties with vector calculus in electrodynamics

Laurens Bollen¹, Mieke De Cock¹, and Paul Van Kampen²

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It is a well-known problem that students struggle with mathematical techniques in a physical context. Typical difficulties arise in electromagnetism, which makes it an interesting research domain. In recent years student problems concerning integration have been investigated extensively, as integrals are prominent when studying electrostatics and magnetostatics. In more advanced courses, vector calculus plays an equally important role. Nevertheless, little research has been done concerning the conceptual understanding of ‘divergence’ and ‘curl’ in an electrodynamics context.

Vector calculus theory and corresponding techniques are covered in multiple introductory and advanced mathematics courses that mainly focus on evaluation rather than conceptual understanding. In this study we pay attention to the latter, by investigating the knowledge of ‘divergence’ and ‘curl’ of second year university students majoring in physics or mathematics at the KU Leuven in a traditional thirteen week advanced electrodynamics course. The subjects of the course are similar to the chapters covered in Griffiths’ textbook [1], and are instructed in one two-hour lecture and one two-hour tutorial per week. These students already completed an introductory electromagnetism course that leads up to Maxwell’s equations in integral form and at least two calculus courses including a chapter on vector calculus. Therefore they should be equipped with the necessary knowledge of both the mathematical tools and physical situations presented in electrodynamics.

A test was taken at the start and at the end of the thirteen week semester. Both pretest and posttest include questions that examine students’ difficulties with calculations, graphical interpretations and conceptual understanding. The pretest contains little physics, as the students are not used to the incorporation of vector calculus in a physical context. It mostly focusses on the graphical representation and algebraic calculation of vector fields in different coordinate systems. The posttest pays more attention to applications in electrodynamics in terms of Maxwell’s laws in differential form. The type of questioning is open-ended, and the analysis focusses on the solution method and thinking process rather than the result. In contrary to what students are used to, most questions are formulated in a way that conceptual thinking and understanding is required rather than complex calculations. The goal of the research is to really dig into the difficulties that students encounter when using their mathematical tools in a situation concerning electric and magnetic fields. This work is the onset to a reformation of the tutorials in this matter.

Improving students’ understanding by using ongoing education research to refine active learning activities in a first-year electronics course

Alexander Mazzolini and Scott Daniel
Swinburne University of Technology, Australia

Interactive Lecture Demonstrations (ILDs) have been used across introductory university physics as a successful Active Learning (AL) strategy to improve students’ conceptual understanding. We have developed ILDs for more complex topics in our first-year electronics course. In 2006 we began developing ILDs to improve students’ conceptual understand of Operational Amplifiers (OA) and negative feedback, and diagnostic tools to determine their efficacy. The ILDs are used after traditional lecture instruction to help students consolidate their understanding.

In this paper we argue that an ongoing critical analysis of student performance (using education research principles) is essential for improving education practice. Our analysis of student surveys, pre- and post-tests, and final examinations, have yielded valuable feedback on how well we have designed and delivered our OA ILD interventions. During the period 2011-2013, we have found that:

(a) many hours of traditional lectures do little to improve students’ conceptual understanding. In fact student pre-test scores (after traditional instruction but before the ILDs) are typically only around 25%.

(b) a few additional hours of ILDs significantly improves students’ conceptual understanding. In 2013, students that attended all ILDs showed an average normalised gain of 0.21 comparing their scores after the ILDs to those they earned after only the traditional lectures.

(c) few students attend lectures consistently (either traditional or ILDs). For example, in 2012 only 26 attended all 3 ILD sessions compared to 154 who sat the exam, and in 2013 only 31 attended 3 or all 4 ILD sessions out of 135.

(d) students find the concepts relating to OAs difficult, and their exam marks on related questions are lower than on the rest of the final exam. However when we introduce OA ILDs, students achieved much better scores on the OA examination question. For example, in 2011 when we did not run OA ILDs, the average exam score for the OA question was 26.9% and the average total exam score except for the OA question was 55.3% (ratio 0.49). In 2012 and 2013 when we ran OA ILD activities, the average for the OA question was 58.3%, and for the total exam except for the OA question was 64.1% (ratio 0.91).

(e) Students recognise the learning benefits of the ILDs. Students were surveyed about their perceptions about ILDs in 2012 and 2013. In 2012, 72% of the students gave a positive response to how effective and helpful ILDs were compared to traditional lectures; 24% gave a neutral response and 8% gave a negative response. In 2013, 68% gave a positive response and 32% gave a neutral response.

Our ongoing education research has driven improvements in our active learning strategy, including:

(a) introducing clickers and an anonymous research code for each student so we can track the learning progress of individuals (in an ethical manner) throughout the ILD intervention.

(b) redesigning our diagnostic tool so each question tests students’ understanding of a single concept rather than a number of interwoven concepts.

(c) redesigning our ILD equipment and activities to make them simpler and clearer to understand.

The implications of using ongoing education research results to refine the effectiveness of our L&T approach are clear. If we had implemented our initial ILD approach back in 2006 and continued on without the critical review that came from our own education research, then we may have assumed that what we were doing was an effective AL approach. Instead, our education research results are an ongoing trigger for review of, and self-reflection on, our teaching practices. Our education
research gives us a quantitative measure of the success (or otherwise) of the interventions that we try in our teaching.

**learning for understanding in pre-college level through prototypes of thermal solar energy**

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*Universidad Autonòmoma Chapingo y Cicata, Mexico*

As a teaching-learning approach, solar prototypes were studied with pre-college level students in the Chapingo Autonomous University, that is, those students completing the requirement course in order to be admitted at the college. This study allows us to understand the way that constructing of this kind of prototypes (solar water heater and solar cooker) improves the learning process linked to energy-matter interaction topics. We focus on energy conservation principle but with the idea that for understanding the energy concept is necessary carry out measures of all physics quantities involved. Therefore, in order to talk on energy, we need get data about their transformation and get conclusive definition with the students. As a motivational factor is the growing interest in clean energy and more specifically, harnessing solar radiation, this has led us to teach pre-college level students at the UACh the design, operation, manufacturing, characterization and evaluation of Concentrating Solar Collectors for heating water or cooking. This experience "Explorative-Integrative Teaching" on thermal solar energy comprises the design, the use of different materials, its manufacture, operation, characterization and evaluation on the concept of energy and its transformation. Students in this level have studied Newton’s Laws, topics such as heat and temperature, optics and electromagnetic waves. The mainly target is integrate the students knowledge with the new topics, putting attention in a specific type of energy (kinetic or electromagnetic) and indicating where they come from this kind of energy (thermal solar). Therefore, we believe that this working methodology would help to integrate concepts related to solar energy, thus favoring a broader and more integral view of Physics. Considering that the measuring is fundamental to get the understanding the energy concept in application context. We worked through worksheets, rubrics, assessments and connections between concepts of thermodynamic, fluids and optic. The students were involved in the scientific inquiry, in the functioning of thermal solar energy and in collaborative work. By means of an explorative-integrative didactic proposal, gathering data from multiples sources, decomposition of systems into subsystems, formulating questions, presenting advances and all kind of assessment resources, it was possible developed a proposal designed in four stages. The first stage defines the theoretical framework of the proposal called "learning for understanding". The second describes the didactic model, which consists of worksheets and rubrics. The third stage includes the discussion on the data collected and how the manufacture of a solar prototype improves the physics learning process among pre-college students. Finally, the last stage shows how the learning for understanding helps students to develop their knowledge as active pursuers and not like passive acceptors of information when they carry out these applications in different rural and urban contexts.
Investigating university students’ understanding of the mechanism of electric current

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In many introductory physics courses on electricity, the core of the theory of electric circuits is a set of simple DC circuit laws, which relate algebraically voltages, currents and resistance. These laws are included usually related to the Drude model of the electric current. One could think that all details about the simple system of DC circuit are well known and understood. Yet literature has pointed out an important gap in the usual presentation of the subject and two major sources of students’ difficulties in understanding Electricity (Closset 1983, Eylon & Daniel 1990, Barbas & Psillos 1997; Guisasola 2013):

a) A lack of linking between the qualitative model of description of circuits, in terms of variables at macroscopic level, and the processes described by the models at microscopic level;

b) Misunderstanding of fundamental relations between the model of description of electrostatic phenomena, in terms of electric field and potential, and the model of description of electrical current in circuits, on which theory uses Kirchhoff’s Laws.

c) Students consider electric current as a “substance” which flows through the circuit. (Reiner, M., Slotta, J. D., Chi, M. T. H., & Resnick, L. B. (2000)

Recently, new models have been proposed for teaching DC circuits (Chabay & Sherwood). Those models aim to encourage students to articulate macroscopic and microscopic levels of description and understand the physical processes underlying the steady state laws (Kirchhoff laws). The development and implementation of these teaching models, which are more detailed and explicit than those usually used in the introductory textbooks to electricity, raise new questions about the structure of students' reasoning and understanding about transient states of the electric current. In this work we present a study of reasoning of first year university students on transient states of electric current at a phenomenological level (macroscopic) and at a microscopic level the mechanisms underlying the flow of electrons.

To carry out this study an open-ended questionnaire with 4 questions has been used. Two of the questions were about transitory current situations and two about continuous current. Students performed all the questions after receiving teaching about electricity issues, and they were required a reasoned explanation in all the answers. Moreover, to go more in depth into the reasoning of the students, the inquiry will be completed by interviews which will enable us to understand better the mechanisms students use to understand phenomena.
Is it difficult to motivate our students to study physics?

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The main issue of this paper is the discussion around the question „how can we teach and motivate the why-generation learners?“ . The why- generation, called also Y gen, Millenial generation was born in 1980-2000. The generation Y students learn and study in such a different way as the previous gen X did. They have other characteristics than generation X that are important and affect their learning in positive and negative ways. Gen Y students are characterized as www users and technology users. Gen Y is powerful and able to change the world. They want to learn with technology, online and doing thing that matter – this is almost important for them. Being on line is necessary for learning, research, socializing. The aim of our project was to find out teaching and learning methods that teachers and learners can use in 21st century classroom. Strategies how to engage gen Y learners in the learning process should be found. During our research various methods were used: problem based learning, project based learning, team work, inquiry based learning, interdisciplinary approach, experiments – from very simple and low cost experiments to computer based experiments and remote laboratories. It was found out, that generation Y learners can be motivated by various instructional methods based on their own activity. Their own doing seemed to be more important for them than learning itself. It is necessary to use educational materials including charts, graphic presentations, cartoons. Also it was found out that a very useful tool for our students can be the mind mapping. Mind maps are not common during students instruction at secondary and high schools in the Czech republic. We prepared a set of mind maps on the basis of high school physics textbooks, from mechanics, molecular physics, via electricity and magnetism to optics, and nuclear physics. In this paper the outcomes of our project will be presented so as some examples of interdisciplinary modules that have been prepared – "realworld" physics modules with everyday life problems that can be integrated into the high school curriculum physics (physics in the kitchen, crime scene investigation, environmental physics), non traditional experiments, properties of non-Newtonian liquids (experiments with dilatant fluids, oobleck, the suspension of starch, the Weissenberg effect, Barus effect, the Kaye effect), modern physics – nanotechnology (cooperation with the Regional Centre of Advanced Technologies and Materials - a faculty establishment) . The findings of this project are incorporated into the subject „Didactics of Physics“ in the undergraduate physics teacher study programme at the Faculty of Science. The paper is supported by the project OPVK CZ.1.07/2.2.00/28.0182.

Correlation between Mathematics and Physics Concepts in Kinematics

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ETH Zurich , Switzerland

We have developed a diagnostic test in kinematics to investigate the student concept knowledge at the high school level. The multiple-choice test items are based on seven basic kinematics concepts we have identified.
We have performed an exploratory factor analysis on a data set collected from 56 students at two Swiss high schools. We have found that there are two basic mathematical concepts that are crucial for the understanding of kinematics: the concept of rate and the concept of vector (including direction and addition). The context and the content of the items seem to play only a minor role. If a student understands the concept of rate he is able to answer correctly to questions about velocity and acceleration in different contexts.

We have further investigated the correlation between the mathematics and physics concepts by adding mathematics items to the test. A factor analysis has shown that the items that are associated to the mathematical concept of rate actually group with the items assigned to the kinematics concepts "velocity as rate" and "acceleration as rate". Moreover the correlation of the total scores of the mathematics items about rate and the kinematics items about rate has a considerably high value of 0.63.

This result has direct implications for the instruction. It suggests that in kinematics courses the focus should be first on the learning of the mathematical concepts. Transferring the mathematical concepts to physical contents and applying them in different contexts is suggested to be easier for students than learning physical concepts without a mathematical fundament. These findings are somewhat in line with the results of Christensen and Thompson (2012) who investigated the graphical representations of slope and derivative among third-semester students. Moreover also Bassok and Holyoak (1989) found similar results analyzing the interdomain transfer between isomorphic topics in physics and algebra. Finally, it has to be mentioned, that even if the understanding of the mathematical concepts seems to be a requirement for understanding kinematics, it does not guarantee success (Planinic, Ivanjek and Sussac, 2013).

The kinematics test used in our study contains 27 items, the mathematics test additional 9 items. Therefore, a bigger number of students is needed to produce a reliable result by means of a factor analysis. Still, the preliminary results are very promising and we are currently analyzing further data in order to corroborate our findings.

Assessment of Student Constructed Models of Simple Systems in the Topic of Heat and Temperature

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²University of Amsterdam, Netherlands

Introduction-Theoretical Framework

The interest in getting students to work with models and modeling is grounded in the premise that this process promotes conceptual understanding (Chapman, 2000) and helps them improve their modeling practices, that is their ability to construct, revise, compare, evaluate and validate models. This strengthens the need for (a) empowering teaching interventions aiming to develop the modeling competence and (b) establish methods for assessing students modeling competence.

An important constituent of assessing the modeling competence is the evaluation of the modeling outcome, i.e. the student constructed models (Louca et al., 2011). This paper describes two approaches for assessing student models and their application in a real-word case, and addresses the research question: “How can the quality of learner constructed conceptual models be assessed?”

Methods

The participants, 17 high-school students constructed conceptual models using the Dynalearn modeling tool (http://hcs.science.uva.nl/projects/DynaLearn/). The intervention was implemented in a period of 7 ninety minutes lessons, and its structure is based on two modeling-based learning
cycles (MBLC), where students constructed, evaluated and improved models involving heat and temperature concepts (figure 1).

During each of the MBLC students constructed a model and filled in a model coding form to accompany it as well as evaluated the model of another group and filled in a model assessment form. Students worked in six groups of two or three members and therefore 12 models emerged (6 simple and 6 complex).

Two different assessment methods were used to evaluate the emerged models. Method 1 is based on specific modeling guidelines and takes into account the model errors identified in the model (50%), the scientific adequacy of the model (25%) and its communicative value (25%). Method 2 uses artifact analysis techniques to evaluate the models with respect to three distinct features; representation, interpretation and prediction, which correspond to the three roles of models as identified by the model epistemology. Based on this analysis a hierarchy of levels of student competence in constructing models was formed.

Results and discussion
Data analysis based on method 1 (Table 1) indicated that student models (both simple and complex) were overall better in the second criterion, the model adequacy, and worse in the model communication aspect. When comparing model 1 and 2, students constructed models which were improved in all three aspects of the modeling guidelines; they reduced modeling errors, constructed models with improved adequacy and strengthened their communicative value.

Data analysis based on the second method resulted in categorizing student models in 6 levels of modeling competence. Models of the sixth level are those close to the scientifically accepted model while those of level 1 are the models which are away from the scientifically accepted model. The data suggest a move of student models from the lower levels to the upper ones when comparing model 1 to model 2.

In conclusion, the two assessment methods are useful and can be used complementary and comparison of the 2 methods is not the goal of this paper. By using the first method, evaluators can easily score and rank models according to their scientific and modeling accuracy. The second method is qualitative and provides feedback which is useful in exemplifying which parts of the model need and how they can be improved. It acts as formative assessment, informs educators and modelers about the model constituents and avoids the fallacy of assigning weight in explicitly different criteria.

References

Role playing game as a tool for the STS approach to science education and physics teaching

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Although there is much literature on games as tools for science education, these are not so often employed in physics teaching. Probably because physics teaching is predominantly committed to technicist worldviews where students are encouraged and valued mostly for their performance in standard problem-solving situations. Another possible reason is that educational games are often considered as playful, humorous and motivational activities rather than powerful tools to reach for educational results that would not be privileged in traditional classes.
The purpose of the paper reported in this abstract is to review the literature on science education and to produce an account of how educational games have been employed in innovative Brazilian science classrooms. Throughout this review, we are particularly interested in understanding how Role Playing Games (RPG) may work as tools for the STS (science, technology and society) approach to science education. In fact, this research is part of a wider project aimed at creating an educational RPG to approach the topic of heat engines through STS lenses, educating critical citizens interested in and able to intervene in controversial situations where science has a potential impact in society.

The review involved 15 leading journals with papers published from 2008 to 2013 and written in Portuguese, Spanish as well as English. Our analysis aims to design a map of how frequently each discipline of science is employing games as teaching tools, what types of games are employed and, particularly, which science topics were approached through role playing games. Based on this review it has been possible to highlight that games (and, particularly, role playing games) have been put to work as tools for science education under very different approaches. From this review we also observed that the use of games in science education is mostly motivational and more frequent in elementary school. The potential of the role playing games as tools for developing critical perspectives in controversial social-scientific situations is demonstrably underexplored.

In the review we noted that the RPG is seldom used as a teaching tool in science education and most games are board games. Some other dynamics used in classroom, like the simulated jury, work like they were an RPG, although they are not so named as RPG. These games are usually used for chemistry, biology and mathematics, and in physics they are still underutilized.

Finally, this review is important for innovative research in physics education because it alerts for the importance of games in education and illustrates the potential of the RPG in the STS approach through means of successful teaching experiences.

**Secondary students’ views about scientific inquiry**

_Silvia Galano, Italo Testa, Luigi Smaldone and Alessandro Zappia_

_Department of Physics, Naples, Brazil_

Recent curriculum reforms put an increasing emphasis on developing and improving student’s views about scientific inquiry at secondary school level. However, while many studies have been devoted to investigate general views about nature of science, few studies have identified specific aspects of scientific inquiry on which students may hold not informed conceptions. In this study, we investigated the views about scientific inquiry of about 220 students at the beginning of the secondary school course (14-15 years old). All students were taught physics and sciences courses, for at least four hours weekly. An adapted version of the recently developed Views about Scientific Inquiry (VOSI) questionnaire (Lederman et al., 2013) was used as research instrument. The questionnaire features 11 open questions on the following aspects of scientific inquiry: 1) there is no single set and sequence of steps followed in all scientific investigation; 2) all scientists performing the same procedures may not get the same results; 3) inquiry procedures can influence the conclusions; 4) scientific investigations all begin with a question but do not necessarily test a hypothesis; 5) scientific data are not the same as scientific evidence; 6) explanations are developed from a combination of collected data and what is already known; 7) research conclusions must be consistent with the data collected. A four-level categorization based on the theoretical framework about Nature of Science and Scientific Inquiry developed by Lederman and colleagues was used to analyze data: a) informed view; b) partial view; c) naïve view; d) unclear. Two independent researchers analyzed the data: inter-rater reliability ranged from 0.55 to 0.72. A global analysis of the students’ answers show that about 70% of students have a not informed conception about scientific inquiry. Only 23% of the students hold informed or partial views. General results show,
in particular, that the great majority of students (about 80%) think that there is a single scientific method (aspects 1-3) and that scientific investigations could exist without any research question (aspect 4). About 90% of the students either collapse or do not distinguish between data and evidence (aspect 5). Only about 45% of the students are aware that scientific explanations are developed from both data and background knowledge (aspect 6) and are able to draw conclusions that are coherent with collected data (aspect 7). A more detailed analysis of the students’ answers show the following naïve conceptions: - science methods can be either deductive or inductive; - data are the results of an experiment, whereas evidence is a clear result; - scientists draw conclusions mostly on experimental certainties; - any mathematical expression is a result of a scientific investigation; - any hands-on activity could be an experiment; - performing the same procedure must lead scientists to the same conclusions. Such results primarily show that scientific inquiry aspects should be explicitly taught to students early in secondary school curriculum. To this aim, in the paper, three teaching-learning sequences aimed at improving students’ conceptions about the above described scientific inquiry aspects using physics, biology and Earth sciences contexts will be discussed in detail.

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Archimedes’ Principle Remote Experiment and buoyancy force elucidation

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The Archimedes’ principle is one of the laws of Physics used most in real life applications both in gases and liquid environments. Though it is application rich, the deep understanding by students of its physical background is often overwhelmed by misconceptions. The paper presents this new remote experiment available on http://remotelab9.truni.sk and its utilization in education process at University course of Physics. By building the remote experiment Archimedes’ principle, we created the experimental instrument for elucidation the phenomena connected with the buoyancy force.

The whole experiment was built using Internet School Experimental System (ISES) and consists of the mobile platform with the controlled and measured displacement using ISES components, on which are placed three vessels with liquids. The bodies are suspended from the ISES dynamometers, measuring the resulting suspension force. The apparatus enables the controlled displacement of the platform and thus relative movement of the suspended bodies towards and beneath the liquid surface. The simultaneous measurement of the suspension force enables either recording of the weight, total force or buoyancy force alone.

The remote experiment enables the study of the buoyancy force of both regular bodies, or bodies with varying cross section, the influence of density of liquids on measured forces used and even their inhomogeneously distributed density in a vessel.

The transformation of the hands on experiment to the remote one was executed by the environment Easy- Remote ISES (ER ISES), creating control programs for remote experiments and controlling web page without programming by expert approach.
We are preparing the pilot implementation of this experiment not only into University level, but also for the secondary and primary physics education via the strategy of Integrated e-Learning

Light Sensors and Displays for Student Projects

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Involving high school physics students in engineering projects and exploration experiments is a valued instructional paradigm for promoting knowledge extension through application and integration. Lack of financial support and the lack of information about available resources often act as barriers to implementation of this valued learning activity. Over the past decade we have been involved in designing and coaching school-based and extracurricular student projects, and we shall relate to a variety of inexpensive light sensors and displays that can be employed to facilitate project work and to attain satisfying effects. The solar cell is an inexpensive component which responds to light in the visible and IR spectrum and produces a potential difference of millivolts between the terminals. It is available in various sizes, and the surface area can be partially covered to detect directional lighting. Covering the cell with a filter enables selective color detection. Students use the solar cell to explore the decrease of light intensity with distance, the effect of a spectral filter, the threshold voltage for IR LED's or the frequency pattern of a fluorescent tube. Used in connection with a laser beam and a printed ladder-grid of black stripes on a transparent plastic sheet, the solar cell forms part of a light-gate, and provides a means of calculating motion velocity by measuring time intervals between successive obstructions of the laser beam. A Light Dependent Resistor (LDR) is a very small and inexpensive component which responds to light in the visible and IR spectrum by a change of resistance between kilo-ohms in bright light to mega-ohms in darkness. The response to light intensity is non-linear thus it is used mainly for identifying the change between Light and Dark. Students have used LDR's for detecting the presence of people or objects in a given space. The small size of the LDR makes it suitable to be placed at the focal point of a converging lens thus enabling collection of scattered light from a large area. The output of these light sensors can be displayed in several ways. Connecting the terminals to a multimeter enables the students to measure relative light intensity and detect slow changes. However, this simple method does not support documentation, especially for rapid changes and requires individual monitoring of each multimeter. We have devised an innovative method of producing a visual time-trace of changes in light intensity by using freely available audio analysis software which responds to high frequency signals (e.g. Audacity or Goldwave), and connecting the light sensors to the microphone input of the computer. Since the microphone input only accepts small changes in voltage, the solar cell can be directly connected to it using a standard microphone plug. However, for the LDR it is necessary to transform the changes in resistance to a suitable voltage change. This is achieved by connecting the LDR in series with a 10-100 kOhm resistor and a single cell battery, thus creating a voltage divider. The microphone plug is connected across the additional resistor to display the increased voltage following exposure to light of the LDR. Inputs from two light sensors can be connected to the computer using a stereo microphone plug. We shall present relevant examples of student projects and will demonstrate some experiments using the described light sensors and displays.
Chaotic behaviour of Zeeman machines at introductory course of mechanics

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Education of engineering students is based on classical physics therefore topics of modern physics can be discussed in a relatively short time. However, modern physical aspects of the subject have great importance in raising the interest of the students and motivate them to learn physics. The investigation of deterministic systems with low number of freedom can be very excitingly joined to the problems solved at introductory course of classical mechanics. In the present paper it will be demonstrated that the Zeeman Catastrophe Machine can be a versatile and motivating tool for students to get basic knowledge about chaotic motion via interactive simulations.

Ever since Edward Lorenz has discovered that simple nonlinear systems can produce inherently unpredictable behaviour, which is called chaotic motion the interest in the theory of it has risen rapidly, and much effort has been invested in integrating it into the graduate as well as the undergraduate curricula. Excellent introductory monographs are available which explain the basic ideas and concepts, and in which a wide variety of simple mechanical systems producing chaotic behaviour are deployed. Maybe, in the light of these, it seems to be a superfluous effort to increase the number of examples of the simple chaotic systems. Although the scepticism is reasonable, we think that the Zeeman Machine got exceptional advantages as a teaching material. It will be proven that in spite of its simplicity, by investigating it, a broad range of characteristics of chaotic motion can be covered which generally needs the discussion of several different systems. The machine was originally prepared for the demonstration of the catastrophe phenomenon which is a result of a quasi-static process. However, applying a periodic driving force it produces chaotic motion which can be easily studied both theoretically and experimentally. Initial enthusiasm and motivation of students are often lost, when they are unable to understand the theory behind chaotic behaviour. The Zeeman Machine provides an easily understandable theoretical background of various chaotic features, and gives an insight into the dynamics of chaotic motion. Simulations of the motion help us to avoid too mathematical or abstract teaching, and interactive programs support the exploratory activities of the students.

The Zeeman Catastrophe Machine is a typical example of a quasi-static system with hysteresis. It works in a relatively simple way and its properties can be understood very easily. Since the machine can be built easily and the simulation of its movement is also simple the experimental investigation and the theoretical description can be connected intuitively. Although Zeeman Machine is known mainly for its quasi-static and catastrophic behaviour, its dynamic properties are also of interest with its typical chaotic features. By means of a periodically driven Zeeman Machine a wide range of chaotic properties of the simple systems can be demonstrated such as bifurcation diagrams, chaotic attractors, transient and conservative chaos, Lyapunov exponents and so on. For the numerical investigations we have used the Dynamics Solver (developed by Juan M. Aguirregabiria) which can be downloaded freely from his website. Our simulation-programs can be downloaded also freely from our website in the form of *.ds files and can be run with the Dynamics Solver.

The oral presentation makes possible to run “in situ” the programs and to show their didactic advantages. Furthermore the properties of this relatively simple system have given analogies to such exciting phenomena as the hysteresis of the human brain and the spontaneous symmetry breaking.
Interactive Whiteboards (IWBs) offer a wide range of opportunities for classroom interaction as they allow students to become active players in their learning processes (Hennessy, Deaney, Ruthven, & Winterbottom, 2007; Murcia, 2008). Different large-scale projects to equipped schools with Information and Communication Technologies (ICTs) of many countries and led to a normalization of the use of IWBs in classrooms (Türel, 2011). From the physics education perspective, IWBs offer a range of positive effects for teaching and learning specific concepts. These ICTs allow teachers and students to address complex and abstract concepts through dynamic representations, to switch between different modes of representation and to combine real world phenomena with virtual experiences (Becta, 2003; Hammond, Reynolds, & Ingram, 2011). Despite all of these educational benefits, international researched showed that IWBs are little used by teachers or that they are who mainly employed them to display pictures, PPT presentations, and to write on the board as traditional Whiteboards (Hammond et al., 2011). Thus, the whole educational potential of IWBs remains underexploited (Glover & Miller, 2001; Cutrim Schmid, 2007).

In this context, we aim to identify good practices in the use of IWBs that could benefit teaching and learning of specific physics concepts and models, and also to define a set of criteria to analyse these practices according to specific learning goals. For this reason, we are carrying out a project involving teachers and researchers from Italy and Spain with the aim of giving contributions to physics teachers’ professional development (both pre-service and in-service). The results of the project will be included in the design of a physics teachers’ training course, in order to promote a rich and valuable use of IWB in physics classrooms, making full use of IWB’s potential. In this proposal we will present the first part of the project, focused on the analysis of how a group of different (volunteers) teachers use the IWB in their physics’ classes and on the classification of the good practices that can be identified.

This first investigation was conducted through video-taping 20 sessions where teachers used an IWB with their students during four hour of work sessions in an ICT-equipped laboratory. Each of these work sessions addresses a specific physics’ topic: kinematics, electricity, energy, gases behaviour, radiation and temperature. We divided each video into small episodes (1 or 2 minutes per episode) according to different dimensions:

• Action: (1) Write and draw, (2) Underline, circle, highlight and spotlight information, (3) Import and display virtual objects, (4) Drag and drop virtual objects, (5) Modify the size of virtual objects, (6) Display students’ PC/laptops information, (7) Use of classroom Response Systems and (8) Use of other specific software.
• Control: (1) Teacher controls the IWB, (2) Students control the IWB.
• Pedagogical purpose of the action: Identify students’ spontaneous reasoning, (b) Share, discuss and compare ideas, (c) make and share predictions of experiences, (d) Plan students’ work, (e) Organize concepts, (f) Analyze graphics.

Bibliography

Study of conceptual change about parabolic motion among high school students in a physics video-based laboratory

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Among the physical phenomena studied in high school, the parabolic motion causes many difficulties for students. Two main reasons have been put forward by researchers: alternative conceptions of students on the parabolic motion and the emphasis on the mathematical treatment of their properties. In this regard, many students harbour alternative schemas that can be associated with the historical pattern of the impulsion (Dilbert, Karaman & Duzgun, 2009). These schemas lead students to conceive the parabolic trajectory as the resultant of successive forces. Firstly, the initial impulse acting continuously upon the projectile induces it to travel in a straight line along the direction of the initial throw. Secondly, as the impulse weakens, the gravity took over, resultant either in a sudden vertical drop or a more gradual one where a circle segment connects the two trajectories (Bertoloni Meli, 2006; Kargon & McCloskey, 1988). Mathematically speaking, students have difficulty separating the horizontal and vertical components of parabolic motion (Aguirre, 1988).

To palliate these difficulties, it was suggested that the investigation of the students in the physics laboratory would be supported by the computer. In this approach, called 'video-based laboratory' (VBL), the motion of objects are recorded in form of videos, treated by software allowing at the same time the measurement of the positions of objects according to time and the organization of these data in form of tables and graphs. In its conception, the VBL followed constructivist principles: 1) to favour expression and comparison of the ideas of the students about projectile motion by working in small groups; 2) provide the students the possibility to put, in a fast and easy way, their ideas on probation; 3) to guide the step of the students by the teacher (Koleza & Pappas, 2008).

As regards the activities of conceptual change, two cases of parabolic motion were proposed to students to study the independence of motion along X and Y coordinates.

Our sample consists of two classes of students of 11th secondary of the secondary school and their respective teachers. To study the implementation of the approach, the researcher held a diary where he recorded daily his observations on the sequence of events, the critical details regarding the implementation of the approach by the teachers, comments of the teachers in interviews with the researcher, and links the researcher could establish between his observations and the theoretical framework of the present research (Altrichter and Hollly, 2005). To assess students’ conceptual change, we analysed the contents of the activities guide whom the students had to fill. Traces written by the students in these guides expressed themselves under different modalities: verbal when they answered questions, iconics when they performed drawings of the object in motion, graphs when they predicted certain aspects of projectile motion. According to the perspective of social semiotics, information coming from these different sources can be regrouped in form of metaphors allowing the clarification of their meaning (Kress & Mavers, 2005). Verbal modality, being the most important, benefits from an analysis by categorization (Miles & Huberman, 1994).
Our results indicate that, following the implementation of VBL, a majority of students changed their conceptions of parabolic motion. In conclusion, we outline the advantages and limits of our research and offer directions for future research.

Session 1.4: In-service and Pre-service Teacher Education
Monday 7, 14:15-16:15 Room 10 (Aula 10)

Wave-particle complementarity: teaching quantum physics with a Virtual Mach-Zehnder Interferometer

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Several researchers have developed studies on the teaching of quantum physics in undergraduate courses in the last decade. Among other issues, those researchers aimed to investigate the students’ difficulties on their understanding of the core of this theory, to conceive alternative teaching methodologies and/or to develop teaching resources. In this sense, the discussions focused on quantum physics concepts in research literature have been stated as very important to provide connections between mathematical formalism and these concepts. The use of experimental activities and computational simulations as didactical resources are highlighted as ways to promote conceptual approaches to some quantum phenomena. One of these resources is the Virtual Mach-Zehnder Interferometer (VMZI), a computational simulation of the Mach-Zehnder Interferometer, wherewith one can perform several experiments involving single photons (e.g., interference, non-demolition detection, polarization, etc.). This software, developed originally in 2004 by our research group, was remodeled in 2012-2013 to account additional phenomena. In the original version, it has been used in teaching activities on introductory quantum physics undergraduate disciplines as well on research papers and projects conceived by our group. In this newer version, our intent is to take a step into more advanced topics, allowing more parameter configurations. The possibility of choosing the reflection coefficient of each beam-splitter, as well the inclusion of non-demolition detectors and its efficiency parameter, opens the possibility to explore and investigate students’ responses to teaching activities focused on the wave-particle complementarity. An experiment to observe intermediary quantum interference phenomena has been first proposed by Wooters and Zurek, in 1979. Since then, complementarity principle has gained wide attention. Among others, Englert independently obtained in 1996 a general duality relation between visibility of interference pattern and path distinguishability. These two quantities are very important to quantify undulatory and corpuscular behavior of the quantum object, especially in intermediary situations where the visibility is less than one. This study is part of a PhD thesis and aims to investigate how undergraduate students (pre-service teachers) can understand the concept of wave-particle complementarity, paying special attention on how the software, as a mediational tool, acts in order to create the Zone of Proximal Development (ZPD) of pre-service teachers when they collaboratively work in pairs. Coherently with this aim, the theoretical framework adopted in this study is the Vygotsky’s mediation theory, revisited by James Wertsch. Assuming that language is the main human cultural mediational tool, the sociolinguistics of Mikhail Bakhtin has been adopted to perform discourse analysis on the students’ interactions (speech and discursive interactions), expliciting the relationship between their discursive exchanges and the organization of their actions during the teaching activities. The students were organized in pairs and their speeches were
recorded in audio and video. The analysis, mainly centered in counterwords and voices (central concepts in bakhtinian theory), reveals interesting results: a) some student speeches reveal that there is an underlying tendency to attribute corpuscular behavior to the photons, even in situations where undulatory behavior is evident, which leads to difficulties in the understanding of the complementarity principle; b) counterwords can provide useful information about how these students change their actions when they work together along the teaching activities; c) the role of more capable partner is evidenced as very important not only for the other element of the pair (the less capable partner), but for himself, in the sense that the dialogical interaction with the other create a ZPD and leads both to better understand the concepts involved and to organize their actions along the teaching activities; d) students use private speeches in some moments to organize their actions, showing that their reasoning takes place as resulting from a linguistic process.

The influence of mathematical representations on students’ conceptualizations of the electrostatic field

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The abstract character of the field concept poses a major challenge for physics education. In fact, a deep understanding of this theoretical construct seems to correlate with the ability to represent it in different ways (e.g. field lines, vectors, functions, differential operators, etc). Considering the electrostatic field, one student of an introductory course at university level will be introduced to (at least) three different ways to conceptualize it: 1) Coulomb (E = \textit{F}/\textit{q}), where the field is defined in terms of the force acting on a test charge located in some point in space; 2) Potential (E = - \textit{grad} V), which is derived from energy considerations and is enabled by the conservative character of the electrostatic field and 3) Gauss (\(\oint E \cdot n \, dA = Q/\varepsilon_0\)), where the notion of electric flux is central and symmetry arguments play an essential role. In this sense, to understand the concept of electrostatic field is associated with the ability to recognize these different conceptualizations, to identify their applications as well as their limitations, and also to connect them through reasoning. Focusing on this latter aspect, we are mainly interested in the following question: What is the relation between a sound knowledge of mathematical representations and one’s ability to connect different conceptualizations of the electrostatic field?

In this study we analyze the influence of mathematical representations in the way physics teacher students structure their knowledge of electrostatics. A semester course called “Concepts and Structures of Physics” was given with the goal of deepening students’ understanding of the electromagnetic theory and also to introduce them to a particular way of representing their knowledge with concept networks (similar to concept maps). A part of the course was dedicated to the teaching of central concepts, experiments and principles of electrostatics. One of the final products of the course was the students’ creation of concept networks that express their knowledge of the electrostatic field and encompass the development of this concept. Together with the networks, the students wrote reports where they explained in detail the meaning of each node (concept, principle, experiment, model or law) and their connections. In this work, we correlate the mathematical representations used to define core concepts like work, field, potential and flux in the reports with the connections they established between the three conceptualizations of the electrostatic field in their networks. Preliminary results indicate that students who made use of more formal (abstract, advanced) mathematical representations (e.g. differential form, vector field, integrals) were able to make more meaningful connections when compared with the ones that had less mathematical (more “conceptual”) reports. Some of these specific differences are presented and possible reasons are discussed.
The use of solar devices in an investigative practice in context, developed in Salta, Argentina, helping in the re-significance of what is to “understand energy”

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During three years of investigative exercises developed in the penultimate course of a secondary school of the suburbs of the city of Salta, Argentina, knowledge of renewable energies physics based were incorporated at the curricula.

With frame in the investigation action, the educational researcher proposes to his students activities using solar cookers, solar dryers, solar heaters, and photovoltaic panels/systems to favor the learning and the understanding of energy as a transphenomenological concept.

During the practices of investigation developed in the dictation of the subject Technology of the energy, the teacher/researcher asks himself: ¿what is to comprise, and what is to comprise what energy is?

The use of these devices fed with solar energy to exemplify and to explain the transformations that energy suffers, positioned as “generative topics” in the sense proposed by Martha Stone Wiske in the frame of her education for the understanding. On the other hand, they operate like instances of interaction with the physical world of the energy and enable to bring into play different skills associated to the understanding.

In the effort for building an integral explanation of the concept of energy, the teacher faces the needed to deepen the significance of what is to understand the energy and also to expand her theoretical investigative frame.

The contribution of the social semiotic of J. L. Lemke enriches teacher’s point of view. It allows her to deepen about what is to understand, but also allows her put in perspective science teaching (physics and by extension renewable energies with base in physics) in contexts of poverty and social vulnerability.

The investigation which takes place in an educational center of a poor neighborhood of Salta city, a particular context away of sciences development centers, is claimed by an emergent paradigm - the Designed Based Research. In this way, the knowledge generated in this particular configuration of application contributes giving account with greater support, of the processes of teaching and learning of what energy and solar energy are.

Starting with the need to explain how different devices fed with different energy types (electrical, chemical or solar) work, the article describes the evolution and re-significance of what is understand energy as an integral concept for the teacher/researcher, following a spiral route such as the investigation-action proposes.

It also analyzes the contribution of solar devices as generative topics and as instances of interaction with the physical world of energy, making possible new strategies and activities applied by the teacher.

The new performances attained by the students, the questions that a solar cooker shoots, the assessment and adhesion to activities like the construction and use of mini solar cookers or the viewing of an educational video about a solar heater, are observations collected and categorized as evidence of the analysis in the frameworks mentioned before.
Practical work revisited: A case study using a lesson study approach

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Practical work is a standard part of physics education. It serves to teach the skills of experimentation and to contribute to conceptual understanding. Also hands-on science is supposed to make learners understand how science works, by involving students in empirical research. However, these multiple goals can cause an overload of the practical. In turn this can lead to overscripted practical instructions, reducing the effectiveness of practical work (Abrahams & Millar, 2008).

As a response the Getting Practical method was developed as a means of revisiting goals and effectiveness of practical work (Millar & Abrahams, 2009). Starting with defining what learners have to learn, this is translated into learning activities. The next step is to check what is actually done and finally what is learned.

In this paper we present a case study in which the Getting Practical approach was implemented and optimized using the method of Lesson Study (Verhoef, Tall et al, 2013). In this approach teachers collaboratively (re)design a lesson. One of the teachers performs the lesson and the colleagues observe. Based on the observations, a second cycle of redesign completes the cycle.

In our case study, the physics teachers of a large secondary school reported that learners miss the relation between practical and theory and lack conceptual understanding of the physics that is subject in the practicals. Using the lesson study method teachers together redesigned a practical on calorimetry. In the original lesson teachers scored 10 goals out of a possible 17 as learning goals for the practical. The result was that learners only focused on the practical execution of the task, without paying attention to achieving learning goals.

Discussions in the teacher team resulted in a reduction of the number of learning goals to only three: better understanding of calorimetry, careful measurements and drawing conclusions. Also workload should be reduced for both learners and teachers. An article on student understanding of calorimetry (Christensen et al, 2011) was used as a theoretical basis.

The practical was simplified, e.g. by omitting computer measurements, and conceptual questions were added to the written instruction. During the practical, learners discussed their understanding of heat capacity. The lesson was observed by all teachers, and based on the observation outcomes the lesson was further improved. The redesign removed the time and workload problems. Also teachers now can easily assess students’ work. Important spin-offs using this approach are team building, professional development of teachers (Clarke & Hollingsworth, 2002) and an open lesson culture. In conclusion, this case study shows lesson study to be applicable and useful for the redesign of practical lessons. More case studies will be performed to further determine the way Lesson Study and Getting Practical are a good match.

References
Project based learning for teacher formation in Brazil’s state with the lowest literacy rate

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JUSTIFICATION: Alagoas is the Brazilian state with a long-standing history of the country’s worst educational results. Most recently, an international comparative study among 15 years old students [PISA] reconfirmed this, while a national study revealed that 21.8% of the population over 15 is illiterate [PNAD]. In spite of governmental efforts, most teachers’ content knowledge and pedagogical knowledge are low. For instance, less than half of teachers giving science classes at primary schools or even physics at secondary level possess any degree in natural sciences (Fischer, 2013).

CONTEXT: This research was organized as qualitative study with 13 adult students at the Federal Institute of Alagoas who are trained to become math teachers.

THEORETICAL FRAMEWORK: In our proposal we used the project method according to Carl Rogers (Rogers, 1977), consisting of 4 phases: Students 1) define project and learning objectives in a contract; 2) conduct project work; 3) self-evaluate their work and learning; 4) and finally present their work to peers.

RESEARCH QUESTIONS: We aim to answer the following research questions: 1) In how far do the participants a) feel motivated and b) secure and prepared to implement project based learning in their own teaching? 2) What differences can be observed for the implementation of this approach in an evening class for working adults compared to young full-time students? 3) How did the self-efficacy, skills and fact knowledge of the participants develop during the course? 4) How can the course design and implementation be improved to foster learning in Alagoas?

RESEARCH METHODOLOGY: The qualitative method was applied. Research instruments were validated by four professors at the Federal University of Rio Grande do Sul. The specific qualitative methodology chosen for this research was ethnographic (André, 2005). For the data gathering we used a quasi-experimental design for time equivalent samples (Campbell and Stanley, 1979). The data is analyzed based on Bloom’s revised taxonomy of educational objectives (Krathwohl 2010) and the work of Bardin (2009).

SOME RESEARCH FINDINGS: Our preliminary results (the subjects are still in the teacher training phase) indicate a strong motivation among students to apply this approach in class, while at the same time a majority does not yet feel sufficiently prepared and thus confident to implement it themselves. According to the student’s comments, more than one project-based course was needed in their training to prepare them better. We also found, that while the course encourages participants to take more responsibility for their own learning and fostered skills, the acquired fact knowledge was small compared to a common ex-cathedra approach. Project based courses would therefore have to be complemented by a more fact-knowledge focusing learning unit. All students showed improvements in procedural knowledge (as defined by Krathwohl, 2010; “How to do something; methods of inquiry, and criteria for using skills”) along with increased self-efficacy, but their conceptual knowledge (“Interrelationships among basic elements within a larger structure”, Krathwohl 2010) showed considerable gaps. This indicates to us the need of a greater emphasize on conceptual knowledge in our next trial, e.g. via a conceptual pre- and posttest along with a comparison to traditional teaching approaches.

PERSPECTIVES: Our findings suggest additional studies aimed at answering the related questions: 1) In the context of adult teacher education, can the Project Method be a better facilitator of conceptual, procedure, attitudinal, application knowledge than traditional teaching? 2) What changes in design and implementation are needed to improve the conceptual knowledge? 3) How
can this project be scaled to foster modern didactic methods and better teaching at Alagoas’ schools?
Curriculum evaluation of Undergraduate Programs: the case of the BS Applied Physics in the University of San Carlos

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This study was aimed to develop and implement a model for curriculum evaluation of undergraduate programs using the case of the five-year BS Applied Physics in the University of San Carlos, Cebu Philippines. Using the Context-Input-Process-Product (CIPP) Evaluation Model as framework for a more customized model for undergraduate program evaluation, data were collected from multiple sources through survey, questionnaires and interviews, documents and class observations. Survey respondents included 75 students and 59 alumni while 6 employers, and 8 instructors served as key informants for in-depth interviews.

As to context evaluation, the extent of the program’s relevance to the alumni’s current employment was assessed in line with the program goals and current needs of society. Around 86% of the alumni-respondents were employed while others were either self-employed or pursuing graduate studies or research. The results indicated that while most alumni-respondents perceived the Physics program as relevant to their present career, the program was perceived as highly relevant to alumni in the manufacturing industry like the semiconductor and optical filters industry while moderately relevant to the majority who were employed in Business Process Outsourcing and Information Technology (BPO-IT) industry.

Input evaluation included appraisal of the quality of students, faculty and the department facilities and resources for program implementation. The findings revealed that the BS Applied Physics program has attracted students with potential for pursuing career in science. Most of them were male with average Intelligence Quotient (IQ), above average English Proficiency Test (EPT) score, DOST scholars and with positive attitude towards Physics. The program has a good pool of qualified faculty who are academically qualified in both teaching Physics content and research. Resources and facilities for the implementation of the program were considered by alumni and students as moderately to sufficiently available and accessible.

Process evaluation focused on program delivery in terms of the teaching-learning and assessment methods used in the delivery of Physics courses and their degree of alignment with the planned curriculum. Review of course syllabi and class observations indicated the need for improving alignment between the learning goals and objectives articulated in the course syllabi and the teaching activities and assessment methods implemented in Physics courses which required higher cognitive demand in problem-solving applications. Moreover, there existed a degree of vertical alignment in the building up of Physics courses relative to the program goals.

Product evaluation considered the outcome of program implementation in terms of the graduates produced along with the knowledge and skills developed through the course of program implementation. The graduation, dropout and post-graduation success rates varied from year to year with an average graduation rate of 61.6% while dropout and retention rates averaged 10.3% and 90.7, respectively, over a span of six academic years.

In conclusion, the CIPP-based evaluation model used in this study has provided a systematic organizing framework for evaluation of a curricular program shown in the case of the BS Applied Physics program of the University of San Carlos. The model has provided the framework for
generating relevant information to support value judgments made on the extent to which the program achieved its goals and purposes. While the BS Applied Physics program has achieved its goals in providing good education and preparation for careers in industry, physics teaching and research, this study recommends that the Department reviews its program offerings periodically to address the evolving needs of the employment sector, thus, making the program updated and relevant. Feedback from alumni and employers can help revitalize the intended outcomes of the program. Further, it is recommended that the researcher-developed CIPP-based evaluation model may be used as model for future curriculum reviews and evaluation of undergraduate programs.

An open inquiry research-based teaching-learning sequence about change of seasons

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Research in physics education has shown that students often hold alternative conceptions about the change of seasons (Atwood & Atwood, 1996; Baxter, 1989; Sharp, 1996; Trumper, 2000). Students’ explanations range from the naïve idea that when the Earth is closer to Sun it is summer to more sophisticated ideas that the Earth’s axis flips back and forth during the motion around the Sun. As suggested by many authors, inaccurate students’ explanations may be due to a lack of laboratory activities about such basic astronomical phenomenon. For this reason, low-cost laboratory experiments are increasingly proposed in physics education courses in order to help students’ grasp basic concept as the motion of the Earth, Sun, Moon and the stars (e.g., Hughes, 2010; Ruangsuwan & Arayathanitkul, 2009). In other cases, 3D computer simulations have proposed to address misconceptions about seasons (Kücüközer, 2008). However, most of the proposed activities are isolated and not inserted in a coherent learning path focused on all the students’ cognitive stages. To address this problem, we developed a teaching-learning sequence (TLS, Meheut & Psillos, 2004) to connect the change of seasons to the underlying physical mechanisms. We adopted a guided-inquiry approach (Bybee, 2006) in which the students are first engaged in a scientifically oriented question, then look for experimental evidence to respond to the question, develop an explanation of the observed phenomena and finally connect the explanation with existing scientific knowledge. The design of the TLS was framed in the Model of Educational Reconstruction (MER, Duit at al. 2012) and went through two cycles of design–implementation–redesign. In this model, key ideas at the basis of a given content are first identified; then, the content structure for instruction is constructed using these key ideas. We chose as key idea the difference of the sunrays flow on Earth surface due to the tilt of axis. In the TLS first version, four activities were featured. In the first one, students, in small groups, are asked to identify factors underlying the change of seasons and to design an experiment to show the role of the identified factors. During this activity, the students are guided to understand that, to reconstruct the mechanism behind the change of seasons, it is necessary to measure the intensity of sunrays on Earth surface. In the second activity, the students are given a photovoltaic panel (presented as an instrument that can measure light intensity) and an incandescent light bulb (the laboratory “Sun”) and are asked to measure the output voltage of the panel as its inclination with respect to a reference system changes. In the third activity, the students are given a typical image that shows the angles formed by the sunrays with respect to the normal to the Earth’s surface in different periods of the year (spring/autumn equinoxes, winter/summer solstices) and are asked to simulate the represented situations with the photovoltaic panel. The aim is to show how the location on and the exposure of the Earth surface influence the experienced seasons. In the fourth activity, the distance misconception is addressed by asking the students to move the laboratory “Sun” towards or away
the panel to simulate the change in the “real” distance between the Earth and the Sun along the Earth’s orbit. The aim is to show that the small eccentricity of the Earth’s orbit cannot justify the change in the sunrays intensity, as measured in the previous activity. Twenty secondary school students (16-17 years old) have been involved in the first implementation of the TLS. Results from follow-up instruction interviews show that all students who held at the beginning a distance-based idea about the cause of seasons moved towards a more informed conception based on the tilt of the Earth’s axis. However, some of the students’ answers suggested the need to better clarify the relationship between the change of seasons and the perceived temperature changes. Such result informed the design of the TLS second version, in which a new laboratory activity on the factors that affect a given region climate (e.g., presence of water and soil) has been added. Overall, students’ positive outcomes suggest the effectiveness of our didactical sequence that progressively relates a basic astronomy phenomenon as the change of seasons to the underlying physical mechanisms.

**Explaining phenomena scientifically and identifying scientific issues in physics education: Some interesting observations of the high-performing economies in PISA 2006**

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Explaining phenomena in physical systems scientifically and identifying scientific issues for purposes of scientific inquiry are important outcomes of physics education for the junior secondary students around the world today. Regarding this, OECD’s Programme for International Student Assessment (PISA) in 2006 conducted a comprehensive sampled survey of 15-year-olds to assess their scientific literacy performance, and based on the questionnaire responses examined factors explaining performance variations from a comparative education perspective. The eleven top-performing economies in scientific literacy performance in PISA 2006 are: Finland, Hong Kong, Canada, Chinese Taipei, Estonia, New Zealand, Japan, Australia, Netherlands, Liechtenstein and Korea. After the dissemination of the PISA 2006 results, a few exemplary test units have been released to the public so that the various stakeholders can understand how scientific literacy and its constituent competencies are assessed internationally. For example, the two test units CLOTHES and THE GRAND CANYON require sampled students to deploy both the knowledge of physical science (i.e. knowledge of phenomena pertaining to electricity and heat in the physics curriculum) and knowledge about science (i.e. identifying scientific issues for scientific inquiry in areas such as frontiers of science and technology and the living environment) for an adequate answer to the items in the two test units. It is PISA 2006 Expert Group’s conviction that the test units purport to assess what students can do with what they know in their daily lives as a result of science education in their schools. Drawing data from the PISA 2006 database which is publicly available on the web, it is possible to compare student’s scientific literacy performance in these two released test units amongst the afore-mentioned eleven top-performing economies. Some interesting findings regarding how students of these high-performing economies are able to demonstrate what they can do what they know in the physics lessons, i.e. explaining phenomena scientifically and identifying scientific issues, are summarized. Another purpose of the present study is to examine the PISA 2006 database so as to find out whether there is any statistically significant association between an educational system’s scientific literacy performance and enjoyment of science learning. Sensibly, an educational system is considered exemplary in its science education provisions only if it is high-performing in scientific literacy (and its constituent components) and its students’ enjoyment of science learning is of the highest level amongst all participating economies in PISA 2006. This paper reveals that in PISA
2006 that there is a strong negative correlation between an educational system’s science performance and enjoyment of science learning. Amongst the eleven economies, Finland, Hong Kong, Canada, Chinese Taipei, Estonia, New Zealand on one hand are able to achieve highly in scientific literacy performance and on the other hand strike a balance not to go to the two extremes regarding enjoyment of science learning. However, Japan, Australia, Netherlands, Liechtenstein and Korea may not be considered as exemplary educational systems because their students indicate that their science learning experiences are far from enjoyable compared with the rest of the participating economies in PISA 2006. Implications of these interesting findings are discussed for the betterment of science (or physics in particular) education at the conclusion section of the paper.

Introduction of Current Scientific Results into Education: Metastudy and a Theoretical Framework

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Students consider physics as boring, abstract and detached from everyday life, and they are not aware of ongoing research. However, our society and almost all of its welfare is based on research results, where applicative potentials were recognized. The society being thoroughly familiar with current research is rather specific. Researchers are usually not involved in education except at graduate levels, and usually they do not feel a desire or an obligation to transfer the new knowledge to younger students or to the lay public. Nevertheless, this step toward non trained researchers is crucial in order to get a support for a research from a general citizen and a taxpayer and to increase a motivation of best students to pursue scientific careers.

We have recently developed a module that has introduced current research results on liquid crystals into education [1]. The module consists of lectures and laboratory work in chemistry and physics. Several problems have arisen during the development of the module, for example: goals and an expected conceptual level of understanding had to be defined; a necessary preliminary knowledge of students had to be determined; most appropriate methods for teaching novel concepts had to be chosen; the research topic had to “translated” from professional language of researchers to semi - several experiments for illustrations and support for conceptual understanding; tests for assessment had to be developed and several other smaller problems had to be solved. Introduction of new research results into education is an interesting and a difficult research problem by itself. Inspired by our experiences during an introduction of current research results into education for a case of liquid crystals, we tried to find similarities or differences in existing approaches to a transfer of new scientific knowledge into education. There were not many reports on introductions of new topics. Reports mainly considered designs of new laboratory experiment (in advanced optics and similar), only few modules were found (on tribology, semiconductors), sometimes topics aimed for teachers are presented (nanotechnology, superconductors) and only one example on semiconductors was found where a module was developed and evaluated [2]. This contribution reports on results of this metastudy and we will share detailed results on (a) Considerations and steps that were used at introduction of a topic »liquid crystals« to education at all levels [1].

(b) Metastudy of reports on introduction of other topics: superconductivity, tribology, semiconductors, advanced optics and other modern topics.

Based on this data, we shall suggest a theoretical framework for introduction of current research results into education with an emphasis on physics. The theoretical framework will consists of criteria for the choice of a modern topic, for determination of teaching goals, of prerequisites required from students and from teachers, a suggested procedure of module construction and implementation and finally, a suggestion for assessments of goals.
The Karlsruhe Physics Course (KPC) is an innovative approach to the teaching of physics, that had been developed some thirty years ago and has since then been spreading at a slow rate. Recently, the course has been discovered by the German Physical Society (DPG). The Board of the DPG came to the estimation that the KPC represents a danger, since it calls some of the traditional teaching contents and methods into question. So, the DPG initiated an uncommon campaign with the objective to ban the course from schools and universities. Moreover, measures have been taken to impede any spreading of KPC ideas, not only in Germany but worldwide. In particular, the DPG board appointed a commission that was assigned to search for errors in the KPC. The commission presented a report according to which it is pretended that the KPC contains a certain number fundamental errors. However, the commission had not taken great pains to study the KPC. It soon turned out that none of the „fundamental errors“ they believed to have found was an error. On the contrary, it was the DPG report that was rather faulty. Interestingly, several of the DPG’s allegations against the KPC are based on the same misconception: A naive and unscientific understanding about what is a physical quantity. 

1. It is believed that a physical quantity is something that exists in the physical world and that has only to be discovered and studied by physicists.
2. The concepts „physical quantity“ and „physical system“ are not distinguished, or in other words: the measure and the object to which the measure refers are confounded.

In the talk one of the allegations is chosen as an example to demonstrate the reviewers’ misunderstanding. The DPG reviewers write: „The KPK introduces magnetic charges although they do not exist.“ Indeed, the KPK introduced the physical quantity magnetic charge right at the beginning of the chapter about magnetostatics. The reason for the reviewers’ opinion is that no magnetically charged particles, so-called magnetic monopoles, have been found up to now. Though, the argument is not valid. Magnetic charge is a physical quantity. Physical quantities are mathematical objects, which are introduced by man, in order to describe the physical world. They are introduced if and only if they are useful. Instead of asking if a physical quantity exists one better asks if it is opportune to introduce it.

In the case of the magnetic charge that question has been asked a long time ago and answered affirmatively. To convince oneself one only has to look at the text books. And what is the physical quantity magnetic charge good for? Here some examples: – to express that every magnet is magnetically neutral; its north pole carries exactly the same amount o magnetic charge as its south pole, but with the opposite sign; – to formulate Coulomb’s law for magnetic poles; – to express the fact that no magnetically charged particles have been discovered.

Magnetic charge and magnetic monopoles: The mistaken interpretation of a physical quantity

Friedrich Herrmann
KIT, Karlsruhe, Germany

The Karlruhe Physics Course (KPC) is an innovative approach to the teaching of physics, that had been developed some thirty years ago and has since then been spreading at a slow rate. Recently, the course has been discovered by the German Physical Society (DPG). The Board of the DPG came to the estimation that the KPC represents a danger, since it calls some of the traditional teaching contents and methods into question. So, the DPG initiated an uncommon campaign with the objective to ban the course from schools and universities. Moreover, measures have been taken to impede any spreading of KPC ideas, not only in Germany but worldwide. In particular, the DPG board appointed a commission that was assigned to search for errors in the KPC. The commission presented a report according to which it is pretended that the KPC contains a certain number fundamental errors. However, the commission had not taken great pains to study the KPC. It soon turned out that none of the „fundamental errors“ they believed to have found was an error. On the contrary, it was the DPG report that was rather faulty. Interestingly, several of the DPG’s allegations against the KPC are based on the same misconception: A naive and unscientific understanding about what is a physical quantity. 

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Contradictory reasons for bringing innovations into the science classroom: understanding how Brazilian in-service teachers argue for the relevance of their educational products

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Professional master’s degree in physics teaching (PMPT) has become possibly the most important vehicle for bringing innovations into Brazilian science classrooms and the major contemporary modality of in-service physics teacher education funded by the federal government. The analysis reported in this abstract constitutes a large national assessment of these graduate programs aimed at expanding the possibilities of in-service teacher education through means of critically analyzing the actual impact these PMPT have in physics teaching. PMPT programs are usually committed to the elaboration of innovative educational products (such as supportive texts, hypermedia and laboratory activities) aimed at transforming physics classroom. One of the main challenges that PMPT programs pose to enrolled physics teachers is to develop such educational products as well as a small thesis presenting this product to the academic community.

In particular, this abstract reports a critical analysis of how PMPT graduates justify (in their small theses) the relevance of the educational product they have developed. These assertions of value are very important if we want to understand the purpose that drives this activity of developing and implementing innovations. The theoretical-methodological framework we elaborated for this analysis is based on Mikhail Bakhtin’s approach to language. Under this framework, the authorship of any utterance is never limited to the speaker (or the writer), but it is shared with the audience (the person or social group addressed). From this standpoint, we may observe that recurrent types of justification amid PMPT graduates reveal most institutional beliefs about what should be valued as innovative physics teaching and what should not. In fact, one may observe that, despite there is a large agreement on the importance of bringing innovations to the physics classroom, the reasons and purposes that arguably justify this need for innovation (such as to improve student conceptual understanding, interest in Physics, epistemological awareness and scientific citizenship) are very different or even contradictory. Hence, the empirical analysis reported in this abstract is aimed at the following research questions: (1) What is typically observed when PMPT graduates justify their educational products and what do these findings tell us about the enacted purposes of bringing innovations to the physics classroom? (2) Which reasons and purposes for innovation are privileged by PMPT graduates and which are more often ignored?

Through the analysis, we observed that the recurrent orientation toward interdisciplinary and contextualized approaches to physics content matter is often justified on the (alleged) need for adjusting physics teaching to national guidelines and curricular standards. In different degrees, school students are often pictured as unable and uninterested subjects while the moral commitment of the physics teacher is to make them more able and more interested in physics. The actual relevance of the physics taught for scientific citizenship is hardly ever considered as a main issue. Group work and other social-oriented strategies are often aimed at putting the most capable students in contact to the less capable ones so as to improve the performance of the whole classroom. Finally, the focus of these justifications usually lies on the concern of improving students’ performance in and attitude toward physics while science education for citizenship is often ignored. These differences tell us much about which reasons are considered legitimate in
these PMPT and which ones are not. Despite these results must be improved, it is already possible to notice that PMPT is a modality of in-service teacher education related (or even limited) to technical rationalism, an approach to education that tends to separate science content from issues of ethics and politics of vital importance to educate students for informed and democratic participation in socio-scientific issues.

Propective physics teachers’ understanding of radio carbon dating: a teaching experiment

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Radiocarbon dating is a current application of the radioactivity theory. It is commonly proposed in the educational sphere, but it is also present in documents addressing a larger audience. However it is rarely exposed in a completely coherent way. This presentation concerns part of a previous investigation. A teaching experiment [1] was designed in order to have students - 10 fourth-year university students - critically react to written explanations of the phenomenon under study, and to express their possible frustration or intellectual satisfaction relating to these texts [2-4]. Our goal was twofold. Firstly, we aimed at documenting the possible link between students developing conceptual understanding of a topic and their ability to express their frustration, when presented with very incomplete explanations, or their intellectual satisfaction in the opposite case. Secondly, we intended to observe – as a side product - some of their ideas at the beginning of the interview concerning radiocarbon dating. Based on a previous study concerning colour absorption[5-6], we thought in particular that some of these difficulties would probably be related to the “multiplicative” nature of this process: the radiocarbon disintegration rate is proportional to the total amount of radiocarbon. This presentation is focused on the main results concerning the second component of our study. We see it as a preliminary exploration which might guide the design and evaluation of a forthcoming teaching-learning sequence on this topic.

Among the difficulties that were observed, a first category confirmed our expectation concerning the multiplicative aspect of the disintegration process.

Another difficulty can be linked to the need for simultaneously understanding a stationary state (the radiocarbon amount in the atmosphere is globally stable) and a transitory state (the radiocarbon decreasing in living-beings after their death is exponential). These difficulties remind us of those observed when students were asked to explain the greenhouse effect [7].

More unexpectedly, another aspect was also observed: several interviewees thought that radiocarbon would give rise to normal carbon after decay. This view suggests to further explore some possible confusions between nuclear and chemical reactions.

Among the research perspectives, it seems important to test these preliminary results concerning a topic as yet little documented in research literature: radio carbon decay. We also suggest that this study confirms the interest of exploring students’ understanding of multiplicative processes as such. Finally the distinction between chemical and nuclear processes appears, through this study, as a promising research topic.

The Role of TPCK in Physics Classroom

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Generally, physics course is perceived as a difficult subject by students. Especially, when teaching physics combined with the traditional method, the situation becomes much more difficult and some troubles occur for reaching the goals of meaningful learning. Today it is a scientific reality that knowledge learned through hearing, seeing, doing or living is permanent. Especially, the devices such as computers, which offer multimedia presentations, images, animations, videos, and opportunity to test the learners’ ideas by means of simulation programmes, are filling a large gap in this subject. One of the most outstanding media addressing to the all 5 senses, is simulations. Simulation is the imitation of the operation of a real-world process or system through the computer. The feature of getting the result immediately after changing some parameters of simulations makes them more advantageous than animations and videos. Together with it, the opportunity of making the experiments which may have fatal results in real-life, by means of computer simulations, emphasizing the importance of simulations at the Computer Aided Education. For example, it is not possible to conduct a radioactive decay experiment at a school laboratory but the results of the decay can be seen by simulation software. So, to make the learning of the students more meaningful and permanent, to construct the intangible issues at the students’ brains more easily, to comment on physical events, to increase the motivation of students by addressing both to their eyes and ears at the same time, it is necessary to prevalent Computer Aided Education. TPCK is a framework that includes the relationship and the complexities between all three basic components of knowledge (technology, pedagogy and content). It is a full frame for thinking about what knowledge teachers have to integrate technology into teaching and how they might develop this knowledge.

Participants:
30 pre-service teachers of Physics Education at Faculty of Education, Marmara University, were attending “Teaching Physics “class during the 2nd semester of academic year 2012. Four of 30 pre-service physics teachers in the class were chosen to participate in this research as case studies. The participants of the research were two female and two male. All of them have basic computer skills but they had not any experience with using ICT for instructional purposes. They allowed to use PHET simulation software program, and than it was expected them to integrate it to their subject they would teach. Initially, it was given two lessons regarding to technology based physics education. They attended a micro lesson instructed by the researcher about how they would integrate Phet simulation software program into the their micro-teaching.

Data Collection:
Data collection tools were very diverse in this study such as field notes, interviews, lesson plans and questionnaires about their self evaluation after micro-teaching. Various data collection tools
were used for triangulation and supporting rich data about participants after technology (simulation program software) integration period.

Results:
This study was designed to determine how pre-service physics teachers’ instructional beliefs are related to integration of simulation software programs. According to data, pre-service physics teachers used simulation for two distinct purposes. One of them was just illustration purpose, without asking question, making inquiries and interpreting. The other usage purpose of it to integrate was to collect, analyze and interpret data with preparing paper physics experiments. (The details will be given in the full paper)

In situ physics teachers training for netbooks class incorporation by the Conectar Igualdad Program in the setting of a volunteer university project in Salta, Argentina.

Verónica Mercedes Javi, Martín Morales and Ariel Durán
Universidad Nacional de Salta, Argentina

In 2010 in Argentina, the Conectar Igualdad Program is created as a public policy that delivers netbook computers to students and teachers of public secondary education schools. Teachers, students, directors and tech support personnel are fundamental actors to this process. The massive delivery of netbooks to students and teachers and its incorporation into the classroom requires new teachers performances. Training programs are offered to teachers through the Program's online, through each provincial Educational Ministry and through a call for university volunteers.

The Voluntariado Universitario Program that depends on the Ministerio de Educación Argentina funds the training Proyect ”Education and Comunication in the age of needs” (ECAN). It is an in situ training workshop focused on the use of netbooks as a new didactic element for secondary physics courses. During the Elementary Dynamics Workshop it is expected that students and teachers develop new skills to take advantage of such a powerful tool. It attempts to validate in classroom new methods for teaching the Newton's Laws.

Some issues raised early in the project: Is it possible to teach physics using netbooks? How is problem solving and experimental practice put together with the activities facilitated by the netbooks? Do they improve the teaching and learning of physics? How do they impact on teacher's role? The ECAN project's physics team and the body of teachers are aware of this issues. It thinks over, adjusts to and comments upon them, thanks to the intrinsic flexibility of the workshop and the cooperative work that promote and facilitate these exchanges. Results are recorded and a final interview collects teacher's opinions and judgments.

The Workshop of Basic Dynamics has three stages: the preparatory one with the teachers; other one of application and another of reflection and exchange. The developed experiences are: determination of the type of movement of a washer falling down in a threaded rod and a bubble that climbs in a pipe full of water, determination of coefficients of friction (three courses of 4to year). Later it is added a practice on electrical circuits (5th course). It qualifies teachers in basic handling of the Scilab and Modellus and incorporates the recording of videos for data logging and the online Google chronometer to measure time. When discussing the principal motion’s laws, it’s logical structures and operational definitions A. Arons is followed.

Results of the applications realized in the classes are presented: participation of students, advantages and difficulties found, the use of available software that teachers make, the incorporation of other programs (PHET and the FW), achievements reached.

Some aspects of teacher’s practice and of teacher’s role, put into play, seem to be enriched: the preparing of appropriate and ad – hoc materials, the searching of new didactic strategies, the deepening in conceptual analysis of laws, physical variables and functional relations.
Critical discernment on the teachers own practice and the incorporation of the innovation to unplanned instances are auspicious performances achieved by physics teachers and their students. These performances uncover new learning, answering some of the initial inquires about the use of netbooks.

**Making the most of limited time: efficiently and effectively training pre-service science teachers in conceptual physics**

*Christine Lindstrøm*

*Oslo and Akershus University College, Norway*

At the largest teacher education institution in Norway, Oslo and Akershus University College, pre-service science teachers (for grade levels 5 to 10) undertake two courses in physics. These have 56 hours of contact time across lectures, experiments and tutorials, substantially less than two standard first year university physics courses covering the same topics. In tertiary physics, courses that employ Interactive-Engagement (IE) methodologies have consistently been found to yield greater learning gains without increasing contact time (Hake, 1998). The goal of this project was to implement IE methodologies to investigate whether similar learning gains to those reported in the literature could be achieved despite the limited number of contact hours and the wide range of physics topics covered.

IE methods used were Flipped Classroom (FC), Just-in-Time Teaching (JiTT) and Peer Instruction (PI). Forty-three pre-service teachers undertook either one or two FC physics courses in the 2013-2014 academic year. Physics A (24 contact hours) covered the topics of thermodynamics, gravitation, buoyancy, sound, light and mechanics, whereas Physics B (30 contact hours) covered electricity, magnetism, induction, atomic- and nuclear physics, and astronomy. Both courses had a strong emphasis on developing conceptual understanding. As a proxy for measuring learning gain, the widely used and acknowledged Force Concept Inventory (Hestenes, Wells & Swackhamer, 1992) was used. Newtons laws and kinematics were dealt with in topics spanning nine hours in each course.

In the FC approach to the course, students received their initial exposure to the subject matter before class, through readings, videos and online pre-work, thus freeing up class time to work on concepts students found particularly challenging. In accordance with the JiTT methodology, the instructor used student feedback obtained from the pre-work to tailor every class to the students' particular difficulties. During class, relevant mini-lectures were given interspersed with student discussions on conceptual questions. For the discussions, PI was used, delivering questions to students on their digital devices. Both online pre-work and in-class questions were delivered using the online platform Learning Catalytics. Each class lasted two hours and forty-five minutes. Of the two concluded autumn courses, 96 minutes were, on average, spent on JiTT and PI, 48 minutes on experiments and problem solving, and the remaining 21 minutes on breaks and general information. The group of 11 students who undertook both Physics A and B showed an improvement in the FCI from 36.7% to 56.7%, corresponding to a normalised gain (as defined by Hake, 1998) of \( <g> = 0.33 \). This falls within the range of average normalised gains for IE courses, which was \( <g>_{IE} = 0.48 \pm 0.14 \) (Hake, 1998). Another group of 22 students had studied Physics A in the previous year, and so did the FCI pre- and post-Physics B only. They also exhibited an improvement in the FCI from 47.6% to 55.9%, \( <g> = 0.22 \) (N = 17), corresponding to average normalised gains for traditional courses \( <g>T = 0.23 \pm 0.04 \). Although pre-Physics A scores were not available for this second group of students, it is worth noting that their post-Physics B score is nearly identical to the first group. Other findings from the autumn courses were that students were motivated to do their pre-work (62% compliance, N = 36) and attend classes (88%, N = 36), both of which were voluntary. In the course evaluation questionnaires, students indicated that of the different teaching
methods employed, PI and JiTT were the two most valuable for learning (M = 4.46 and 4.00 out of 5 respectively). Although there is room for improvement, the technology-rich IE courses were considered an efficient and effective use of class time.


Session 2.3: Physics Teaching and Learning in Informal Settings
Monday 7, 16:45-18:45
Room 9 (Aula 9)

Methods of using self made devices and physics toys at the lessons and beyond

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The methods of using non-standard devices and physics toys in physics teaching process have been proposed, developed and experimentally tested. The main goal of the methods is motivation developing and increasing the secondary school students’ knowledge level. The structure of non-standard devices has been worked out and its position in existent system of physics experiment has been given. The examples of all described structure components have been developed and used in teaching process. Industrial and self-made physics toys, which have been used in Ukrainian physics course have been classified. Teaching techniques of using created non-standard devices at summarizing lessons have been proposed. Eight thematic physics shows provided beyond lessons have been worked out and demonstrated to the secondary school students. The self-made kits for physics teachers have been methodically described and used at the lessons and beyond. Six non-standard devices have been improved, some of them are known as "Cartesian diver"; versatile optical self made device for demonstration colors composition and some optical illusions; model of a heat engine, which have been made by secondary school students, "Paradoxical chair"; holder for laser pointers to demonstrate the Geometrical optics laws; "inclined plane and billiard balls demonstration.

Short analysis of the methods and forms of physics teaching in Ukraine have been given and compare with enquiry-based teaching method with using non-standard devices and “physics toys” for creating a problematic situations at the lesson. The classification of physical toys with detailed recommendations how to use them at the lessons have been proposed. It was based on the Former Soviet Union list of toys, created by I. Lanina and the well known “Catalogue of physics toys” proposed by German expert in Physics Didactic Prof. Dr. Christian Ucke.

Teaching methods proposed by the authors are not contrary to the existing ones, they can be considered as an effective supplementation to traditional methods and forms of teaching physics. In this connection proposed techniques of summarising lessons organisation, where teachers can use interactive methods, elements of the physical shows, created non-standard equipment, and industrial and self made physics toys have been very effective.

The results of the pedagogical experiment showed the advantage of the proposed method over the traditional system of education in Ukraine. It have been shown that the proposed method based on created non-standard equipment can increase then motivation to learn physics and raise the level of students knowledge.
Junior Physics tutors - 14 years of success story

Smadar Or, ORT, Israel

ORT Israel, a net of middle and high schools in Israel decided to respond the challenge of increase the number of students that study science in an advance level by this project of Junior Physics Tutors.
This project has started with 37 students from 4 ORT schools on 2001 and through the last 14 years we have about 2,000 physics tutors and more than 10,000 attendees, from schools all over Israel not only ORT schools. For our small country it’s quite impressive numbers.
This project increased the number of high school students that study physics from 8% to 12% in schools that it takes place.
There are two main objectives to the project
1. Increasing the number of high school students studying and excelling in advanced Physics.
2. Change students’ attitude towards Physics.

How do we achieve this?
A. Junior tutors - ORT identified the potential of having students in grade 11 in the advanced physics track serve as role models for younger students in 9th grades. Those in grade eleven can
B. Experimental learning- experiments, models’ construction, trial and error and simple demonstrations. This can make physics terminology more comprehensible and meaningful and introduce the younger students to everything that is beautiful and interesting in physics studies. Suddenly physics terms as forces, vectors and radiation turn to be more clear and meaningful.
Simple experiments such as: taking a flashlight, coloring it, then stick nylon string to demonstrate how light goes through optical fiber.
Or – trial and error while building a hot – air balloon until it takes of.
C. Engaging topics – by teaching physics through subjects that interest the youth such as: Light and radiation, electricity, playing with physics, Astronomy, Physics in sport, Physics in toys, Physics in flight, Physics in sea crafts, Physics in amusement park.

WHO are the junior Physics Tutors?
11th grade physics students.
They receive training both in physics topics and in guidance and leadership skills like: team work, tools to handle with group, how to deal with variant kinds of students, giving and getting feedbacks, etc.
For the training all the tutors from all the schools all over the country gather together to study.
The junior tutors run these clubs themselves with no teacher with them. All the responsibility on the equipment and on the attendees their interest and diligence are on the tutors. There are about 30 students in the physics club in each school.
The junior tutors run these clubs by the junior do some extra activities at their schools, for example – scientific summer camp for younger kids from 6 grade.
In each school there is a teacher that us response on this project at school
The teacher's responsibility is mainly logistics and administrative.
The project can easily be replicated to cover any education system.
Development of students’ interest in particle physics as effect of participating in a Masterclass

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Supporting the development of interest in physics is an important goal of physics education. Interest is a crucial condition to achieve openness towards science in general and especially in physics. Giving /presenting an insight into recent physics research and answering fundamental questions about our universe should inspire young people to deal with physics not only at school, but outside school as well. In order to promote these goals in Germany the “Netzwerk Teilchenwelt” (engl.: network particle world) was founded in 2010, a network of particle physicists, physics teachers and young people. It has developed an educational activity – the “Particle Physics Masterclasses”, inspired by the International Hands On Particle Physics Masterclasses – that brings real particle physics research into the classroom and allows the most interested students to engage in the network with more advanced activities in workshops and own research. In addition, one idea of the network is to help teachers to support students’ interest development in physics.

During the Masterclass events students have the opportunity to obtain an insight into recent particle physics research, e.g. into still open and already answered questions, into scientific methods and how researchers collaborate. Consequently the participants conduct own measurements with original data from experiments at the particle accelerators at CERN promoting own activity and providing them the authentic experience of concrete research. The facilitators are particle physicists themselves so the students come in direct contact with young researchers. The events last between 4 to 6 hours and typically take place in schools in order to reach as many students as possible. Whole classes as well as selected students between the ages of 15 to 19 years can take part.

In order to investigate the effects of the Masterclasses and the mechanisms behind them, an evaluation study was implemented. It was focused on the development of students’ interests in physics and especially in particle physics. An important goal of this investigation was to find recommendations on how to improve the desired effects of these events.

The construct of interest was based on the person-object-theory by Krapp. The instruments applied were an interest questionnaire specifically developed on the basis of existing evaluation instruments and a short particle physics knowledge test. The questionnaire contained the interest in physics as subject in school, in a scientific career, the perceived event properties (e.g. the perceived authenticity) several dimensions of interest in particle physics and additional questions concerning control parameters. After piloting and improving the questionnaire 25 Masterclasses were evaluated in a pre/ post/ follow-up design which means that the participants (N=340) were asked before, immediately after the event and again after 6 to 8 weeks (experimental group). Additionally, a control group with students who did not attend a Masterclass were asked with the same instruments.

The results indicate among other things that the students indeed perceive these events as very authentic, in general as well structured and as adequate. In order to clarify the mechanism of action structural equation models were used. With these it was analyzed how the different interest and event variables influence each other. An important result, which will be presented, is how the different variables interact with the focus on practicable approaches to improve the Masterclass’ effects on students´ interests. The presentation will include the most important results and essential findings of this investigation. From these implications for the improvement of the Masterclasses with respect to enhancing interest in particle physics and physics as a science in general will be derived.
Physics competitions for learners of Primary Schools in Slovenia

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Physics became a primary school subject in Slovenia even before the major educational reform in 1958, when obligatory 8-years (in 1996 changed to 9-years) primary school was introduced. Learners of ages 13 and 14 are taught physics in the last two grades of the primary school since then. In 1981 the first national competition in physics for learners of primary schools took place and in the school year 2013/14 Slovene Association of Mathematicians, Physicists and Astronomers (DMFA Slovenije) [1], with substantial help from Universities of Ljubljana and Maribor and also teachers from all participating primary schools organized 33rd competition already. Only mathematics competitions have longer tradition in Slovenia.

Since its beginning the format of the competition gradually evolved and in the present it is a three-stage competition, starting with the first, school level, followed by the second, regional, and completed by the last, national level. In the last decade approximately stable one quarter of generation participates in the physics competition. Competitors literally come from almost all Slovene primary schools. Being itself completely voluntary for learners, we consider this proportion of learners showing enough interest for physics to put some additional efforts and invest some spare time into preparations, satisfactory. We understand it is a result of united efforts not only of the learners themselves, but also of their teachers, acting as their mentors and also as more or less voluntary organizers of school and regional stages of the competitions, and finally, members of competition committee, the authors of physics problems on all three levels of the competition.

In accordance with the nature of physics, being experimental science discipline, the last stage of the competition consists of two parts: theoretical and experimental. Each part lasts for 90 minutes (changed to 80 minutes this year). Physics competitions are, expressing appreciation for experimental part, rather unique among other existing science (and mathematics) competitions. Before this year competitors had to solve two (shorter) experimental tasks, and from the last school year two (more simple) experimental tasks were changed for one, more complex experiment. Due to this organizational change also the rationale of experimental problems changed a little, to ensure the optimal (normal) distribution of performance in solving the problems.

We are going to present our experiences with physics competitions for young learners. We will present some experimental problems, given at the last stage of the competition in the past, we will comment achievements of learners at experimental part and show also frequency of physics topics, having a role in experimental problems in competition. Some topics are significantly more popular and exploited for that purpose than others. We shall discuss the reasons for that.

Early childhood science education in an informal learning environment

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In this paper we present an environment for extra school science education designed and continuously improved through a dialogue between experts/operators in informal education, researchers in physics learning/teaching and schools. Giocheria-Laboratori is an educational service of Sesto San Giovanni municipality (near Milan), operating since 1987. In collaboration with the authors and an expert in childhood education, four specialized educators design and manage laboratories on math and science topics: weight and forces; counting and measuring; light and colour; water; etc. Kindergarten and primary school-classes can participate to one laboratory three
times per year integrating school and informal learning on one of these thematic areas. Particular attention is devoted to link emotional, expressive and cognitive dimensions through care of spaces, materials and relationship.

This year in collaboration with architects and designers (funded by the Italian Ministry of Education) are under construction new laboratories and an open space about materials, based mainly on re-use stuff according to Remida creative recycling tradition (www.reggiochildren.it).

Our research questions are: can the experience with early childhood suggest new perspectives on the design of extra-school spaces and informal activities? And vice versa can the new team work help renovating the preschool and school science education?

Our research with young children (2-5 years old) is in line with recent findings about their potentialities and competencies. Many researches show that children are far more competent in their scientific reasoning than first suspected and have since very early childhood substantial knowledge of the natural world. In particular thinking about matter, substance, and transformation appears very early and children seem to know "that substance and the stuff that things are made of apply to a different level of conceptual analysis from thinking of things as objects." (NRC, 2007, p. 70). To answer to our research questions we planned three environments to propose kindergarten children to manipulate objects made of different materials in interaction with light; heat and cold; water respectively. Groups of 5-6 children work in different environments making free explorations guided mainly by selected objects and tools. Only the heat and cold lab is more guided for safety reasons. Adults are reference points and discreet guides trying not to interfere with children explorations. Photos and some video recordings are made to allow careful observations of their explorations, of gestures and body actions, to listen words and sounds by the team at the end of each meeting.

We started planning and testing laboratories with younger children (4-5 years old) and depending of the kind of activities and explorations they realized we arranged more complex environments for older children and an open space for all visitors.

The aim of laboratories is to understand how children of different ages (between 4 and 11 years) explore the behaviour of different objects when: lighted, heated or cooled, in interaction with water and to see if they are able to get what depends on material objects are made of and what depends on their shape, dimension, structure (extensive properties). Besides these laboratories architects and designers are arranging a spacious room holding containers with a large amount of objects made of the same or different stuff that suggests to start from materials, looking for their intensive properties, common to different objects and independent of stuff quantity.

In the oral communication we will present qualitative data to show the quantity and quality of explorations and discoveries by children of different ages in relation to the two complementary perspectives we adopted: looking at objects/looking at materials.

Some conclusions will be proposed about the interaction between school and extra school scientific education based in researches with Giocheria-Laboratori staff.

Acknowledgements

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References

Teaching Physics in elementary education: Design and Planning of a Workshop of Recreational Physic.

María Guadalupe Martínez Borreguero, Francisco Luis Naranjo Correa and Florentina Canada
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In this work we present an experience carried out in the 2012/2013 academic year with 230 students in the fourth year of the Degree in Primary Teaching in the Faculty of Education at the University of Extremadura. The work has been developed within the framework of the course Knowledge of the Natural Environment in Primary Education within the knowledge area of Didactics of Experimental Sciences, in order to overcome the rejection and disinterest in learning physics that most students feel. This course covers the scientific and educational content that will enable the primary teacher to perform its teaching in relation to the Knowledge of the Natural taught. One of the objectives of this course is: “To train future teachers of primary education to meet the challenges of the educational system and adapt the lessons to the training needs of the 6 to 12 years old stage of the educational system, performing their functions under the principle of collaboration and teamwork”.

In order to achieve this goal, in this research it has been designed and planned the development of different laboratory experiences that could be used to teach physics concepts to elementary school students. This is intended, from a conceptual, procedural and didactical point of view, to create teaching tools that foster meaningful learning of science content in children. The methodology has been carried out based on cooperative and collaborative learning techniques in which have been developed and coordinated the experiences that have been part of the workshop elaborated on “The Magic of Physics”. The experiments selected by our students, future teachers of elementary school, are based on observations, curiosities and very simple interpretations of the everyday environment of the child, which had a surprising character to arouse interest and the sense of wonder in them, thus converting a physics laboratory in an attractive activity for children. For the qualitative validation of the work the opinions of the students who participated in the experience have been collected. The results obtained in the analysis of the data have shown the usefulness of such methods as teaching and learning strategies in science for primary education.

Teaching energy using cooperative learning in a primary teacher training degree

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The framework of the European Higher Education Area has changed the university education paradigm, which devotes to educate future professionals that are able to apply the concepts learned throughout their education in their professional field and to be able to sustain arguments and solve problems with a high degree of autonomy(1). The use of active methodologies such as Cooperative Learning (CL), constitutes an efficient tool to promote such change of paradigm, which is moving from a vertical model of knowledge transmission, individual work and final evaluation towards a
model, where: i) both individual and cooperative work is necessary, ii) students organize themselves in small groups to solve academic tasks that will help them to develop their own learning, and iii) evaluation is a continuous process (Johnson et al. 1991).

In this work I present a module of 5 ECTS credits implemented in a Primary Teacher Training degree, which is based on CL. During this module, the students, organized in groups of 3 to 5 people, learned about basics aspects related to the Nature of Science (NoS) and the concept of Energy. The module was presented as a project where the students analyzed an scenario reflecting a professional situation, in which they must explore the way energy is taught in the last stages of Primary Education (10-12 years) and design a lesson plan where the energy concept is taught along other scientific topics or contexts, with the ultimate goal of engaging future primary teachers into studying scientific concepts because they will be useful in their professional life. The theoretical premises in which this scenario is based are: i) the current agreement on the NoS (AAAS, 1990) and the goals of Science Education (Harlen, 2010) and ii) the approach to teaching energy based on learning progressions (Duschl et al., 2007) and the seminal work by Driver and collaborators (1986,1987).

In this work I will also present the starting point and learning outcomes of these students in relation to understanding concepts such as the idea of Energy as a physical concept, Energy transformations, Energy degradation and the conservation of Energy. In order to evaluate this, the students were asked to answer individually two questions to detect whether they understood energy transformations and degradation. At the end of the course an individual test was passed in which the students had to perform exercises related to energy transformations and the Principle of conservation of Energy. An analysis of the evolution of their ideas will be discussed. The students also filled a survey about the employed methodology, which received an overwhelming support.

REFERENCES

Evolution of pre-service primary science teacher's pedagogical knowledge during reflexive training based on dialogues' analysis.

Nora Sánchez-Oussedik, Marina Castells Llavanera and Mercè Izquierdo Aymerich
Universitat Autònoma de Barcelona, Spain

The results of science education research point that science teacher must develop professional skills to foster communication and argumentation in science classroom. To reach this goal, science teacher has to become aware of its own Pedagogical Content Knowledge (PCK) (Shulman, 1987) and make it evolve. In this work, we propose a reflexive training based on the analysis of dialogues between science teachers and primary school students, to make evolve the conceptions of Pre-service Primary Science Teacher (PPST) about Previous Scientific Knowledge (PSK) of the students, Argumentation and Communicative approaches (CA).

Based on Vygotsky's sociocultural psychology, we understand the science classroom as a sociocultural context where meaning making occurs while communicating, with teacher's mediation in a "science education activity" which should enable students think, talk and act.
In this context, previous scientific knowledge (PSK) takes a central place and the teacher must act on it. This "student's science" is constructed by the interrelation of its experiences, ideas, reasonings and language, surpassing reducionist conceptions that only relate students’ previous science knowledge (PSK) with children's ideas. In this research, we distinguish students’ previous scientific knowledge (PSK) and PPST's Pedagogical Content Knowledge (PCK), on which we want to influence.

To make evolve PSK, students must engage in group argumentation processes as a way of sharing, analysing and changing knowledge (Driver et al., 2000). This reconstruction of “students’ previous science knowledge” (PSK) needs a special communicative approach conduced by the teacher: the interactive-dialogic approach (Scott et al., 2006). Finally, we agree with the idea that pre-service teacher education must be real case-based, offering opportunities to reflexive thinking.

This study was conducted with 15 PPST enrolled in a science education course (which includes content and pedagogy of science content) at the University of Barcelona. In this course, PPST have to prepare an experiment or specific situation of any physics or chemistry topic and establish a dialogue with primary school students about it. Our reflexive training analyses some dialogues from the previous course (videotaped and transcribed) with the 15 PPST before they conduct their own dialogue during the present course. Throughout 4 months, the written argumentative-dialogic activities that the PPSTs produce are the data for our research. A qualitative and iterative method was used to define categories of analysis.

Initially, the PPST conceived the students’ previous science knowledge (PSK) as a scholar preconception, unrelated to the student's life and with no implications for teaching practice. They also consider that argumentation is a logical construction decontextualized, typically associated with communication.

Throughout training, that vision of PSK evolves into a complex body of knowledge that goes beyond the school. PPST understand that previous science knowledge (PSK) must be rebuilt as a fundamental part of science education activity, using argumentation fostered by dialogic approach (CA).

Thus, PPST's Pedagogical Content Knowledge (PCK) evolves from simplistic and traditional to complex and current conceptions. Furthermore, we intuit a close relationship between the development of this Pedagogical Content Knowledge and the development of a most suitable view on the Nature of Science (NOS).

Finally, our methodology can’t validate in general the training proposal but, according to the notable development of PPSTs PCK and its positive feedback, we consider that real case-based AD activities facilitate reflection and awareness regarding PPSTs future career.

**Effect of problem based teaching about diurnal astronomy (cycles and symmetries of Sun movements and the Sun/Earth model) in knowledge and attitudes of pre-service primary teachers.**

*Asuncion Menargues, Rafael Colomer, Ruben Limiñana and Joaquin Martinez-Torregrosa*

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Despite knowledge on specific content influences how primary teachers teach sciences, the level of learning that they should be reaching about scientific topics during their education is a controversial issue. Furthermore, the dilemma appears when it is observed that most of the pre-service primary teachers enter the University from a high school education without specific science subjects, and also most of them have negative attitudes to science teaching and learning (specially against physics, whereas biology is usually positively rated by students). Thus we are facing pre-service primary teachers that do not have a minimum scientific education and that they have negative
attitudes to science learning and teaching. Furthermore, we have no time in the University curriculum to correct this situation.

We believe that primary teachers must have had opportunities to learn with understanding some of the big science ideas in a coherent manner, so they could teach sciences on the way we aspire. We think that primary teachers can reach a high understanding level on some specific science topic independently of their high school education. On the other hand, we know that it is necessary to change negative attitudes towards science teaching and learning if we want future teachers to transmit a positive attitude to their pupils about science learning. However, it could be possible that trying to teach some of the big ideas of science in depth, it may increase their negative attitudes to science learning. Therefore it is very interesting to study the effects of instruction received by future primary teachers on both learning and attitudes simultaneously.

Thereby, this study was guided by the following questions:
- Is it possible to achieve learning with understanding of some of the big ideas of science by pre-service primary teachers through oriented research (fundamental problems-based teaching)?
- What kind of effect would have this way of teaching in their attitudes towards science and its learning?

The aim of this study is to test the effect of in depth teaching on diurnal astronomy (cycles and symmetries on Sun movement and its explanation, The Sun/Earth model) as oriented research in knowledge and attitudes of pre-service primary teachers.

And our hypotheses were the following:
- Problem-based teaching of diurnal astronomy promotes learning with understanding in pre-service primary teachers independently of their high school education in specific science topics.
- Teaching as oriented research about cycles and symmetries of Sun movement and Sun/Earth model produces high positive attitudes to teaching/learning sciences independently of their initial attitudes.
- Attitudes generated by teaching received are positive even in students that do not have achieved the learning indicators intended.

This study shows the experimental design and the results of six samples (classrooms) statistically equivalent (of 60 students each one, being those randomly assigned to three lecturers). Advance in the knowledge of pre-service primary teachers was assessed by pre-test and post-test questionnaires and by two exams adjusted to learning-understanding indicators designed by experts. Attitudes were assessed by a questionnaire in which they had to explicit their grade of agreement with statements. The second way to get evidences about attitudes was estimating the level of students’ interactions with other people outside the class, which are addressed to science topics discussed in the class. This level of interaction was estimated through a questionnaire which gave us information about the number of times and number of people that students claimed to have spoken about some topic treated in the class with outsiders.

Science Teaching Self-Efficacy and Alternative Conceptions of Floating and Sinking in Pre-Service Elementary Teachers

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Obviously, science teaching of primary school teachers is influenced both by their science teaching self-efficacy beliefs and their conceptual understanding of basic science concepts. Based on contemporary ideas about the teaching of science, prospective elementary science teachers should develop a comprehensive science knowledge base, concurrent with a deepening understanding of the links between the content knowledge and the teaching and learning process (Ginns & Watters, 1999). Furthermore, research results identify two factors influencing elementary science teaching:
(1) teachers' level of understanding about science and (2) their beliefs regarding science (Stevens & Wenner, 1996). However, elementary teachers do often have negative attitudes towards science and do not have confidence in their ability to teach science (Cakiroglu & Boone, 2002). Furthermore, students come into the classroom with prerequisite knowledge and prior conceptions, which sometimes are incompatible with currently accepted knowledge. Consequently, learning has to be viewed as an interaction between new and prior knowledge. In order to teach science effectively, it is essential that teachers - besides being proficient in regard with the content - can facilitate conceptual change by identifying students’ current conceptions about the topic and guiding them to realize the limitations of those misconceptions. Furthermore, based on Bandura (1986), Riggs and Enochs (1990) postulated that two factors, personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE), might affect science teaching behaviours. In consequence, they developed the Science Teaching Efficacy Belief Instrument for pre-service teachers (STEBI-B).

The focus of the present study is on examining the understanding of pre-service elementary teachers with respect to the concepts of floating and sinking, on exploring pre-service teachers' self-efficacy beliefs regarding science teaching and on investigating the relationship between these two issues. The data for the study was collected within a combined science content and methods course for prospective primary teachers by utilizing two instruments: (1) a misconception test involving the topic of floating and sinking administered prior and after the course, and (2) STEBI-B. Primarily, the course addressed the development of fundamental science content and pedagogical content knowledge of the prospective elementary teachers helping them integrate other knowledge bases that are important to teaching. After completing the course, the students should be able to apply fundamental science concepts to everyday situations, demonstrate the appropriate use of science process skills and the nature of science by designing an age appropriate science instructional unit for the elementary classroom. In addition, they should also be able to identify effective teacher characteristics and become aware of effective teaching strategies for science instruction. 158 pre-service elementary teachers (8 male, 150 female) participated in the study. Whereas 42% of the teacher students (G1) complete their teacher education in addition to another regular job, 58% are full-time teacher students (G2). Over and above responding to the test instruments mentioned previously, the teacher students also delivered other data: (1) a portfolio with answers to distinct questions, (2) a lesson plan for a self-chosen topic within the content of the course, and (3) a design of an experiment in regard to floating and sinking with focus on varying guidance and a specific alternative conception.

Quantitative and qualitative data analyses reveal a range of alternative conceptions held by the pre-service elementary teachers prior to the course. Generally, the pre-service teachers indicate positive self-efficacy beliefs regarding science teaching. Looking closer, some differences do appear according to the social affiliation to one of the two student groups. The results suggest that teacher students belonging to group G1 show significantly higher learning gains in the conceptual post-test and easily outperform their colleagues from group G2 in regard to their professional development and the quality of their assignments. In conclusion, no significant relationship between self-efficacy beliefs and achievement could be identified.

References

Teaching and learning biophysical models in master studies: effect of a protein mutation

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Introduction
The importance of using models to help students understand complex structures of biomolecules and introduce similar abstract ideas has increased notably over the past decade. One example would be the use of hydrodynamic modelling to teach the effect of single mutations on proteins through the study of their oligomerization states. This content is included in the optative subject “Macromolecules: Structure and Properties” in Master of Molecular Chemistry coursed by students of different degrees at University of Murcia. Herein we show a didactic application of a relevant program to teach and learn solution properties of biological molecules and its application to study the effects of different point mutations in the sequence and, as a consequence in several cases the structure, of a protein.

Methodology
Structural determinations are nowadays of great importance in biophysical science and it is a fact that hydrodynamic properties are intrinsically related with the structure of the macromolecule. This explains the renewed interest in measuring hydrodynamic and other solution properties and the development of new measurement techniques in addition to the importance of predicting such properties from models with high or medium resolution.

A relevant development for the prediction of properties of rigid, globular proteins from their atomic-level structures was the methodology implemented in the HYDRO programs [1]. These tools have been widely employed for the analysis of hydrodynamic coefficients and other solution properties.

In this activity students have learned the program, its use and operation and made a simple application to understand its usefulness. They worked with the protein TenA from Bacillus subtilis [2] using HYDROPRO [3] to calculate the theoretical properties from its model. The program is public domain and is hosted on the site http://leonardo.inf.um.es/macromol from where it can be downloaded, along with examples for use and user manuals.

For this purpose, they must have assumed the monomer, dimer, trimer and tetramer association states of the rigid protein of TenA and calculate the properties, to then compare the obtained values with those measured in the laboratory for different mutants. They calculated the properties of biological macromolecules by means of the rigid spheres model to interpret the experimental data.
obtained for the native protein and that having mutations and thus answered the question of how these mutations affect the structure and conformation of the protein. They compared the values obtained by HYDROPRO with experimental values concluding the differences in quaternary structure between the native protein and the mutants, and were able to reason the default hazard function observed in the mutant. It was even possible to explain the nature of the species that was observed in the small additional peak appearing in the sedimentation velocity experiment.

Conclusion
We have evaluated the learning of the students taking into account their initial academic training. After this activity, they acquired the ability to apply a shell-model calculation to predict solution properties of rigid biomacromolecules with successful results. Therefore, we show how state-of-the-art software used worldwide in scientific research has its applicability in teaching at university levels.

Bibliography

Inquiry-Based Teaching with Computer Simulations in Physics

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1 Introduction
In this study we investigate the relation between how teachers teach with computer simulations, and how teaching with computer simulations is experienced by their students. Salinas (2008) provides a theoretical framework in which he relates the needs of the learners, the levels of Bloom’s Taxonomy, the role of the teacher, and the appropriate technology to use. The framework links a need for information with a low level in Bloom’s taxonomy and relates this to use of presentation technology, e.g. PowerPoint and a directive role of the teacher. Other relations that are suggested by this framework, are that teaching with computer simulations allows for fulfilling the learners’ need to apply knowledge, that this relates to learning at a higher level of Bloom, and that this requires the teacher to be less directive.

2 Method
In this study 24 physics teachers were observed during a lesson in which they used computer simulations in their teaching. During and after each lesson data were collected from three different sources: observations, questionnaires, and interviews. We coded all teacher questions in two ways: on whether they were answered by the teachers themselves or by one of their students (Student-Centeredness-Score), and on the kind of question in relation to the inquiry cycle, e.g. ask for a prediction, a hypothesis etcetera (Inquiry-Cycle-Score).

During the last ten minutes of each observed lesson all students filled in a questionnaire asking about their opinions about lessons with computer simulations. The questionnaires were analyzed using factor analysis.

3 Results
As a result of the factor analysis on the questionnaire answers, we found two factors of acceptable internal consistency: insight (Cronbach’s $\alpha = .724$) and inspiration ($\alpha = .719$); and one of good internal consistency: motivation ($\alpha = .824$).

We related the SCS and ICS to the factors insight, motivation and inspiration to investigate the extent in which insight, motivation and inspiration can be predicted by the SCS and ICS. The results of these analyses indicate that the ICS accounts for 25% of the variation in the insight factor scores ($R^2 = .25; p < .05$), whereas the relation between SCS and insight is non-significant. SCS accounts for 18% of the variation in the motivation factor scores ($R^2 = .18; p < .05$), whereas the relation between ICS and motivation is non-significant. Regressing the factor inspiration on SCS or ICS does not reveal significant relations. The factors insight, motivation and inspiration all correlate positively at the $p < .01$ level (2-tailed): $r_{\text{motivation-insight}} = .70$, $r_{\text{motivation-inspiration}} = .62$, and $r_{\text{insight-inspiration}} = .55$.

4 Conclusions

By relating the results of the different data sources, we discovered two relations: a positive relation between the Student-Centeredness-Score (SC) and the factor motivation, and a positive relation between the Inquiry-Cycle-Score (ICS) and the factor insight. This means that the more a teaching approach is student-centered, the more students are convinced that teaching with computer simulations contributes to their motivation; and, the more a teaching approach resembles the inquiry cycle, the more students are convinced of that teaching with computer simulations contributes to their insight.

5 Reference


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**Study of the diffraction of light: A new Optics experiment in UNILabs virtual and remote laboratories network**

*Juan Pedro Sánchez-Fernández, Carmen Carreras Béjar, Manuel Yuste, Luis de La Torre, Rubén Heradio and Sebastián Dormido*  
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UNILabs (http://unilabs.dia.uned.es) is a network formed by a large number of universities that share their laboratory resources in form of online laboratories in many different areas: Physics, electronics, control theory, etc. These interactive labs can be either virtual (simulations) or remote (using real devices and performing real experiments), and all of them can be collaborative [1-2]. This work describes the experiment “Study of the diffraction of light: Fraunhofer approximation”. This is a fundamental practice in every Optics course. In this particular case, an experimental setup has been especially designed and built in order to use it in a remote way. The experiment counts with a virtual (simulated) counterpart so students can familiarize with both the phenomena under study and the user interface before they access the actual, remote lab. This practice offers all the documentation needed so the students can work in an autonomous way: a practice guide, a user interface manual, tests for auto-evaluation… This experiment has been extensively tested by our students of the subject Optics over the last 30 years. It has also been used in virtual version. The successful incorporation of optics experiments in a remote version in the past [1-2] has encouraged us to go one by one incorporating experiments from our laboratory. This particular experiment will be available on the net in the second half of this course and will be tested with students in the course "Experimental Techniques III" of the Degree in Physics. Regarding the theoretical / conceptual framework, it is the same as indicated in the [1-2]. Our purpose is to include the major Physics experiments in UNILabs.
The experimental setup consists of a He-Ne laser, a collection of diffracting objects with easy geometries, a translucent screen with a coupled webcam and a photodiode connected to a digital multimeter. The aim of the experiment is to study the diffraction patterns produced by different diffracting objects. First, students must observe the diffraction patterns projected over the translucent screen, thanks to the use of a webcam. From the visual analysis of these figures, they can check the validity of the light diffraction theory and, by determining the position of the intensity minima and maxima, estimate the size of those objects that produce such figures. As second task, students obtain the intensity outline of a diffraction pattern acquiring intensity measurements with the photodiode; the later processing of such measurements allows the total characterization of the figure, checking the validity of the theory and determining the object size with higher precision.

In order to allow the remote control of the experiment process, two motorized linear positioners are used: one (of 10 cm) in horizontal position and another one (of 25 cm) in vertical position. This X-Z positioning system allows choosing one particular diffracting object among the collection and calibrating its position. The translucent screen with the coupled webcam can also be moved thanks to a linear positioner of 2 meters, which allows adjusting the distance of observation (Y axis) for each case. Over the slide with the different diffracting objects, a mirror is also mounted. The mirror forms a 45º angle with the incident laser (Y axis) so the ray can be diverted to a perpendicular direction (X axis) in order to project the figure of a different diffracting object over the photodiode, also mounted over a horizontal motorized positioner with micrometric precision. Placing or not the mirror in the incident ray trajectory allows changing between the measurement of intensities with the photodiode and the mere visual observation of the rest of figures.

**References**


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**The photoelectric effect: A new Physics experiment in UNILabs virtual and remote laboratories network**

*Carmen Carreras, Juan Pedro Sánchez, Manuel Yuste, Luis De La Torre, Ruben Heradio and Sebastian Dormido*

*UNED, Spain*

A laboratory practice of great relevance for the first lectures of Quantum Physics is presented, the photoelectric effect, which is added to the list of Physics experiments developed by the Department of Science of UNED and shared in the UNILabs network [1-2]. In this practice, fundamentals of the photoelectric effect are studied and an experimental determination of Planck’s constant, h, is carried out. A commercial experimental setup from LEYBOLD DIDACTIC was used to allow students performing this experiment in a remote way. This setup consists of an optical bench with a mercury lamp, a collimator lens, a disc with a collection of interferential filters of different wavelengths and a photoelectric cell. A power supply for the mercury lamp, an amplifier circuit used to take measurements, a second small power supply for this amplifier circuit and a voltmeter are also part of this commercial setup. The tweaks made over this commercial setup in order to allow it to operate in a remote way were: 1) replacing the original disc with the collection of filters by a larger and motorized disc (which allows a larger number of filters) thanks to the use of a stepper motor, 2) connecting a USB module for data acquisition (to complement the original voltmeter), 3) placing a webcam to provide visual
feedback, and 4) programming the control of the instrumentation and the graphical user interface (which was created using EJS [3]).

The experimental procedure consists in registering the charge voltage in the capacitor (saturation value) when radiations of different wavelength act over the photoelectric cell. The selection of the different wavelengths is achieved by means of the corresponding filters. An analysis of the data registered in this experiment allows to determine Planck’s constant.

The experiment also counts with its virtual counterpart; a simulation developed with EJS. By means of this application, students become familiarized with the system before accessing the remote lab.

Finally, the practice offers all the documentation needed to allow the students working with it in an autonomous way: a practice guide, an user interface manual, tests for auto-evaluation…

References

What is light? From optics to quantum physics through the sum over paths approach

Massimiliano Malgieri, Pasquale Onorato and Anna De Ambrosis
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The history of the answers to the question “what is light?” runs as a fascinating thread intertwined with the history of physics as a whole. In this work we propose a sequence on the nature of light for high school students, departing from wave optics and leading to a first approach to quantum physics. The work originates from a wider research project aimed at favoring the introduction of quantum physics in high school using the sum over paths approach. Feedback from previous in-service teacher courses convinced us that a revision of the traditional approach to wave optics can favor a gradual and effective approach to quantum physics. In this perspective, the main research question we are tackling is:
Can an early development of the sum over paths perspective in optics favor a seamless introduction of quantum concepts at high school level?

Moving from an established research line on the educational use of the Feynman sum over paths method, we made an effort of better clarifying the transition from the phasor representation of waves to the sum over paths approach. In addition, we implemented the necessary simulations using the widely praised, open source software GeoGebra, and coupled them to a solid experimental base using low-cost equipment and the Tracker software, also open source.

1) Wavelike behaviour of light: The sequence starts from the demonstration of the wave phenomenology of light using classic experiments of wave interference and diffraction. Experiments are set up using commonly available materials; measurements employ a video camera and the Tracker software. Some of the key points we raise are:
- Monochromaticity and coherence: an elementary treatment of optical coherence is useful in view of its importance in modern optics, and especially in dealing with lasers.
- The Huygens principle and the wavelet concept: the basic idea that the wave disturbance produces a new spherical wave source (wavelet) at each point in space it reaches leads to considering all possible paths for the disturbance.

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- Sum over paths: Remaining fully in the wave optics perspective, alternative paths are discussed as “coherence routes” for the wave propagation. The sum over paths analysis of interference phenomena is introduced through GeoGebra simulations.

2) The Fermat principle. In the second part of the sequence, we establish a connection with the Fermat principle, also in view of future introduction of similar “least action” principles in mechanics. The experimental activities and, in parallel, GeoGebra simulations used at this stage include free light propagation, reflection, refraction (Snell’s law), examples with lenses and mirrors of various shapes.

3) What is light, after all? Finally, we introduce students to some of the experimental evidence making both the purely wavelike and classical corpuscular interpretations of light untenable. We do not follow an historical perspective, but rather try to elucidate why a radically new interpretation is needed. Some of the threads we pursue are: “granular” interaction of light with matter (photoelectric and Compton effects); indivisibility of the photon; single photon interference. Stressing in particular the importance of the last point, we introduce the Feynman conception of the photon. We revisit the sum over paths method, completing it with the probabilistic interpretation. We re-discuss previous experiments, putting forward new concepts such as the uncertainty relation for light, seen in single slit diffraction, and the measurement problem and postulate, exemplified in double slit interference.

We are currently proposing our approach to high school teachers undergoing both pre-service and in-service training. Preliminary data are available, and more detailed results will be presented at the conference.

SESSION 3

Session 3.1: ICT and Multi-Media in Physics Education
Tuesday 8, 14:15-16:15
Room 7 (Aula 7)

Developing representational fluency in undergraduate physics students through weekly online learning modules

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Physicists use multiple representations such as graphs, words, equations and diagrams for various tasks of communication, problem solving and learning. It is expected that students would know, or be able to learn these representational skills while developing other elements of physics expertise. Most research on multiple representations in physics has focused on individual particular representations such as how do students use free-body diagrams but little has been done on a generic representational fluency combining a range of different representations. Especially, what representational skills should students have in order to be able to discern meaning form new or unusual representation formats? Airey and Linder (2009, p.27) have suggested that “Fluency in a critical constellation of modes of disciplinary discourse may be a necessary (though not always sufficient) condition for gaining meaningful holistic access to disciplinary ways of knowing”. This is especially true for a representationally complex domain such as physics however typical curricula focus on content knowledge over representational fluency. This has the potential to significantly disadvantage many students in the diverse cohorts entering university physics studies.
The authors have been trying to answer the two questions: (1) How can we measure representational fluency in physics (of which no attempt has been made in the literature); and (2) Can we facilitate learning of the required representational fluency amongst university students.

(1) In 2011, the Representational Fluency Survey (RFS) (Hill, Under Review) was developed and has been evaluated as a test focusing on a broad representational fluency independent of physics content knowledge. This is the first survey of this type. Using the RFS, investigations at The University of Sydney over the last three years have revealed a potential gap between the representational fluency (the ability to use graphs, words and equations to communicate and solve problems) of some of the first year physics students. Particularly, the students who had a high university entrance ranking performed significantly better on the RFS than students with a lower ranking.

(2) For semester 1 2013, 11 sets of research-based, online modules were created to specifically target the use of multiple representations when considering questions in physics. These were designed to improve representational fluency of students across their first semester of university physics. These pre-instruction modules, completed by half of the students randomly assigned, were designed to be relevant to the upcoming material to be covered in that week’s lectures which has been shown to be an effective way of introducing material to students (Seery & Donnelly, 2012). Parallel to the online modules were another set of modules targeting the conceptual knowledge required in first-year university physics.

Results from the 2013 study indicate that both sets of modules have a positive effect on both representational fluency (measured by the RFS) and conceptual knowledge (measured using the Force Motion Concept Evaluation (Thornton & Sokoloff, 1997). This indicates that explicit teaching of representations and their use can have a positive effect on in-lecture learning. Furthermore, the modules were adapted and improved for a second year of the study in first semester 2014. Results from the large scale study (n>1000) over two years will allow for insights into student representational use, mechanisms for teaching representational fluency and the impact of supplementary online modules on student learning in lectures.

This investigation presents the ‘tip of the iceberg’ of analysis into physics representational fluency and novel approaches of introducing the teaching of multiple representations into university curriculum. The use of online modules, also, has provided a research-based approach of the transition towards flip-lectures to be realised.

References:
On-line Coursework for Students of Optics

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New network technologies especially those based on the Internet stimulate extensive search of new approaches to teaching physics. The main advantage of these technologies is their ability to deliver and control great volumes of educational materials, which significantly exceed those used in traditional training. This feature of network technologies is especially advantageous for organizing on-line coursework.

Present paper illustrates students’ use of network technologies for their Optics on-line coursework (fall semester of 2013). On-line coursework was part of the course which included other kinds of training activities (lectures, lab works and practical trainings). Its share in the total final rating was 50 per cent.

The training materials included the authors’ course of lectures (texts and presentations), training video demonstrations of classical physical experiments and explanations of the most important parts of the course as well as control and measuring materials. They were placed in LMS MOODLE in the website of the University. Control and measuring materials in the form of tests included up to 50 assignments. Each assignment required students to make 5-10 decisions.

The course contained three sections – Geometric, Physical and Quantum Optics. Each section had four subsections in accordance with four different ways of presenting physics content:

1) Conceptual Technique is implemented in a verbal way in forms of definitions, rules, physical laws, which are generally accepted;

2) Symbolic Technique (apparatus of symbolic links) of formal relations between physics varieties;

3) Technique of Theoretical Problem Solutions is formed on the basis of ownership of the Technique of Concepts, Symbolic Technique of formal relations and elements of other code systems (graphs, charts, figures and tables);

4) Technique of Computer Simulation represents dynamic models of physics phenomena.

In other words, online-coursework involved successful passage of 12 specialized tests and one research test for those students who were interested in getting high final points.

The students were given 90 minutes to have all tests on a certain day and at a certain time. In terms of these temporal limitations the only exception was made for tests based on computer simulation of physical phenomena. Assignments for virtual computer experiments were chosen from collections of 2D animation applets created in different countries. In this case the students were given two days to accomplish the tests without any time limitations. As a rule this type of tests included 8 assignments. Doing these assignments the students were supposed to take tens of measurements from virtual computer devices and compare them with the offered set of twenty figures out of which they had to choose the right ones.

For doing the research test on the basis of applet “Photoelectric effect”, created in Colorado State University, the students were supposed to determine the linear dependence of light frequency on electron’s kinetic energy. Using the obtained data they were further supposed to calculate the Work function, Cutoff frequency and Planck’s constant. One third of students (59 out of 182) who signed up for the course expressed their willingness to do the assignment. As a result they were given additional points.

The students’ average grades for the tests were always over 75 and the number of students who got the maximum result (100 points) was not less than 20 per cent. This indicates that the students are better motivated to accomplish assignments in the interactive mode. After the course a survey was conducted among 182 students. The survey asked if they found their on-line coursework useful to
preparation for practical trainings, labs and exams. 97 percent of them said “yes”. The resource itself as well as the students’ results will be demonstrated at the conference.

A platform to support CO\(_2\) emissions mapping on the Aegean Sea islands

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The present study is part of a multimedia application, adequate for environmental education and awareness regarding the fossil fuels combustion and its consequences at the secondary and university level. The application consists of a software platform that has the objective of proposing a scenario for the highest possible RES-E (Renewable Energy Sources Electricity) penetration in the Greek electricity network up to 2050. For this reason the present study considers the electricity production on the non-interconnected Aegean Sea islands that depends almost exclusively on oil combustion. The electricity produced by RES on the non-interconnected islands increased from 7% (2000) to 15% (2012). A database is created consisting of the monthly electricity production (2000-2012) per thermal power plant (TPP), RES-type and island. The National Inventories, the Energy Balances and the annual verified CO\(_2\) emissions (2005-2012) of the power plants that participate in the EU Emission Trading Scheme are also exploited for the estimations of the emissions. Estimation of the annual CO\(_2\) emissions and their disaggregation at monthly and individual TPP level for 2000-2012 is accomplished by a methodology, especially developed for this purpose. A GIS-based platform is created that includes the administrative divisions of Greece, the TPPs and the connections between islands. The included CO\(_2\) maps are implemented using the kriging geostatistical method for spatially interpolating the CO\(_2\) values at annual/ monthly level, using a 16-grad classification. In a computer laboratory environment, where adequate GIS software is available, the student can create maps for selected months/years, since the disaggregation results organised in a separate database are embedded in the platform. Furthermore the student can pump information from the created maps and draw conclusions for example about the possibility of the RES-E penetration to cover the increasing demand and stabilize the CO\(_2\) emissions or even cause a decrease during the examined period. Additionally the monthly CO\(_2\) maps can visualize facts like the seasonality of the increased emissions in summertime on almost all islands and the reduced emissions due to the greater RES-E penetration on some of them.

The problem of a ladder leaning on a wall: experimental investigation of its static equilibrium and dynamics using software Tracker and modelling/simulating using software GeoGebra.

**Jose Oliveira\(^1\), Paulo Simeão Carvalho\(^1\), Fátima Mota\(^1\) and Maria Quintas\(^2\)**

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The problem of a ladder leaning on a wall has been discussed in numerous introductory physics textbooks and in journals [1-4].
We use high-speed photography (220 frames/s) to investigate the motion of a ladder leaning on a wall, assuming that the vertical wall is frictionless but there is a frictional force between the ground and the ladder. The experimental conditions were set up in order to reach a good approximation to that assumption. Video analysis was done with Tracker, a freeware software that includes the module Data Tool for video modelling.

The experimental data are in good agreement with theoretical results and, in particular, the observation of a maximum of the normal force from the wall, just before the ladder loses contact with the wall. The comparison between the video of the experimental work, with the simulation of the experiment using software GeoGebra, has a great potential in physics education and gives a new approach for teaching mechanics introductory physics courses.

References:
[4] Yehuda Salu, Revisiting the Ladder on a Wall Problem , Phys. Teach. 49, 289 (2011);
Apart from the global test score, we looked in detail at the different misconceptions. It turned out that for most misconceptions, the learning outcomes of students that worked through the material by means of the learning path, are not as good as those from the other two lesson types. The survey on the student opinions on the lesson format they were assigned to however showed that students appreciate the lecture with the tablet-pc very much.

Both the developed material and detailed analysis of the student answers on the questionnaires will be presented.

Session 3.2: Physics Teaching and Learning at Secondary Level
Tuesday 8, 14:15-16:15 Room 8 (Aula 8)

A proposal for an experiment to the refrigeration cycle

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The experimental activity with equipment and methods assistance can promote understanding of scientific concepts. Supporting teaching and learning through teaching laboratories and their equipment favor the teaching work and enables the reduction or even elimination of gaps in conceptual understanding of physical phenomena that occur in students. However, when this knowledge is constructed only by simple visual observation of physical phenomena can produce failures in conceptual understanding. True that the economic reality of some countries may make it difficult for an educational institution has a didactic laboratory. This work had as objective the development of experimental didactical module made with easy access material that would enable the understanding of the concepts of thermology, thermodynamics, through the refrigeration cycle of a simple domestic refrigerator. This equipment is made such a way that we can observe its thermodynamic behavior by a thermometer in the cold chamber (freezer) and checking the pressure readings on coils (condenser and evaporator) and the compressor by means of two manometers inserted in the module. To reach the objectives, we use an old upright refrigerator that no longer served for domestic use. The cold storage (freezer) and the cold source (evaporator coil) are located at the top and your compressor that performs the work is at the bottom of the apparatus. The condenser coil is located in the back of the machine, so as to maintain similarity with the original equipment (refrigerator). After the refrigerator is disassembled, the cabinet (housing) was discarded in order to visualize the necessary operation of the refrigerator, such as components: the compressor, condenser coil (hot section), the evaporator coil with cold chamber (freezer) and the pipe that connects the components mentioned. The module has been rebuilt and set in a wooden frame in conjunction with a transport trolley. The cold chamber (freezer) was isolated with polystyrene (styrofoam) and received a digital thermometer with the possibility of reading from -50°C to 150°C with the uncertainty of ±0.05°C. Measurements of temperature and pressure were performed to verify the functioning of the didactical module. Previously, measurements of temperature and pressure were performed to verify the functioning of the didactical module. So we developed a teaching sequence with basic principles of refrigeration and the script for the experience and then apply the module to two classes of second year of secondary school, in order to test the viability of the module and the possibility to make it an experiment relevant to the practical lessons. The class with the module has been implemented on conventional time and lived up to expectations since the students showed interest and also the teacher of the class signaled positively.
that the module could be used in the classroom in order to teach the subject of refrigeration in practice.

**How does epistemological knowledge on modelling influence students engagement in Climate Change issue?**

*Giulia Tasquier*

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Involvement in Climate Change (CC) issues is proved to be hindered by emotional and social barriers (1), as well as by conceptual difficulties that students can meet in understanding the scientific contents (2). CC represents moreover a demanding epistemological challenge for students and, more in general, for citizens (3). Scientific debates on CC imply indeed sophisticated epistemological argumentations which refer to the crucial issue of the predictive power of climate models and to the crucial passage from deterministic to non-linear models. A large body of research demonstrates that, usually, students are not pressed to develop a refined epistemological knowledge and they reach poor understanding of what models are (4). In our study we made the conjecture that many conceptual difficulties and emotional barriers have their roots in naïve and stereotypical beliefs about science: the beliefs that science still has the role and the power of providing a unique, unquestionable explanation of what happens. Such a naïve idea about modelling deeply clashed with the intrinsic complexity of Climate Science (3, 5).

According to the conjecture, we designed teaching materials where a special emphasis was put on the epistemological fil rouge about “models and the game of modelling” and where students were guided to think about epistemological implications of complex non-linear systems (5). The materials were implemented in a class of secondary school students (grade 11). The implementation took 25 hours. During the implementation many different data were collected, mainly qualitative ones. A previous analysis allowed us to identify some markers to make visible if and how students enriched and refined their epistemological knowledge (6). The markers concern: i) the number and the quality of epistemological words used by the students in writing and talking about physical phenomena and their modelling; ii) the patterns of argumentation used by students in talking about the relation Model-Experiment-Reality. The markers’ application highlighted a significant improvement in students’ epistemological competence. The research question addressed in this paper is: Did the improvement of epistemological knowledge influence students’ emotional and social attitudes and their personal involvement in CC issue? If so, how?

Data come from questionnaires and individual semi-structured interviews, which both include societal and epistemological questions. The analysis is still in progress but preliminary results have been achieved. The main result is the evidence of different types of emotional reaction to the epistemological dimension: from the enthusiastic intellectual satisfaction by some students, to “cold” acceptance, or prudent and responsible curiosity by other students. The types of reaction seem to have interesting links with students’ emotional and social attitude toward CC. In order to investigate such correlations, 5 students were selected as case studies. Three cases concern students who had an initial distrust or resistance toward CC issues and found personal new reasons for engagement in the epistemological perspective of complexity. Two of them found, in the epistemological dimension, a stimulating opportunity to nurture their intellectual or artistic talent. One, more pragmatic, found new arguments to see and evaluate possible directions of action.

The other two students were chosen as contrastive cases. They are students who found epistemology simply as other pieces of knowledge to be learned.
A classroom idea for conceptual understanding about lightning and lightning rod in secondary education

Caio Cesar Barroso Tavares, Vitor L. B. de Jesus and Alexandre Lopes de Oliveira
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With the purpose of introducing the concepts of electricity for secondary education classes, we adopted as motivational strategy the theme of lightning and lightning rod. This theme was chosen because Brazil is the country where there is a higher incidence of lightning in the world. In quantitative terms, there are about 50 million lightning strikes per year, mainly between seasons of spring and summer. Unfortunately, this amazing phenomenon of nature has a bad consequence. On average, the number of deaths due to this phenomenon is around 130 people per year, which represents, on average, one person every three days. These numbers are greater than those registered in our country in deaths by other natural disasters such as landslides or floods. The fact is that if people knew how to proceed during storms, it is estimated that 80% of these deaths could have been avoided. The lightning rod or lightning conductor is a protection system designed to protect a structure from damage due to atmospheric electrical charges. It was designed not to attract or to repel lightning but to provide a low impedance path to ground for potential strikes. However, in some books for Physics for Secondary Education is possible to find some inconsistencies when they explain how it works and as a result this makes a bad conceptual understanding. With the purpose of making the learning of its functioning a more meaningful way, was constructed and used some apparatuses easy to construct, with easy access materials and preferentially with low cost and was developed a teaching sequence on physics concepts related to subject. Thus, we intend to explain the working and the physics of lightning rod and break with existing myths. The elaborate activities were divided into four parts and were applied in a physics class in a secondary education of youth and adults education class (this kind of education includes students who could not complete their studies within the estimated age for any reason). In the first part, it was initially performed a pre-test consisting of a few questions, which in addition to check the students' prior knowledge in order that they arouse curiosity about the subject. In the second part, students were divided into groups of 3 or 4 students and then each group started assembling the experimental apparatus works as an electroscope but by a model of a building, where you can see the electrization of electroscopes (when the model is not grounded) and non-electrization (when the model is grounded). In the third part, some slides were presented to the students on the electrostatic, the formation of lightning, the lightning rod and how we should act to prevent us during a storm. This presentation was required to provide a discussion about the topic. Finally, in the fourth part, a post-test is applied to check whether the learning and conceptual understanding acquired by the students were those expected. As a result, the pre-test, despite the advanced age of the learners, lack of knowledge with scientific arguments about the phenomenon of the lightning, on the working of the lightning rod, and a series of myths with respect to how to protect you in storms were observed. Moreover, in the post-test were found that the students changed their initial conceptions and they appropriated the physics concepts involved. Thus, from the results obtained allow us to conclude that teaching physics concepts in
context in the environment where we live gives us a good indication that the adopted teaching strategy contributed to a more meaningful learning.

Investigating 12th Grade High School Turkish Students’ Cognitive Structures about the Atom Concept Using Concept Mapping Tool

Ahmet İlhan Şen and Serkan Ekinci
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As being directly related to many important concepts, learning the atom concept is very crucial; for instance, it may contribute students to understand the current technological applications they experience in their lives, and it may help them improve their abstract thinking skills, as well. In this respect, research on that concept is important and may provide valuable implications for science education.

Until recently, many studies have been conducted to investigate students’ cognitive structures about the atom concept. In general, these studies are observed to be conducted with university students. In contrast, this research involves high school students. From another perspective, it is reported in the literature that it is essential to use different assessment tools for this purpose. For example, interviews and multiple choice questions are mainly used. Although concept mapping is known as an effective assessment tool, review of literature reveals that there are few studies in which students’ cognitive structures on the atom concept are investigated with concept mapping. For that reason, in this research, it is used as the main assessment tool. Considering these significances, this research aims to investigate 12th grade high school students’ cognitive structures about the atom concept using concept mapping, and the following research question will be answered:

How do 12th grade students conceive the atom concept?

In order to provide answers to the research question, several steps were followed. Firstly, currently applied chemistry and physics curricula from 9th to 12th grades published by Ministry of National Education were evaluated. The reason why we evaluated both of them was that they were designed in spiral structure. Then, 16 concepts related to atom concept were determined to commonly take place in both curricula; hence, a comprehensive list of concepts was constructed. 30 students were involved in the pilot study and the concepts were found to work in the map construction. After that, data were obtained from 150 students at 5 different schools which were located at two districts of Ankara. A qualitative data analysis of students’ concept maps was carried out. 20% of the participants were selected randomly and interviewed in order to verify the findings of their concept maps.

Findings indicated that most students did not use all concepts in their maps; however, almost all students used sub atomic particles like electron, proton and neutron and linked them to the “atom”. Similarly, the concepts “mass” and “charge” were generally linked to these particles. Although students were told that they were free to add more concepts to their maps, few preferred integrating extra concept(s) in their maps. In addition, students who used “orbit” concept in their maps generally connected it to “electron” and stated; “electron moves around the nucleus in orbits.” It is concluded that most students attributed classical properties to the atom. Although 12th grade students studied quantum model of the atom at 10th and 11th grades, the analysis of their maps revealed that they were not able to comprehend the quantum model of the atom. Moreover, the common use of “orbit” with “electron” among students implied that the Bohr model strongly affected students’ cognitive structures. Therefore, the conclusions derived from the analysis of students’ concept maps resemble to those stated in previous studies. From another aspect, this study also shows that concept mapping is an effective tool to investigate students’ cognitive structures about the atom concept.
The Practical side of Quantum Mechanics: development and evaluation of a box with conceptual practicals for the subject of Quantum Mechanics

Henk Pol, Aernout van Rossum and Wouter van Joolingen
Twente University, the Netherlands

In 2013, the Netherlands renewed its physics curriculum for upper secondary education. This reform introduced the topic of ‘quantum world’ referring to phenomena in the real, visible world that can only be understood using quantum mechanical concepts. The new domain includes wave-particle duality, the photoelectric effect, quantum effects (including particle in a box, spectral lines), the uncertainty principle, and tunneling. The emphasis of the new topic is on conceptual understanding rather than on the mathematical formalism of quantum mechanics (Taber, 2005; Akarsu, 2011). For example students should understand in a qualitative way something about the quantum mechanical models of atoms and molecules, chemical orbitals, as well as energy saving bulbs or colorants.

When introducing the subject of Quantum World, the first need for teachers is a suitable toolbox containing practicals to support teaching the subject of Quantum Mechanics in a conceptual way. Apart from demonstrations of phenomena such as the photoelectric effect and spectral lines no conceptual practicals for quantum mechanics are available (Akarsu, 2011). Another problem is that many teachers think that Quantum Mechanics is a subject that can only be taught in a theoretical way. Therefore, development of practicals should not only focus on the practical work itself but also on supporting the teachers in the conceptual teaching using the practicals (Fullan, 2001).

In our study we developed and evaluated a toolbox of quantum mechanical practicals, focussing on (1) improving teachers’ attitude towards quantum world as a conceptual topic and (2) to improve students’ conceptual understanding of quantum mechanical phenomena. The practicals were selected on the following criteria (Abrahams & Millar; 2008):
- Does the practical support qualitative discussions about quantum mechanics?
- Does the practical fill a gap in already available material at schools?

Six practicals were selected for inclusion: the photo-electric effect; electron diffraction; spectral lines of beaming gas; quantum dots; particle in a box for colorants, and a double-split experiment with single photons.

As suggested by Tiberghien (2000) and Abrahams & Millar (2008) the practicals in the toolbox attempt to stimulate interplay between observations and ideas during the practical activity. We realised this i.e. by providing conceptual questions that teachers can use to initiate discussion for example, ‘which particle / wave occurs in the colorant when we are talking about a particle in a box’?

Currently, the practicals are implemented in schools. The first experiences of teachers with the practicals show that in classroom many questions are raised by students, but that teachers still have problems with answering them in such a way to improve conceptual thinking. The presentation will present the box of practicals, as well as the first experiences with the whole box.

References
Measuring The Learning Effects of Inquiry-Based Teaching with Computer Simulations

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1 Purpose
Ample scientific research has been focused on the learning effects of computer simulations in science education. However, most research has ignored the pedagogical context in doing so (authors, 2012). The purpose of this study is to investigate different approaches to teaching with computer simulations, and in doing so, taking the pedagogical context into account.

2 Theoretical framework
The difference between the two simulation-supported teaching approaches that we investigated, is that in one of the conditions the teacher taught in a way that was prepared by the teacher himself/herself, and in the other condition the teacher taught with the same computer simulations following a Peer Instruction approach (Crouch, Watkins, Fagen, & Mazur, 2007).

3 Method
This experiment has been performed in the classes taught by three teachers. Each teacher taught physics to parallel classes, whereby each class was taught in a different way with computer simulations: in one of the classes Newtonian mechanics was taught in a way that was prepared by the teacher, and in the other class a Peer Instruction approach was followed, supported by an electronic voting system. In both conditions teachers used the same computer simulations. The lesson series of both conditions were designed as follows: in the first lesson the students conducted a pretest, in the second and third lesson the experiment was conducted, in the fourth lesson the students performed a posttest, and in the fifth lesson –one month later– a delayed posttest was conducted. At the pretest, the posttest, and the delayed posttest data was collected by having the students fill in the Force Concept Inventory, a questionnaire measuring conceptual insight in Newtonian mechanics (Hestenes, Wells, & Swackhamer, 1992). Learning effects were investigated by performing paired-samples t-tests.

4 Results
Paired-samples t-tests show that when teachers prepared the lessons themselves, scores on the FCI do not increase between the pretest (M = 12.24, SD = 4.01) and the posttest (M = 12.88, SD = 4.00): t(41) = -1.65, p = .11; or the pretest (M = 12.23, SD = 4.03) and the delayed posttest (M = 13.20, SD = 3.74): t(39) = -2.01, p = .05. However, in case teaching with computer simulations is supported by our Peer Instruction approach, FCI-scores increase between the pretest (M = 11.96, SD = 4.30) and the posttest (M = 13.93, SD = 4.49): t(56) = -4.28, p < .01; as well as between the pretest (M = 11.85, SD = 4.35) and the delayed posttest (M = 14.46, SD = 4.57): t(53) = -5.35, p < .01.
5 Scientific significance of the study
One of the conclusions in our review study of the literature was that ample research has been focused on the learning effects of computer simulations, but the effects of the surrounding pedagogical context has been mostly ignored. As this pedagogical context has received insufficient attention, the question of how one is supposed to teach with computer simulations remains unanswered. With the present study we specifically focus on this question by keeping the simulations and the teacher constant between conditions, and only varying the pedagogical approach.

6 References
--Authors (2012)

Integrating Project Method and Potentially Meaningful Teaching Units to facilitate meaningful learning of concepts of thermodynamics to undergraduate students in Engineering

Mara Fernanda Parisoto and Marco Antonio Moreira
Universidade Federal do Rio Grande do Sul, Brazil

JUSTIFICATION: In Brazil, according Brandan (2009), there is a scarcity of professionals in the field of Engineering. While in countries like Japan there are 25 engineers for each 1000 people professionally active, in Brazil there are just six. This little interest might exist because the students perceive little or no relation between Physics and Engineering in their high school classrooms.

CONTEXT: This research was applied in two classes of the engineering, where was taught concepts of thermodynamics.

THEORETICAL FRAMEWORK: In our proposal we used the project method according to Carl Rogers (Rogers, 1977), consisting of 4 phases: Students 1) define project and learning objectives in a contract; 2) conduct project work; 3) self-evaluate their work and learning; 4) and finally present their work to peers.

RESEARCH QUESTIONS: this research was organized into three studies, in which the first one attempted to answer the following research questions: 1) How to integrate, in a didactical proposal, situations of physics applied to engineering, the Potentially Meaningful Teaching Units (PMTUs), and the Project Method so that this integration could work towards facilitating the meaningful learning of physics concepts? 2) What problem-situations that can help engineering students to give meaning to physics concepts of thermodynamics? 3) Can the students learning of concepts of physics, which may derive from the implementation of this proposal, be considered meaningful?

RESEARCH METHODOLOGY: qualitative and quantitative methods were triangulated, and research instruments were validated and tested for their reliability. The qualitative methodology chosen for this research was ethnographic (André, 2005), while the quantitative one was based on descriptive and inferential statistics (Dancey e Reidy, 2007). Data gathering used a quasi-experimental design for time equivalent samples (Campbell e Stanley, 1979). The data is analyzed based on Bloom’s Taxonomy of educational objectives (Krathwohl 2010) and the work of Bardin (2009).
SOME RESEARCH FINDINGS: based on the research questions, a proposal for integrating the project method (Rogers, 1977) and the PMTUs (Moreira, 2011), which were composed by problem-situations (Vergnaud, 1993) that had been proven effective in providing meaning to physical concepts of thermodynamics, was applied. We identified, through the use of various instruments, what can be considered evidences of the occurrence of meaningful learning (Ausubel, 2002), based on data stemmed from the implementation of this proposal, as well as what seemed to be an improvement in the representation that engineering students had of physics, since they started to perceive this discipline as vital in their field of professional practice.

PERSPECTIVES: The findings suggest additional studies aimed at answering related questions: 1) What contents of thermodynamics can be used to support the teaching of the interaction of radiation with matter? 2) What kind of problem-situations can give meanings to concepts involving the interaction of radiation with matter when they are applied to medical science? 3) What is the prior knowledge students bring to physics classes that can be used in the teaching of physics concepts applied to engineering? 5) What are the operational invariants students possess in the field comprised by this proposal? 6) Can integration among problem-situations of physics applied to engineering, the PMTUs, and the Project Method be a better facilitator of meaningful learning than traditional classes (expository classes followed by problem solving)? 7) How can situations of physics applied to medical science, the PMTUs, and the Project Method be integrated in order to facilitate the occurrence of meaningful learning of physics concepts?

What is the relationship between personal epistemology about physics and scientific epistemology for 9th grade high school students?

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Epistemology is defined as inquiry of source of knowledge and justification of knowing. As far as the definition of epistemology is concerned, it has been argued that epistemology might play an efficient role in understanding and learning science in spite of little empirical evidence (Vosniadou, 2007). Major difficulty for empirical studies on students’ personal epistemologies is that the construct is defined differently by each developed model or argument (e.g. King & Kitchener, 1994; Hofer & Pintrich, 1997; Sandoval 2003). However, Elby (2009) discussed the variety of definitions should not be the obstacle for further studies on personal epistemology. Trials for narrowing down to make a definition would not be productive unless studies direct the research in a better point to work on it.

On the other hand, students’ views about scientific epistemology (aka nature of science) had become one of the major subjects in science education which is considered essential for learning science. In literature, it is not hard to see that there is a confusion or difficulty that might be faced to separate personal epistemology from beliefs about scientific epistemology. The distinction between those two terms can be clarified by considering parallel distinction between ontogeny and phylogeny (Bradie & Harms, 2012). If ontogenetic consideration is taken into account, the individual is the active mechanism of the development of knowledge and epistemological norms. On the contrary, phylogeny takes attention to another mechanism which is the development of knowledge and knowing across generations. Referring to this distinction, personal epistemology requires individual effort to construct knowledge personally and promote learning whereas epistemology of science continues growing by contribution of generations’ scientific endeavor. Therefore, studies on beliefs about scientific epistemology are subjected to investigate individual’s beliefs about scientific knowledge rather than the knowledge acquired or constructed by the individual.
Referring to this distinction between these two terms, in this study researchers aimed to investigate the relationship between students’ personal epistemologies on learning physics and their views about nature of science. In total, 184 9th grade students participated into the study in March 2014. Students took two questionnaires one after another in 40 minutes (1 lecture hour). One of them was developed by researchers to determine students’ personal epistemology, which is entitled as “How do I learn physics?”. The pilot study of the test conducted with 345 participants (187 girls and 159 boys). Test includes 27 items. According to explanatory factor analysis of the test, six epistemological dimensions appeared that explains 60% of the variance. And these dimensions are categorized as (a) structure of knowledge (linkage with previous knowledge), (b) coherent structure of knowledge (consistency), (c) justification of knowledge, (d) changeability of knowledge, (e) source of knowledge and (f) quick learning.

Researchers used VNOS-C (Turkish) to determine students views about nature of science. The VNOS-C questionnaire was originally developed by Abd-El-Khalick, Lederman, Bell and Schwartz (2002). The questionnaire was translated into Turkish by Kenar (2008). The Turkish version of VNOS-C includes nine open-ended questions. Because of qualitative analysis of the questionnaire, data analysis has not been completed yet. Therefore, the results of the study will take time to be reported.

**Analogies in High School Classes on Quantum Physics**

*Roberto Cruz-Hastenreiter*

*USP & Université de Paris Diderot, France*

The use of representations in teaching activities has been proposed in science education research as a method to construct appropriate meanings from and through science representations. We can find in the literature several articles whose subjects present two major foci. One perspective takes analysis and constructions as a basis for their investigations (Curtis, R. V. & Reigeluth, C. M. 1984; Gilbert, J. et al. 2008), whereas the second perspective has predominantly focused on student-generated representations (Haglund J. & Jeppson F. 2013; Treagust, D. F. 1995).

In the literature, justifications for using analogies in teaching activities are sometimes based on the observation that, when two or more things are similar in at least one way, analogical thinking allows one to draw a conclusion about an unknown factor on the basis of resemblance to a familiar or known factor. However, in accordance with several papers on the present theme, we emphasize the danger of using analogies when the analogous (that which represents the object) is unknown to the student, or when they construct similarity relations based on their observations and these relationships are different from the teacher’s intentions. Overall, our work highlights risks occurring when the instructional content is quantum physics, where the entities or concepts presented to students do not have any relation with the immediate experience of the sensible world. Although ordinary language is unable to describe theoretically the atomic events, it is nevertheless necessary to the physicists practice. We seek to find the role of ordinary language in the context of communication of a physical phenomenon. We highlight that the conditions for understanding physical phenomena are, at the same time, the conditions for possibility of communication.

In this research context, our work highlights some remarks about the use of analogies in physics classes, and, above all, about the use of analogies intended to present concepts of quantum physics. We seek in the philosophy of science some collaboration, admitting that there are similarities between the production of knowledge and its communication. In order to analyze the use of analogies in the activities of teaching quantum physics, we obtained transcriptions from the classes of some teachers from several different public schools in São Paulo. The themes discussed by the teachers were: (i) wave particle duality and photoelectric effect, (ii) atomic models and quantization of energy. Both classes were aimed at students of 10th grade at public schools in Sao Paulo.
Students were between 17 and 18 years old. We generated a categorization of the analogies used in teaching activities based on the work of Curtis and Reigeluth (1984) entitled “The Use of Analogies in Written Text”. We used 18 categories divided into two sets. The first one describes the nature of the analogies whereas the second one describes the usage of the analogies in physics classes.

We emphasize that some findings of this work have already showed that using “simple analogies” and metaphors must be avoided, particularly in quantum physics classes. It is essential for teachers to realize which problems are present in the using of analogies in high school courses on quantum physics. From this perspective, we search to contribute with teaching training. We highlight that it is essential for teachers to be aware of their actions. The recognition of some characteristics of the representations may contribute in making their actions less and less alienated, and enables the sharing of meaning with students.

Getting started in Physics Projects: Students' initial views

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\textsuperscript{1}Holon Institute of Technology; Davidson Institute of Science Education, Israel\\
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\textsuperscript{3}Davidson Institute of Science Education, Israel

Students entering new situations bring with them a range of knowledge, beliefs and attitudes that determine their initial understanding, performance, behavior and feelings. The “Physics & Industry” program has pioneered an effort to organize credit-carrying, out-of-school, regional frameworks fostering excellence and providing a link to physics-based industries among 11th grade, high ability students. The students participate in a 15-month program during which they extend their physics knowledge and skills and design a working model dealing with a real world problem based on electro-optical principles.

In this study we aimed to gain insight into the students’ previous experience and initial views with respect to physics-projects' related issues. The data were gathered over the first four cycles of the program (99 boys and 32 girls), by means of a questionnaire administered at the beginning of the program. The questionnaire probed sources of student motivation, previous project experience, views about team work, problem solving, dealing with new ideas, lab work, scientists in industry, guidance and activities promoting project building and student concerns and queries. The questionnaire was composed mainly of groups of statements, to which students indicated their degree of agreement. There were also several informative questions concerning background in physics and ICT accessibility and skills. Reliability and validity of the research instrument were examined and proved to be acceptable.

Our main results showed little previous experience with project work, a strong motivational effect of professional, topic-related factors and some experience with team work. The students expressed mature attitudes and avoided stereotypes concerning approaches to solving complex problems. The students accepted that strange ideas might turn into innovative inventions. Requesting a detailed action plan and focusing on the positive aspects of the suggested idea were widely endorsed. Regarding useful models for project work, “Team Work” was the preferred model, followed by the “Individual Unguided” approach.

Students endorsed that physicists could make a contribution to industry at the research & development stage of a prototype and by researching engineering problems. The stereotypes of physicists as “lone individuals” dealing with abstract models, relying on inspiration and not concerned with practical considerations, were not endorsed. However, there seemed to be few sources for informing students about the roles of scientists and engineers.
Lab experiments were seen as mainly helpful for making theoretical concepts and principles more concrete and adding a more realistic view of physics theory. The main contributions to project related knowledge were attributed to traditional, guided instructional activities. Moderate contributions were attributed to extracurricular activities, using technology or participating in team work. Low contribution was attributed to unguided inquiry.

Students' main concerns about project work were centered on a possible clash with school and social commitments, fear of overload and lack of time. They also expressed concern with feeling inadequate to tackle the unknown field or not feeling sufficiently inventive. Finally, there were worries of insufficient guidance or unsuitable team partners.

Our presentation will include data related to the main research issues and report gender dependent differences.

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**Session 3.4: In-service and Pre-service Teacher Education**

**Tuesday 8, 14:15-16:15**

**Room 10 (Aula 10)**

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**Pre-service physics teachers’ development of conceptual understanding and pedagogy through the use of discussion problems and argumentation**

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An emerging focus of recent science education research advocates the benefits of using argumentation as an approach in which teachers can better engage students in a more authentic experience of the epistemic work of scientists, (Bricker & Bell, 2009). Logical argument and critical thinking are considered essential skills for an effective and successful undertaking of scientific inquiry and analysis. Preliminary research suggests the practise of encouraging students to engage in scientific discourse in the classroom (Kuhn, 2009) can provide rich experiences for students and teachers to hone their cognitive abilities. This paper explores the use of critical ‘discussion problems’ purposefully designed for pre-service physics teachers to investigate their own alternative conceptual understandings of key physics ideas. It also discusses how these problems are then used to generate classroom discourse which focuses on the importance of developing effective pedagogical content knowledge rather than just mastery of scientific concepts and their mathematical applications.

Discussion problems when used effectively, can create considerable debate and analysis which encourage the pre-service teachers to reflect on the range of alternate conceptions and to identify pedagogical approaches that may be beneficial in shifting their students’ understanding (or their own) to one which better reflects the current accepted scientific explanation. Critical to the success of this approach is the building of trusting relationships within the class where pre-service teachers can feel at ease in sharing their alternative understandings with their peers without the pressure to be seen as ‘correct’. This pressure is often self-imposed by students who are typically high performing and frequently accomplished in achieving higher degrees or doctoral qualifications.

Further, the paper will detail how pre-service teachers are introduced to the discussion problems via an online learning environment in which they are initially encouraged to consider the problem in isolation from their peers. It is essential that they appreciate the need to resist the now common practice of ‘Googling the answer’ via the internet. Although most students initially believe that posting ‘the correct’ answer to the discussion problem is the only objective, they are eventually persuaded over time to realise that this response is not the most beneficial outcome for the class
when the real focus needs to be on learning and teaching. The online discussion forums hosted on ‘Moodle’ allows the pre-service teachers to post their insights and then only after they have done so, grants them permission to access all of their peers’ postings for scrutiny. In this way students are encouraged to post original thoughts and be less influenced by the arguments or analysis posted by other students. After all the pre-service teachers have responded to a problem the range of ideas contained in the postings are then explored in a face to face class setting where they are frequently debated and defended and the implications for pedagogy discussed.

**Exploring sliding friction: an inquiry-based experience for pre-service science teachers**

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Physics plays a fundamental role in science education as an accessible context for experimental design, scientific argumentation, problem solving, and the development of multi-step reasoning skills. Especially in the physics lab, students can actively develop scientific processes and habits of mind typical of physics and science in general. Nevertheless, pre-service science teachers have few opportunities of experiences in higher education in topics meaningful for secondary education. An unavoidable aim of teacher education is to improve and develop skills in this direction. A very effective way for achieving this results is to engage teachers directly in active learning on selected and meaningful topics. They worked in small groups in an inquiry-based activity performed in conditions very similar to ones that it is usual to encounter at school (few and poor materials, missing or ill-equipped laboratories). The next step is to render teachers aware of which activities had been effective and what role had had the teacher in favoring scientific argumentation, problem solving and learning process in laboratory.

A qualitative introduction to friction is presented by proposing the exploration of different kind of materials in order to suggest which aspects can be relevant and which interaction is involved in order to explain their different behavior. The choice of a qualitative inquiry-based exploration arises from the consideration that pre-service science teachers experienced very different undergraduate and graduate formation. Moreover, it is useful to show, especially to physics or chemistry graduate, that qualitative laboratory can be a rich experience, if it is well designed.

The laboratory was proposed within a course on Physics Lab Didactics a first time to pre-service science teachers attending to the first regular course in Formative Active Training for obtaining teacher qualification. A second group of participants were teachers with at least 3 years of teaching experience at school with a temporary position, attending a Special Qualification Course.

Both groups were characterized by filling a questionnaire by all participants, in order to have more information on their previous education and experience in teaching.

Participants were invited to predict the behavior of different sliding surfaces by using their previous knowledge and experience. Then, they could realize and observe what really happens. New previsions were made and checked. Some hints were given by proposing an activity designed for selecting relevant aspects and involved interaction. Their description of the phenomenon changed during this qualitative path on friction. Participants were guided in the exploration by a detailed worksheet and supported by a researcher. Focus was put on their engagement, how to work in group, how cooperative learning can be checked and facilitated.

Many participants encountered few cognitive conflicts in the activity and rarely were able to overcome them by themselves. Learning difficulties are presented and compared with the ones encountered by two 3rd classes of a scientific high school (age 16 – 17 y) that followed the same exploration on friction during an educational trip at department.
Developing education tools for teaching Physics and Chemistry in secondary education: Treasure Hunts

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The work presented here has been developed in the context of the course of Educational Innovation and Science Research, with 74 students from the Teacher Training in Secondary Education Master at the Faculty of Science. One of the aims of this course is to analyse the educational applications of information and communication technology, as well as other multimedia resources in the educational processes. Therefore, one of the contents of this subject is to learn how to teach in a technological context, analysing what should be the new profile of the teaching profession caused by the new technologies. Given this approach, the overall objective of the experience has been to design and validate teaching materials based on the use of ICTs that can serve our students, future teachers of secondary education, for their integration into their classroom teaching programs, an indispensable competence in the initial training of future teachers. More specifically, we focused on the development of "treasure hunts" as teaching tools that enhance meaningful learning of the contents of the "Physics and Chemistry" course at a compulsory secondary education level. In an initial survey of our students about what virtual resources they knew that could be introduced into their future teaching methodology, we found that only 8% of the surveyed students (graduates in physics or chemistry) were aware of the existence of tools like webquests or treasure hunts. For this reason, in the first session they were taught the structure and purpose of the treasure hunts, analysing the possible advantages and disadvantages of this type of education tools. They were then provided software for conducting treasure hunts aimed at secondary students. Finally, the stage of development of this work was carried out, in which the students had to design, develop and plan the set up of their treasure hunts, linking them to their teaching programs. The teaching experience carried out has resulted in the creation of 74 treasure hunts that focus student attention on scientific content of physics or chemistry, through key questions specifically designed to grab their attention. To make an assessment of the materials developed, we used a rubric that evaluated the aesthetic, functional and pedagogical aspects of the treasure hunts designed. The results have shown the great educational value that such a tool presents to support the learning of the proposed unit in the teaching program in which the activity is contextualized.

A Teaching-Learning Sequences of the Concept of Mass in Teachers Training Courses

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In recent years, a lot of research has been done to evaluate the process of upgrade/modernize contents in science teaching. The construction of an innovative teaching learning sequence (TLS) normally breaks with established educational standards, involving a series of negotiations aimed to fit with classroom commitments. In Brazil, the lack of criteria to produce school knowledge on topics in this area can be considered one of the main responsible for the limited range of the physics content in curricula.

In situations of curricular innovations, the principles that guide the teaching reform should be incorporated into the teacher practice. Pintó (2005) emphasizes that teachers react to innovations because they are influenced by their previous perceptions and experiences. One way to address the curricular innovations and analyze the process in a research perspective is by case studies which focus on the design of teaching and learning sequences (TLA) of specific topic.
There are types of study belonging to a Design-Based Research (DBR) approach, which, according to Collective (2003), can “compose a coherent methodology that bridges theoretical research and educational practice.” The research line Teaching-Learning Sequences proposes the teaching of specific topics through didactic sequences, including design, intervention, analysis, evaluation and redesign steps.

Our sequence and contents were carefully studied in order to show the change in the meaning of the concept of matter / mass from Newton to Higgs. The TLS prepared we proposed focused on the mass properties in the setting of Newtonian mechanics, electromagnetism, relativity and finally particle physics. The TLS was developed in 10 classes of 3 hours each in a group of 20 physics teachers (pre and in service ones). The principal goal is to explore the notions of “didactic structure” (Lijnse & Klaassen 2004) in association with the notion of “didactic flow” (Pietrocola et al. 2012). Furthermore, we investigated Teachers Knowledge (Tardif, 2002) and teachers skills required as necessary to implement such conceptual approach in modern physics.

One of the methods of analysis used to evaluated the teachers understand during the course was made of two short questions that was applied at the end of each class. One referring to a local understanding of the topic and another asking about the motivation the topic has been proposed in that specific moment of the course sequence. This method has given information about the continuity aspects of the sequence and about the student understanding of the “narrative follow” (a new construct Pietrocola, 2012 have proposed to deal with the coherence of the sequence over the time). The answers may also give indications about the performance of implementer teacher regarding each content of the sequence.

With the analysis of data obtained from the assessments, from the teacher relates and from the recorded classes, we could draw some conclusions: i) the global context of the course and didactic flux became clear for the most part of students; (ii) nevertheless, the weakness in their physical knowledge was revealed in the moments of questions and doubts during the course; (iii) the ability to interpret some of modern physics equations could only come with teaching practice and could not be developed in this kind of short training course; (iv) Finally, the richness of the epistemological approach beyond the concept of “mass” need time to be understand. The way this course was made, in some compact package with large number of hours seemed inappropriate for this goal.

These results are preliminary and will be used as a back ground in the preparation of design cycle of a TLS.

References
Understanding transformative cultural practices in upper secondary physics teachers

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The focus of this study is a group of secondary physics teachers working integrated with a research squad at the University of São Paulo, Brazil. The project of research was to develop and implement teaching and learning sequences (TLS) on three subjects, normally out of the secondary physics classes. This project have provided the opportunity to investigate the changes in a educational tradition that these teachers belong to. Our main goals in this paper is to analyze how physics teachers transform their practices and change the pedagogical meanings they share with their fellows.

Our theoretical and methodological baselines for analyses in this study use a socio-cultural approach. We assume the existence of a consistent tradition in teaching physics at the secondary level. The physics at basic school level could be seen as an established culture underpinning the pedagogical practices of teachers. We forge out our study on the basis of the concept of culture made by Sewell Jr, for whom culture should be understood as a “dialectic of system and practices ... with a certain autonomy ... in logics and spatial configuration” (pg. 169, 2005). It involves a combination of material and technical practices, standards of conduct, values and behavior patterns (Whitaker and Bezzon 2006). Thus, when cultural incompatibility is stressed, deeply rooted problems emerge in the system and practices established.

The case study in focus may offers a possibility to search at the same time for the consistency of actual meanings belonging to this culture and the incompatibilities brought by the new objectives, contents and practices. Differences and incompatibilities appears mostly because teachers are influenced by their previous perceptions and experiences and react to innovations (Pintó 2005).

This study willing to discern the shapes and consistencies of local meanings in the heart of this group of physics teachers. It is also important to understand how that tradition of teaching physics was achieved, sustained and dissolved (partially or totally) as the result of being involved in the innovative education.

The methodology adopted fits with Guba and Lincoln's (1989) authenticity criteria to address individual and institutional benefits that arise from the conduct of research. Our data came from a set of sources (video, audio and written register), got during a) the sessions of collaborative work, b) physics classes, c) classes in in-service courses, d) narrative made after in-service courses, e) semi-structure interviews. We have looked for events that could show “contradictions” and “contingencies”. As a organizer for our interpretative inquiry we adopt the dialogical pair agency/passivity and the notions of schemes of action and resources that came from the Theory of Structure of Giddens.

We present our results in terms of statements about the transformations in teachers perception of their practices and in their understandings of the educational goals. These statements allow to put side by side the old and the new ways to conceive their educational profession. We present just some of our results: Shifts in the way interactions took place inside the classroom; transformation of students identity in terms of “bad”/good students; Selection of curricular topics from physics interesting but also from students one's; Curriculum made in competence and abilities base and not only in content base; Open ended practice with a flexible boundaries.

As conclusions, there were a change in the set of expectations and responsibilities perceived by teachers. They realize that the new physics content entrained a modification in the pedagogical environment. This kind of study may help to developing theoretical methods and tools for the in-service and pre-service courses for other teachers.
**Session 4**

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**Physics with Mobile Devices**

*Radim Kusak*

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Mobile devices like mobile phone or tablet are nowadays available to majority our students. But unfortunately they use only a few functions and features available in those devices – Facebook, camera and alarm clock. Thus many possibilities remain unused. In this contribution are shown some of those possibilities - features and apps with respect to physics. Shown features and apps can be divided into the four different groups. First group is a usage of the internal probes - e.g. Accelerometer, Teslametr, Thermometer etc. Those probes are “hidden” in the devices, but can be used as a source for measurements – e.g. to measure the magnetic field of the magnet. Second group is usage of the external probes and devices - e.g. LabQuest 2, Sensordrone or Thermodoo. Those devices use one of mobile phone’s data exchange technology - Wi-Fi, Bluetooth or Microphone connector. Third group is a usage of the camera. Out of the common usage is possible to use a camera for Video-analysis, video-feedback or Slow motion physics. The last group is the physics apps available in Google Play or App Store. In those stores are many apps to download but only a few of them are done without mistakes or with physics and pedagogical aspects.

In point of view of the IPad’s apps will be presented the WolframAlpha and its queries with respect to physics – time of free fall, radius of the Earth, gravitational force of the Sun and Earth. As an example of the internal probe usage will be shown the Cardiograph – app which allows measuring the heartbeat and also app Graphical which allows measuring the x, y, z-axis acceleration. As the simulation tools will be presented the Wind Tunnel which allows to simulate the flow of the fluids and also the Algodo – the simulation environment for mechanics, optics and many other fields. Last of the simulation app will be presented the Solar Walk, which very nicely shows our Solar System. Briefly will be also presented many others interesting apps like The Elements, MyScript Calculator, TED, Khan Academy etc.

In point of view of the Androids apps will be presented the WolframAlpha, Google Sky Map, AndroSensor, Kinetics Sensor Pro, Phyzicle Sandbox, Geogebra and many others interesting apps. Those applications were used on IPad 3 with iOS7, Samsung Galaxy S4-mini, with Android 4.2 and Asus Memo Pad 302 with Android 4.2. List of the apps for IPad and Android will be given to participants.

Many of those apps were used in the classrooms, lab activities or as student’s projects in our high school - Dvorakovo gymnazium and SOSE in Kralupy nad Vltavou as part of the projects eVIM and eVIK. eVIM project was done in 2012 and was focused to make lessons more interactive and modern, the eVIK project started in 2013 and is still in progress improving students individual needs and give teachers opportunity to try coaching in the classrooms. As a part of the eVIK project were created more than 100 lessons plans, and the best of them will be also presented alongside with students’ feedback.
Learning assessment about the Moon’s synchronous rotation mediated computational resource

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Tatiana Silva, FSC/UFSC, Brazil
and Marta Feijó Barroso, IF/UFRJ, Brazil

In this work are presented the results of the evaluation of one learning object of the educational hypermedia named “Phases of the Moon”, a digital teaching material designed to assist in the teaching-learning of lunar phases and movements. This educational resource is designed using the concept of digital learning object and its main guiding theories, the theory of cognitive load and aspects about the role of visualization in science teaching. We assume that the development of models, analogies with the exploration of multimedia resources can provide visual support and aid learning. It is understood the evaluation of the learning object as necessary, so as not to make an trivialized use and do not make assumptions based on that these resources represent a magic solution to the problems of education claims. It is essential to point out the difference that they may have over traditional materials and its positive and negative aspects. In this sense, the evaluation was performed adopting two approaches: one directed to the product and other user-oriented. In the product-oriented approach, experts in Astronomy (academics and researchers in Astrophysics) evaluated the quality of the educational hypermedia as a whole analyzing the dimensions: content, methodological aspects, technical and visual aspects. In the user-oriented approach, we used the teaching resource in a real learning environment and the students’ perceptions were inferred regarding their usage and learning outcomes related to one of the concepts presented by the material, the synchronous rotation of the Moon. The hypermedia “Phases of the Moon” was used in a non face-to-face moment of an introductory undergraduate physics course in the field of exact sciences in which 77 students participated. Their perception on the use of hypermedia was investigated through a questionnaire administered by the subject teacher in accordance with the following dimensions: content, multimedia resources, technical and visual aspects of the material. The result obtained in the expert’s assessment validates all dimensions investigated and demonstrate the quality of educational hypermedia. In the perception of students, hypermedia supports the learning and the phenomenon is well assessed by them in all dimensions considered. The results of learning about the concept of synchronous rotation of the Moon were obtained from quantitative and qualitative analysis of issues drawn from a pre-test and a learning assessment applied by the subject teacher in 2011. They are expressive. The average increase obtained was 50% in a comparison between the results of the pretest and the learning assessment. In a qualitative analysis was also possible to identify the effectiveness of the material as an object of promoting viewing and thus a learning mediator of the phenomenon in question. It is inferred that the instructional material characteristics may have contributed effectively to the results in line with results found in the literature that demonstrate the effectiveness of learning materials supported by computational resources to facilitate learning and pointing to the importance of interactivity, the spatial organization of information and in understanding the role of visualization in science teaching.
Using learning management system to integrate physics courses with online activities: a case study.

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The development of Digital Technologies and especially the increase of their implementation in teaching and learning process have provided the researchers in the field of education, teachers, and experts with the opportunity to experiment with different methods of integrating online activities with traditional courses.

To this end an important tool is Learning Management System (LMS), a software package that enables experts to create, deliver, and manage online courses. Many Universities around the world have used LMS during the last decade and have run surveys about its usage from teachers and students. The results of these surveys and of other research carried out from research groups interested in online education show on one hand that the access to online course information, as well as the ease of use of LMS generally are well embraced by the principal actors of the teaching learning process; that the several tools that LMS offers for each area of the course structure can enrich the traditional course. On the other hand, the results of the research show that LMS usage is not explored in all its parts, especially regarding its use in physics courses.

From 2009, at the Department of Physics of “L. Gurakuqi” University, Shkoder, Albania, the usage of LMS for some physics courses at Bachelor and Master level is experimented. The LMS used is Moodle (Modular Object Oriented Dynamic Learning Environment) and the online courses are delivered parallel to the existing courses, reproducing the structure of the traditional course, with the objective to integrate traditional one with online activities.

The aim of the work reported in this abstract is to explore the effective usage of LMS, specifically for the course of Experimentation of Physics at the Bachelor Level and the course of Micro Computer Based Laboratory at Master level. In addition, the question of the construction of resources, learning objects and digital learning objects, as well as the collaborative production of knowledge, both strongly interconnected with the online teaching learning environment will be discussed.

This study will emphasize what became evident during this experience: both teachers and students welcomed the integration of traditional courses with online activities; differentiating between interests of Bachelor and Master students in regard to their role and involvement in the experience; different issues that were encountered during the development of the work; what were the objectives that were not achieved and the reasons why.

Open ended questionnaires are used to gather some of the data. The sample is composed of the students that attended these courses during the last two academic years. The pedagogical paradigms of teaching and learning that are at the base of a LMS environment, those related to constructivism, particularly social constructivism and social constructionism, have been applied. The answers have been collected and analyzed, and the findings of the research will be presented.
Teaching optics with a virtual mach-zehnder interferometer: an analysis of a collaborative learning activity

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In Brazil, the teaching of optical interference in undergraduate physics courses traditionally involves a detailed discussion on the Young’s experiment and other devices such as thin films and the Michelson’s interferometer (see, for example, Halliday et al., 2005). Another interesting, but not usual way of introducing the interference of light is by means of the Mach-Zehnder interferometer. The Mach-Zehnder interferometer is a simple optical device independently developed by Ludwig Zehnder (1854-1949) and Ludwig Mach (1868-1951) in the early 1890s. In this experimental arrangement, a light beam is split into two components by a beam-splitter and then recombined by a second beam-splitter. Although it has been widely used in researches on nonlinear optics (e.g. Zhang et al., 2014) and technological applications, the Mach-Zehnder interferometer is rarely mentioned in physics textbooks, which makes it quite unfamiliar for most high school physics teachers. Considering that many young students have difficulties with the theory of double-slit interference (Planinšič & Sliško, 2005), we believe that the Mach-Zehnder interferometer could be a good alternative for the teaching of wave optics. In what follows, we present a short analysis of part of a collaborative learning activity focused on the use of a virtual Mach-Zehnder interferometer, developed by our research group (Ostermann et al., 2006). This activity, which involved a group of pre-service physics teacher, was carried out in a computer laboratory at the university, where they were organized in small groups. This activity was part of a wider investigation focused on the teaching of quantum mechanics. The whole activity was divided into two moments: (a) a first moment, involving the interference of light waves, and; (b) a second moment, involving interference of single photons. A short guide was written to direct students’ actions with the software. As we argued elsewhere (Pereira et al., 2009), an analogy between quantum physics and wave optics can be made by giving a stronger emphasis to the wave aspects of quantum phenomena – instead of considering the photons as light corpuscles. Thus, the aim of the first part of this activity was to promote a review of some fundamental concepts of classical optics such as reflection, refraction, polarization, and interference. The theoretical framework used in this study derives from Vygotsky’s sociocultural approach, as outlined by James Wertsch (1991). The data gathered in this study consists of video recordings of students’ interaction during the task, from which a sequence of utterances was selected and transcribed for analysis. The outcomes of the analysis suggest that the virtual Mach-Zehnder interferometer is a powerful cultural tool for the teaching of wave optics.

Reference
Using role-playing game in a Virtual Learning Environment for a new approach to physics classroom lessons

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Although the term “digital native” by Prensky is not appreciated by all pedagogical researchers, it perfectly describes the nowadays students that continuously deal with technology. Over the last ten years, the way in which education and training is delivered has changed considerably with the advent of new technologies. One such new technology that holds considerable promise for helping to engage learners is Games-Based Learning (GBL). The work proposed in this paper stems from the experience of the last teaching years to students aged 14-15: the physics lessons given using games, competitions and group collaboration have been much more effective than the more traditional frontal lessons. In this work, we propose a constructivist approach in which youngsters are called to be the main actors of the learning process and in which a personal construction of their knowledge is a must, starting from their needs and their motivations. Role playing games fit very well these requirements and in order to reinforce this didactic (and non technical) choice we motivate it by referring to the Gardner’s theory of five entry points (strictly related to his theory of multiple intelligences) with examples of possible role playing game implementations. The approach that we propose in this work combines two fundamental aspects in the state of the art of e-learning panorama (that commonly are not combined): the integration of Intelligent Pedagogical Agents - IPAs (that provide personalized instruction, increase learner motivation, and act pedagogically on behalf of the learner) in Virtual Learning Environments – VLEs (that add value to the educational process by giving new possibilities and computational-richness support). One major concern of e-learning systems over traditional methods is the lack of face-to-face interactions and consequently motivational concerns can occur: an IPA tries to compensate this by increasing intelligent interaction with the learner. In this work, we propose that each student has her own IPA (on her own personal device) that guides her throughout the role playing game. The recent use of 3D immersive virtual environments has shown effectiveness in improving the motivation towards learning; therefore we propose it as storyboard for the role playing game. Finally we believe that the role playing game is not as fast as other games used as single spot in classroom lessons, thus it gives time to learners to elaborate and construct a personal knowledge. In addition it gives sense to the use of IPA that acts as personal teacher during the entire learning process through the game solution and elaboration.
Promoting cognitive engagement through Peer Instruction method in a Brazilian university context: a preliminary study

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The implementation of teaching activities focused on the students’ cognitive engagement could be seen as a crucial challenge faced by physics teachers to provide real opportunities for meaningful learning, in Ausubelian perspective. In the international scenario, the combined use of Peer Instruction (PI) and Just-in-Time Teaching (JiTT) methods had been revealed as promising choices to promote such engagement. In opposition to traditional teaching methods based almost exclusively on lectures, PI+JiTT involves students pre-class Reading Assignments (RA) and classroom interactions promoted by conceptual questions posed by the teacher to approach students difficulties mapped through the RA feedback. In this methodology, the teacher does a brief lecture about a specific concept followed by a conceptual test. The answers can be informed through electronic response systems (e.g. clickers) or flashcards. If the score of the class is between 35% and 70%, the students are instructed to form small groups to discuss their answers. After a few minutes, the students vote again and the teacher discuss the correct answer with the large group. Several studies in the literature has shown this methodology can foster student’s conceptual understanding and improve their attitudes about physics. However, most of these studies were carried on educational institutions in USA or Europe which background and infrastructure to support innovative initiatives are not the same of institutions on less-developed countries. Because of the difference between the educational cultures, even student’s resistance to perform the pre-class RA as preparation for the classroom activities during the academic period could be more challenging in the latter than in the former. From this perspective, and considering the significant role that RA plays for the methodology success, we posed the following questions: Will the students demonstrate sustained engagement with Reading Assignments throughout the semester? What will be the level of engagement they would demonstrate with the reading assignments? In this paper we present our preliminary results from an exploratory case study designed to answer it, implemented in an introductory physics course of Electromagnetism at Federal University of Rio Grande do Sul in Brazil. There were two sections of 16 physics majors enrolled, one section taught in the Fall of 2011 and the other in the Spring of 2011. Both sections had 14 students at the end (N = 28). In each RA the students had to read three or four sections from a textbook regarding the content to be discussed in the next class meeting. Also, they were asked to answer two questions about the reading and one question about their difficulties and doubts. After, they should send their answers electronically for the teacher. The students received credit for doing RA (15% of the total grade). The evaluation criteria were students’ efforts demonstrated in answering the questions, not if their answers were correct or wrong. We gathered data from records of 26 RA (for semester) answers and individual interviews with them. Nearly 80% of the students did each RA along the semester and about 90% of the students’ submitted answers demonstrated engagement. As example of evidence of student’s engagement, we considered the justification for a submitted answer, discussion of the content they found difficult, or discussion of the content they found motivating. Data from the interviews suggest the engagement results are mainly promoted by the RA activities and not only from the credits received on doing the tasks. Spite of initial resistance by the students
in the beginning of the semester, these results strongly suggest a highly acceptance of the pre-class activities. In the continuation of the work, the main factors of success for the engagement achieved will be investigated.

Roles of scaffolding in an inquiry-based learning unit of electric circuits

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This study implemented an inquiry-based learning unit of black-box electric circuits. Each circuit set contained four identical light bulbs. Based on observing their levels of illumination, the participating students were required to conceptually reason the possible connections, the current ratios, the electric power of the four bulbs, etc. The rationale of this study is mediated learning, highlighting the essential role of instructor’s scaffolding for achieving successful implementation of inquiry-based learning. By means of three phases of modifications, with the instructor gradually supplementing scaffolding, the participants’ performance was found to improve significantly. Six groups of students participated in the study, including high school students (n=35), second year Medical students (two groups, n=159), and first year Engineering students (three groups, n=152). Research data includes students’ performance to the inquiry learning worksheets and questionnaire survey (closed and open form), after the implementation of the inquiry learning. Despite the fact that the instructor (the researcher) has accumulated more than ten years experience of designing and conducting inquiry-based learning of physics (both to high school students and undergraduate introductory physics), the early phase implementation was found to have lots of drawbacks, such as insufficient clues to specify an unique circuit combination to the black-box circuits. Owing to the lack of scaffolding, the Medical students’ (with PR > 99%) performance was found to be similar to the high school cohort (with PR<55%), who were inferior to the Engineering students (with PR<70%). Informed by the prior participants’ comments in the post learning survey, the required scaffolding including, 1) reviewing the related principles and practicing conventional problems in order to “reawaken” the students’ memory of related knowledge, 2) explicitly denoting the levels of brightness of each bulb to facilitate visualization, 3) disconnecting one light bulb of each circuit to delete the alternative combinations, 4) immediately reviewing the solution after completing each set of black-box circuits to illustrate the valid reasoning strategies, and 5) instantly supplementing the next circuit set with more complexity than the prior one, in order to acquire fluency and extend the levels of scientific reasoning. After intensive modifications of providing sophisticated scaffolding by the instructor, the outcomes reported by the participants included 1) enhancement of conceptual understanding, 2) satisfaction of the “brain exercise”, and 3) lots of fun in the “game”. Many students asked for further participation of similar inquiry learning units. This study highlights the complexity of devising inquiry-based learning. In order to achieve the expected pedagogical goals, providing comprehensive scaffolding is highly demanded.

Correlation between students' understanding physics and teaching methods in Croatian high school

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Students' understanding as the assumption for the achievement of higher cognitive levels is one of the most important achievements in the school physics education. Past experience as well as
research results in the physics education indicates that students have great difficulties in achieving good understanding of the subject matter. Researchers in the field of physics education intend to single out the cognitive processes that lead to students’ understanding and to pinpoint didactical approaches which support the processes of understanding. It is especially important to students' understanding of concepts in mechanics because most of them are used in other areas of physics. The aim of this research is to connect the learning outcomes at the level of understanding in the area of mechanics and the applied teaching methods in order to predict the outcomes of learning.

The research was conducted on the sample of 1093 first year high school students in Croatia. Students attending three types of academically oriented high schools (general, science-mathematics and languages grammar school) were grouped according to 22 different didactical versions which represent subsamples determined by the didactical approaches of the teacher and the syllabus. Correlation methodology using Pearson's bivariate and partial correlation and multiple regression analysis was applied. Teaching methods in processing mechanics were used as the predictor variable whereas students' progress in understanding of mechanics was used as the criterion variable. The use of each teaching method in processing mechanics was confirmed by students' opinions by means of a rating scale. The students' progress in understanding of mechanics is measured by increase of students' learning outcomes with g-gain in FCI (Force Concept Inventory) exams.

The growth of the students' results within didactic versions on the FCI exams is in the range of g=0,01, the least increase in didactic version of one languages high school, to g=059, the highest increase in didactic version of one science-mathematics high school. There are fifteen didactic versions in the area of low gain with g<0,3, seven in the area of middle gain 0,3<g<0,7, and none in the area of high gain g>0,7. This indicates that there were problems in the organization and implementation of teaching methods. The most represented teaching methods are solving numerical problems from the workbook and lectures by the teachers. Both are not variable with gain g in the FCI exams. The correlation analysis shows a significant positive correlation between students' understanding and teaching methods which is related on discussions and students' investigation of physical phenomena in the model of multiple linear regression (R=0,710, R²=0,504, p<0,01)

Research clearly shows that the use of teaching method such as discussion and investigation physical phenomena support conceptual change and improve students' understanding of physics

Flipped classroom on topics of Quantum Physics: a didactic proposal for High School

Marcelo Alves Barros, São Carlos Physics Institute, University of São Paulo, Brazil
and Marina Valentim Barros, University of São Paulo, Brazil

Currently a general consensus has been growing in the area of science education on the need for innovation in the school content and teaching methodologies employed in the classroom. In many countries there has been a movement for curriculum reform, with the emphasis shifting away from the needs of content towards the needs of learners, allowing them to become actively engaged in learning situations. For example, in the American curriculum reform document, the National Science Education Standards (1996), we can identify the concern with a science curriculum based on ‘learning as research’, in which students engage more actively in the learning process.

In particular, researchers in physics teaching highlight the need to introduce concepts of Modern and Contemporary Physics into the High School and there are already some educational proposals that present attempts to overcome the conceptual and didactic-pedagogic barriers which hinder the introduction of these topics to students (Michelini et al 2000; Muller and Wiesner, 2002; Kohnle et al, 2011). These proposals present didactic teaching suggestions for the teaching of certain contents
that are sensitive to the need to adapt the formal mathematical elements to suit these students and to facilitate understanding of concepts considered too abstract or difficult.

The proposal presented in this paper seeks to contribute to this trend of research on curriculum innovation by presenting a teaching and learning sequence on topics of Quantum Mechanics for the High School, specifically: the Mach-Zendher interferometer and the photoelectric effect, using an active teaching methodology currently developed in the USA called the ‘flipped classroom’ (Bergmann and Sams, 2006. This innovative method represents a change in attitude towards education: it removes the attention given to the teacher and places all the attention on the learner and learning (Bergmann and Sams, 2012).

The strategy employed to implement this proposed flipped classroom is Peer Instruction (Mazur, 1997), in which conceptual tests on topics of Quantum Mechanics were applied to a group of 20 High School students attending a Brazilian public school during the implementation of a short 16h-course in the 2nd half of 2013. This short course was taught by a group of 12 pre-service teachers on the Physics Teacher Training Course of the São Carlos Institute of Physics, at the University of São Paulo / Brazil.

The prospective teachers attended weekly meetings with the studying / reading group on topics of Quantum Physics, with the aim of providing them with the necessary conceptual tools and preparing them to work with the proposed topics. After participating in this initial stage, the future teachers were given the task of analyzing the content studied in order to adapt and organize it for the purposes of the proposed minicourse.

In this paper we present a set of conceptual multiple-choice tests in Quantum Mechanics produced for these classes and a quantitative analysis of the results of students’ responses to each of the tests administered before and after the use of Peer Instruction.

From the analysis of the data, we found that the proposal to implement the flipped-mastery model to introduce threads of Quantum Physics in the High School using Peer Instruction as a teaching strategy actually improved the performance of students in the final tests compared to baseline tests, as well as demonstrating a better conceptual understanding of quantum phenomena on their part, and a more participatory group dynamic.

Thus we seek to contribute to the advances in research on curriculum innovation in Physics Teaching from the implementation of an active learning methodology - flipped classroom – in teaching and learning in the classroom.

An American Instructor in an Upper-Level Italian Physics Class

Gerald Feldman

George Washington University, USA and University of Trento, Italy

Interactive engagement strategies are becoming more and more common in physics classes in the United States. While this approach is utilized mostly in introductory classes, it is gaining favor in upper-level classes as well. For example, the University of Colorado group has been conducting an extensive research program on such methods in the advanced courses at their own institution. In my experience at George Washington University, I have used such techniques (Peer Instruction, electronic "clickers", active learning) for over 15 years, and in the past 6 years, we have been employing the SCALE-UP group-learning approach in our introductory classes. When I had the opportunity to come to Italy in Spring 2014 and teach an upper-level class in Nuclear Experimental Techniques, the pedagogical style that I would adopt became a pressing question. How would the Italian students respond to a more actively engaged environment?

Before the class began, my initial impressions were that the physics classes in Italy were taught in a rather conventional style, using formal lectures with lessons written on the blackboard and with relatively little input from the students in the classroom. Colleagues at the University of Trento
more or less confirmed that this was indeed the case, and that the students in the class would not be accustomed to taking such an active participatory role in the classroom activities. In addition, the class would be taught in English, which is not the norm for the undergraduate classes at Trento, and so the issue of language became an important factor to take into consideration. Since the class was offered as an elective for the third-year undergraduate students, their participation was optional (i.e. they could drop the class if they did not like it), and so a balance had to be established between trying out some of these active-learning techniques in the classroom and "testing the tolerance" of the students who had mostly been raised in a more passive classroom environment.

Overall, in the period of my visiting semester in Italy, I wanted to immerse myself in the pedagogical culture and explore the following research questions:

- Is there a predominant pedagogical style in Italian physics classes?
- What are the attitudes of the undergraduate students about science in general, and about doing science in particular?
- What are the reactions of the students towards an active-learning classroom? This can be broken down into 3 components: satisfaction, performance and perception.
- Did they like the more interactive environment?
- Did they participate fully in the activities performed during the class period?
- Did they perceive any educational benefit from the higher level of engagement?
- Was the English language issue a major handicap in teaching the class?
- How did the instructor know what parts were working and what parts needed some help?

In this talk, the questions outlined above will be addressed within the context of the limited case study that was carried out over the period of my visit. I will describe my experience in this upper-level Italian physics class and present the approach that was followed in introducing to the students some of the pedagogical innovations that have been developed in recent years. The assessment methods used to evaluate the performance of the students in the course will also be explained. Finally, an overall summary of how this experiment fared will be presented, along with feedback from the students themselves on how they perceived the active-learning experience in this class.

**Session 4.3: Physics Teaching and Learning at University Level**

**Tuesday 8, 16:45-18:45**

**Room 9 (Aula 9)**

**Imaging in Gradient Index (GRIN) Fibre**

*Ivan Ruddock*

*University of Strathclyde, UK*

In gradient index (GRIN) optics, refraction is achieved by a variation in the refractive index instead of at the interface between two media of different refractive indices. The refractive index gradient is usually radial and approximately quadratic resulting in an element with cylindrical symmetry that acts as a positive or negative lens. Current applications of the technique include GRIN rod lenses for coupling light between miniature components, for example inside lasers, and as GRIN optical fibre to minimize intermodal dispersion. In the latter case, this is achieved by ensuring that the rays of light corresponding to the different modes experience the same effective time of flight due to periodic refocussing along the fibre's axis. Since this phenomenon is equivalent to a series of positive lenses, a GRIN fibre should also be capable of transmitting and relaying an image. This is the basis of the work described here.
GRIN optics has a documented history stretching back to the late nineteenth century. Wood [1] gave an early account of the preparation of a ‘pseudo-lens’ based on a gelatine cylinder into which glycerine had diffused radially to produce a negative lens, while in [2], Walker described an alternative approach based on a potassium nitrate and epoxy combination. A comprehensive treatment of imaging and a survey of GRIN lenses, fibres and their applications may be found in [3].

This paper describes the use of a GRIN rod lens and GRIN fibre as alternatives to a conventional lens in an experiment studying its properties. The traditional analysis of the dependence of image distance on object distance for a thick lens is first performed for a GRIN rod lens using an illuminated aperture as a point object. It is then repeated for an arbitrary short length of GRIN optical fibre along with the demonstration of the transmission of the image of a simple 2-dimensional object. On account of the GRIN fibre having a core diameter of only 63 μm, and with the object and image distances being ~ 1 mm, this experiment is intended for inclusion in a senior undergraduate laboratory or as the basis of a student project in an optics laboratory where the necessary combination of supervisory skill and resources can be found.

References

Students' mental models about the quantization of physical observables

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Reif [1, 2] indicated the importance of knowledge organization in physics learning and drew attention to the requirement of hierarchical knowledge organization, because it is important for having a coherent conceptual framework. One of the theories about knowledge organization is mental modeling. Mental models can be defined as “productive mental structures that can be applied to a variety of different physical contexts to generate explanatory results” [3]. They are working models in the mind [4]. The use of the mental modeling theory is wide ranging and the approaches of researchers differ. In physics education research, while some researchers investigated mental models by qualitative research [5-13], some of them examined large number of students’ mental models by quantitative research [14-16]. In addition, some of the designs examining mental models used both of them sequentially [3, 17, 18]. In this research, we examined undergraduate second year physics and physics education students' mental models about the quantization of physical observables. A modern physics course was determined to examine students’ mental models about a quantum phenomenon, because the basic concepts and ideas of the quantum theory were introduced to the students in this course. Thirty-one purposively selected students enrolled the modern physics course at the department of physics participated in the study. Semi-structured interviews were conducted with the students. Conceptual questions examining the quantization phenomenon were discussed in different contexts (i.e. the photoelectric effect, particle in a box, harmonic oscillator etc.) and a test was implemented. After the transcription of the interview data, qualitative analysis was performed by using a qualitative data analysis software (NVIVO8). We developed code lists and determined the unit of analysis for the coding as a minimum meaningful chunk of a sentence, figure or formula indicating quantization. While determining the mental models, the links among the concepts were considered for coherency, which was not the check of the elements, but it was the meaningful and organized use of them forming a framework. At the end of the fifteen-week semester, we identified that students displayed
six different mental models about the quantization of physical observables. These are scientific model, primitive scientific model, shredding model, alternating model, integrative model, and evolution model. Identification of mental models about quantization phenomenon is important because mental models indicate how students organize their knowledge about the quantum theory.

References:
Transmission of the light through anisotropic media is not simple

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Most of the problems in understanding advanced subjects or phenomena are hidden in the correct upgrading of the already achieved basic knowledge. If the already achieved knowledge in incorrect or misunderstood, the further learning cannot be successfully comprehended by students. The awareness of possible specific problems in understanding of elementary optical concepts and phenomena is a great advantage in physic education filed and is many times underestimated. Such misunderstandings can be easily clarified or even avoided with additional simple experiments or explanations.

During the construction of a module on the explanation of the conoscopic figure formation (an optical method used to identifying the optical and structural properties of anisotropic materials) problems in student's understanding some of the elementary optical concepts were realized. Much to our surprise a great difficulty was a basic understanding of polarization, especially elliptical. For example: The polarization of light can be mistakenly generalized as linear polarization or at times as circular polarization, in some other cases the elliptical polarization state can be incorrectly visualized and comprehend (if at all) because of time dependence varying. Furthermore the superposition of two polarized waves (with or without the phase shift) was even harder to understand or imagine. Consequently the core of the understanding of the conoscopic figure formation, in other words the polarization state outcome of the superposition of two perpendicular linear polarized waves with a phase shift is practically nonpredictable for student who did not achieved the basic knowledge of polarization of light.

A similar difficulty was detected related to the comprehension of the difference in the transmission of light through a birefringent or through an optically active material that appeared even in international publications for teaching the chemistry [1].

More advanced studies of light transmission phenomena in anisotropic materials indicated another difficulty: although anisotropic materials are usually considered in advanced optics classes, the effects of refraction in transmitted waves with respect to their polarization is far from clear even to experts.

In this contribution we show the problems that were revealed during discussions with students (and colleagues), we comment possible reasons for those robust conceptions and present a set of simple experiments purposely developed to clear the ambiguity of persisting conceptions with respect to birefringence, optical activity and polarization of light.

References

Development of the Conceptual Survey in Nuclear Physics

Nikola Poljak, Mirko Planinic and Maja Planinic
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We have noticed that among many conceptual diagnostic instruments in physics education only a limited number of them try to relate to the concepts of nuclear physics [1,2]. It has been demonstrated that there are many deficiencies in traditional instruction in general physics [3], one can assume that this might also be the case in nuclear physics. Throughout our teaching practice, we have also noticed that the students have certain difficulties understanding basic nuclear physics concepts. Since nuclear physics is becoming more and more important in everyday life (i.e. for
medicinal purposes and energy production), it would be important to have a diagnostic tool for evaluating student understanding of the basic nuclear physics concepts. We have therefore started to develop and validate the Conceptual Survey in Nuclear Physics (CSNP).

CSNP is a 16-question survey designed to test students’ conceptual understanding of basic principles in nuclear physics and to enable future measurements of the relative effectiveness of different approaches to instruction in nuclear physics courses. The questions in the survey attempt to cover a few basic principles, such as radioactive decay, nuclear binding energy or nuclear density, and the consequences of those principles. The survey was piloted on the sample of 104 university students (physics majors) at the Faculty of Science, University of Zagreb, before they took a nuclear physics course. Even though the students have learned about basic nuclear physics concepts in their high school physics courses and general physics courses at their university, we assumed that they probably still had many conceptual difficulties in that area. The obtained data was analyzed using Rasch modelling to evaluate the functioning of individual items and of the test as a whole. We describe the reasoning behind the selection of the survey questions in several stages of development, as well as give specific details on the statistical indicators describing the survey in general. In this way, we could clearly test the students’ preconceptions and not the material that they have already learned.

We also discuss some of the most common student alternative conceptions and their implications for teaching of basic nuclear physics concepts.


Student ability to measure physical distances in terms of the wavelength of periodic waves

Paula Heron, Mila Kryjevskaia and Mackenzie Stetzer
University of Washington, USA
North Dakota State University, USA
University of Maine, USA

Waves are a central part of the physics curriculum at all levels. In the United States, the new Next Generation Science Standards identify “waves and their applications in technologies for information transfer” as one of the four “disciplinary core ideas” in physical science. Elaborations at different grade levels encompass light and how we see (primary school) through the interaction of waves and matter that form the basis for medical imaging, communication, etc. and preliminary ideas for quantum physics (secondary school). An understanding of wave phenomena underlies many scientific advances. When two waves of the same amplitude and wavelength ($\lambda$) arrive at a single point, the resulting disturbance depends on the phase difference between the waves ($\Delta \phi$). In many situations, this phase difference arises from a difference in distances traveled by the waves ($\Delta D$). The applications of wave concepts to interferometry techniques – whether using acoustic, electromagnetic, matter, or gravitational waves – all exploit this phenomenon. The analysis of these experiments requires the application of the relationship among frequency, wavelength and propagation speed ($v = f \cdot \lambda$, in non-dispersive media) and the relationship between phase difference and path length difference (e.g., $\Delta \phi = 2\pi \Delta D / \lambda$, for waves from two in-phase sources). We present research results that show that some of the errors made by students in solving interference problems stem from difficulty with perhaps the most fundamental task: expressing a physical distance, such as the separation between two sources or slits, in terms of the wavelength of a periodic wave. To try to pinpoint sources of student confusion we have designed and
administered questions to thousands of university students after relevant instruction by lecture, textbook, and laboratory. In one task, students were shown a top view scale diagram of parallel wavefronts incident on a barrier with two narrow slits. They were asked to determine the distance between the slits in terms of the wavelength of the waves. Since both were shown on the scale diagram (which included a grid) they could simply compare the relative lengths. No knowledge of interference was required. Nonetheless, only about 60% of students gave the correct answer (N > 300). We subsequently gave this problem at different stages of instruction, as well as variations involving similar reasoning in more everyday contexts, such as determining the length of a piece of paper in terms of the length of a pencil. On these tasks, the percentage of correct responses was not the only thing that varied — some tasks elicited different types of responses when given at different stages. The more instruction students had, the more likely they were to treat the task as one requiring additional concepts related to wave motion or to interference, leading some to claim there was insufficient information, and others to offer mathematical expressions that were both unnecessary and unhelpful. We considered the possibility that instruction on interference, and particularly instruction that emphasized mathematical analysis, was leading some students who would otherwise have answered correctly to frame the task inappropriately. We did not find support for this idea. However, the types of incorrect responses we obtained suggest that for many students, the concept of wavelength itself is part of the problem. It was particularly striking that some students were able to apply the definition of $\lambda$ to mark a distance corresponding to a wavelength on a diagram, but not able to use this definition in order to complete a simple task of expressing a specific distance in terms of $\lambda$. This finding suggests that these students either do not possess a functional understanding of wavelength or struggle with basic mathematical reasoning.

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Session 4.4: Physics Curriculum and Content Organization
Tuesday 8, 16:45-18:45
Room 10 (Aula 10)

Ready to Learn Physics: Team Based Learning in First Year University

Maria Parappilly\textsuperscript{1} and Lisa Schmidt\textsuperscript{2}

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Team based learning (TBL) is a specific model of group work [1] which is key to exposing students to and improving their ability to apply discipline-related content. This well-defined teaching strategy promotes higher level cognitive skills among students in larger classes and develops their problem solving and team skills through group-based work. TBL consists of strategically-formed permanent teams, a Readiness Assurance Process (RAP) and application activities. While TBL has not been implemented widely in Science Technology Engineering and Mathematics disciplines, several studies have shown that TBL has been effective in improving student learning. This paper describes the incorporation of TBL activities into a first year Physics topic- ‘Physics for the Modern World’. This topic consisted of conventional lectures, practicals and TBL activities. The TBL activities were designed in such a way that students not only encountered basic concepts but also used the group interaction to develop links between ideas and to develop their relational thinking and depth of conceptual understanding. The aim was to encourage students to take responsibility for their own learning, to enhance independent learning in a dynamic approach and to improve student learning outcomes and graduate capabilities through teamwork. Students were given pre-class preparation materials and a RAP test (pre-TBL quizzes) before the workshops.
Time limits applied for this quiz and students were required to complete the quiz individually. The quiz participation ensured that all students were exposed to concept-based questions before they attended their TBL workshops. Students were placed into random teams and during the first part of the workshop, the teams went through a subset of the quiz questions and in the remaining time, teams then completed an in-class assignment. In the week after the TBL workshop students were allowed another attempt at the quiz (post-TBL) to see if their knowledge had improved. We offered randomized variables in the quiz questions for each student to solve which reduced the chance of them using their pre-TBL quiz answers in the post-TBL quiz. The key questions to evaluate the effectiveness of the TBL were 1) Does TBL promote student learning of key physics concepts? 2) Does peer-peer interaction genuinely occur between students in TBL? The ability of TBL to promote student learning of key physics concepts was evaluated by experiment using pre- & post-testing utilising pre-validated concept tests. Comparison of pre- and post-tests was used to identify what the students did or did not learn. The motivation for the students to sit these tests was that similar questions might be used in the final exam and this was an opportunity for practice. To determine whether peer-peer interaction genuinely occurred between students in TBL sessions, the class was recorded using video cameras. For analysis, the video was paused at regular intervals and the group interactions were scored by looking at who was talking and whether the other team members were engaged.

The trial of this approach was successful. The students were highly engaged in their learning and very positive feedback from students was received. Of all methods of delivery, students responded best to TBL. Analysis of pre-post testing of 2nd and 4th TBL quizzes showed a significant impact (p<0.002, p<0.001) on their learning while there was no notable difference (p<0.05) in the pre and post-test of quiz 1 and 3 by paired t-test. This presentation will discuss challenges and the results of the project.


Guiding principles for a vertical teaching of energy

Ricardo Trumper

University of Haifa, Israel

Science teachers generally agree about the importance of choosing to teach energy as a focus of interest in the science curriculum. This central idea is key to our understanding of the way things happen in the physical, biological and technological world. Despite the fact that the term energy is in daily use in science as well as in everyday life, a satisfactory definition of energy remains a topic of debate. In the history of science, we learn that energy was 'discovered' in the 1840s: Mayer, Joule, Colding and Helmholtz, are generally considered the 'discoverers'. The concept of energy as we know it today (in classical, non-relativistic physics) emerged from Helmholtz, who established the principle of energy conservation. Furthermore, until then nobody, including Helmholtz, had a clearly defined concept of energy. That is, the energy concept became meaningful only through the establishment of the principle of conservation of energy in all its generality.

Many studies on energy concepts, which are held by participants from elementary through post-secondary levels, suggest that, for any age, there is a mix of conceptions of changing scientific validity. Still, the overall pattern seems to show that younger students tend to associate energy more with living things and processes and older students tend to recognise that energy can be transferred and conserved.

When should we start teaching energy? A constructivist approach has to support a teaching strategy in which students' understanding of energy should be extended from its human-centered beginnings to a more general notion gradually approaching the concepts of energy transformations, energy
conservation and degradation. This approach relies on the ideas of many educational researchers who claim that we should begin teaching the energy concept as early as possible and develop a vertical curriculum about energy starting from the elementary grades, that is, a learning progression based upon research describing students' conceptions at various ages. This proposal is based on the premise that students from a young age need to acquire a qualitative and scientifically valid notion of the concept of energy, which can be elaborated gradually so as to become more quantitative and increasingly aligned with scientifically accepted ideas. It includes three hierarchical and spiral stages of concept development:

1. A descriptive, semi-quantitative stage (grades 5-7, ages 10-13). Based on young children's conceptions, we propose to begin by talking about the energy resources students know and conceiving energy as a general kind of fuel, including food, expanding and correcting it step by step in the course of instruction. We should present a semi-quantitative idea of energy conservation based on the fact that 'investing' a larger amount of some energy form 'supplies' us with a larger amount of another form.

2. The scientific, quantitative stage — "learning energy through its conservation" (grades 8-9, ages 13-15). We should start this stage with a class discussion, summing up everything the pupils know, and convincing them of the need for a more precise, systematic, and quantitative knowledge. The following step is to take some simple processes that can easily be carried out and demonstrated in laboratory, and help students describe them in terms of energy.

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

The detailed guiding principles of the proposed vertical curriculum will be discussed in the presentation.

**Real-life contexts in physics assessment upper level: Test and Item Analyze, subjects and gender.**

*Anneke Thurlings-van der Lingen*

Assessment Expert Science, CITO, Arnhem, The Netherlands

We have a context based exam curriculum in the Netherlands in which specific contexts have been prescribed since the 80s. Therefore schoolbooks and lessons in physics are context-concept based. The final Physics, Chemistry and Biology exams are also context based. CITO is responsible for the making of these exams. The design of an exam is based upon instructions of the government in which is specified how many questions a test contains, how the test has to be composed (50% productive questions, 50% reproductive; and 60% quantitative, 40% qualitative), and the distribution on the subjects. The choice for a context that is needed in the exam is free.

After the students have made the test, the teachers who are doing the scoring by a prescribed scoring instruction, have to send detailed information to CITO, Arnhem. We analyze the results in a so called Test and Item Analyze (TIA), which CITO has been doing so since 1995. These analyses give us lots of information about the test and about the students that have made the test.

It is possible to see how a question in an exam behaves: does the question separates the smarter students from those who are less smart? Is there a gender difference in the answers of the students? Does the level of mathematics influence the result? Is there a lack of time at the end of the test?

A study on the TIAs over the last five years shows that girls are scoring structurally worse on the Physics exams than boys. The TIAs show that some of these scores are subject related: girls score better on nuclear physics and optics, and worse on mechanics and electricity. For waves and sound the scores of boys and girls are equal. The type of questions is also making a difference: girls are
scoring better on reproductive questions than productive questions, but there is no difference on
quantitative versus qualitative.

It is also possible to investigate the mathematical level of the students. Students in the Netherlands
can do mathematics on two levels: math A and math B. “A” is the more easy variant and based on
statistics, B the more abstract variant. The TIAs show very clearly that a higher level of
mathematics (B) is necessary for doing the exams well.

The gender difference is smaller on pre-university level than on (higher) vocational educations.
In this oral presentation I will show some examples of context-based questions, and I will show
examples of the results of the study on the Test and Item analyses for the last five year.

Reducing the gender gap in the physics classroom Am. J. Phys. 74, 2, February 2006 Mercedes
Lorenzo, Catherine H. Crouch, Eric Mazur

www.cito.com

Integrated STEM in secondary education: a case study

Jolien De Meester¹, Jan Thielemans², Mieke De Cock¹, Greet Langie¹ and Wim Dehaene¹
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Despite the many study options in STEM (Science, Technology, Engineering & Mathematics) the
Flemish Secondary Education has to offer, too few of its pupils are actually pursuing STEM fields.
As research has pointed out, they seem to be missing the relevance of science and mathematics
(ROSE-study, 2010). In other words: they do not see why one would study STEM. A Flemish
school, Heilig-Graf Instituut in Turnhout (Belgium), started a brand-new initiative in September
2013: a course in which the different domains of STEM will be taught from an integrated point of
view, hoping to reveal the answer to the ‘Why?’-question pupils often ask themselves while
studying math or science. The school implemented this course of 5 hours a week in a new study
option, called ‘STEM’. This option is organized next to the two existing options in the first year of
its Secondary Education, with one of them being considered as cognitively more challenging and
the other one being more general. This initiative, never seen before in Flanders, wants to upscale
students’ interest and skills in STEM-domains and give insight in possible STEM-professions.
Until now, 30 students, showing a high potential for STEM, enrolled in the STEM-class.
The curriculum for this course puts the emphasis on the integration of math and science, and is the
result of the cooperation between five of the school’s teachers and a STEM didactics research
group at the university of Leuven. The five teachers have different educational and teaching
backgrounds, which facilitates integrated approaches. To create a robust learning environment, in
which abstract concepts and hands-on applications are explored, three well-considered guidelines
for the first year of the ‘Integrated STEM’-course were developed: Mechanics, Programming and
Design. Recent research for STEM career interest (Sadler et al., 2012) has proven that those
students, showing an interest in a physics career at the start of secondary school, have the highest
chance to maintain an interest in STEM. As an important part within the discipline of Physics,
Mechanics is a great basis to start from for several reasons: it operationalizes certain mathematical
concepts and creates a manner of thinking that can be useful in many problem-solving techniques.
Also, learning about mechanics can serve a lot of technological design issues: by developing an
early but thorough understanding of physical concepts like velocity and acceleration, the pupils will
soon be able to set up an inquiry-based experiment to, for example, measure speed in function of
time, which will be conducted by their own logically programmed robot! As such, a pedagogy
referred to as purposeful design and inquiry (Sanders, 2009), is introduced.
A curriculum for the next 5 years of the ‘Integrated STEM’-course is under construction. In this
curriculum the level of abstraction and the amount of addressed science study domains will be
increased. The final step will be to measure the efficiency in terms of improved STEM-literacy and motivation amongst the pupils extensively. In this presentation a short overview of the yet developed curriculum and the plans for the near future will be described, as well as the didactical principles behind it. The first results and experiences after one year of STEM-course in terms of teacher and pupil satisfaction will be presented.

How can future European physics studies lead to innovative competences and stimulate entrepreneurial behaviour?

Hendrik Ferdinande
Universiteit Gent, Belgium

Tertiary-level education and physics studies are under increasing pressure to respond to the appropriate skills demands generated in a rapidly changing labour market. After a short introduction on the competence-based description of study programmes (e.g. Dublin descriptors, ‘Bologna Process’, Tuning) the EPS documents on physics bachelor, master and doctoral studies, described in learning outcomes or competences are presented. Recent research on skills for innovation in the STEM field are focused on , as well as an example of a competency model and a master programme with a minor on economics and business administration with accompanying support. The complexity and uncertainty of the society and the economy require physics studies to continuously adapt while upholding quality standards (e.g. Kahn Academy). A European permanent think tank of experts on physics studies (of which part of the members could be renewed every two or three years), established with the help of the national member societies in the EPS and based on a mixture of good practices in the different countries, could represent a great help and should be aimed at. Embryo's could be found in the HOPE network and the EPS Forum on Physics and Society.

Session 4.5: History of Physics in Physics Education and Socio-Cultural Issues
Tuesday 8, 16:45-18:45
Room 11 (Aula 11)

The problem of recognizing objectives in physics

Valbona Tahiri and Jorgo Mandili
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In the late 19th and early 20th century, in order to explain new facts were developed two main groups:
1. Most prominent physicists of the time (Hertz, Thomson, Helmholtz, Lorentz ), insisted to explain the new discoveries with the classical perceptions.
2. Others considered that the further process in natural sciences should be related to radical restructuring of the philosophical foundations of scientific knowledge.
The problem that naturalist faced at the beginning of 20th century was: explain the extraordinary discovered phenomenon with the help of classical methods and merge them with the images on metaphysical-materialistic nature, at that time prevalent in the scientific areas.
The increasing of physicists’ suspicions that new phenomena cannot be successfully explained on the basis of mechanical picture of the world logically led to the opinion on the necessity of a critical review of that scheme, whose consequences rather than led to success, complicate increasingly the work. Especially was needed to show how the mechanical understanding of the world is limited, how to avoid the inherent difficulties outside and beyond classic images? We note that suspicion to the absolute truth of some principles of classical physics, which play a methodological role, their efforts on empirical motivation, had taken place between scientists physicists as long as it was discovered their limitation, as long as demonstrated the impossibility of using their entire system as a founder of physical knowledge. Even before the onset of the known crisis in physics, on the threshold 20th century, scientists began to accept non-classical principles, such as the principle of action in close proximity of Maxwell Electrodynamics. Note that the limitation of principles of classical physics and its methodology, although was evidenced for a while before the crisis in physics and moreover up to the creation of new physics, became comprehensible only when it was created relativistic and quantum physics. The critical analysis of the fundamental concepts of physics, the operation methods with physical and mathematical abstractions, the renunciation from mechanical and electrodynamical absolutism of the world etc, undoubtedly paved the way for a new way of thinking. Under the pressure of revolutionary changes, physicists were forced to give up many claims, that for a long time considered automatically understandable and also by such concepts, the truth confirmed by experiment. One of the most controversial issues on the revolutionary change period was the problem of recognizing the physical objectivity. This problem was born especially after the emergence of new physical reality, as a physical object the correlation in terms of recognizing in cognitive process of observers. In this regard the attention of scientists was attracted by the “mediator” between the researcher and the object of study, which character and behavior substantially affect in information received. Is there a possibility in these conditions to ensure the absolute objectivity of the description, especially when we take in account that quantum physics is forced to use two systems of concepts: classical and Quantum concepts, who reciprocally exclude each other? So, we should find an answer to the description of the new objectivity. In this article we will analyze exactly this response. We will argue the thesis that, for the description and explanation of physical phenomena must refer in two conceptual systems: physical theory and physical picture of the world, which differ only by the logical structure, the generalization degree and conceptual apparatus. During this analysis are identified the functions of world physical pictures and their connections with physical theories and philosophical ideas. Such analysis is very important to clarify the problem of the origin and development of theoretical knowledge in physics.

**Exploration of Korean elementary students’ science related experiences and career aspiration**

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Elementary students are at the early and essential stage of career exploration and career choice. Their science preference, science related experiences, and perception of science related careers are regarded to affect career decision. This study aims to explore constructions that make elementary students avoid or attract science related careers through analyzing science preference, science related experiences, and perception of science related careers. Picture diary is easy for elementary students to represent their experiences and feeling about science and wide-spread in clinical psychology as well as scientific research. 505 5th grade elementary students who are in middle-class family and live in Seoul city and almost of them attend private institutions or community institutions participated in this study. The school they attended is near a market and no science museum nearby. They were asked to response to a survey about career aspirations two times in a
semester, and draw a scientist at the first and the last time. Their scientific related experiences had
been collected through picture diary as drawing themselves doing science twice a month. The
analysis of drawings is based on a modified DAST and a modified Kinetic-School-Drawing.
Students thought that scientists look like projecting themselves, such as very young face and
sameness of their gender and usually do chemical experiments or biological experiments alone.
They showed their science related experiences in contexts such as what, when, where, why they
did, how they felt, and with whom they did. They usually drew themselves doing science in the
contexts of school with friends, home alone, or science museum with family. And they thought that
science activities are making, observing, experimenting, reading and watching, and experiencing
science related objects. Students with the more science aspiration tended to draw oneself doing
science craft, experiencing science activity and so on. To get more detail context, we interviewed 4
students who were extremely increasing or decreasing science related career aspiration. We asked
them science preference, science related experiences, and perception of science related careers
based on their drawing. We can get the context that how and why they choose the science related
careers, how and why they change their mind, and how science preference, science related
experience, and perception of science related careers influenced their career choice. The results of
this study suggest how we can correct the negative change and reinforce the positive change of
science related career aspiration in Korean elementary school’s contexts.

A teaching proposal on Electrostatics based on the History of Science
through the reading of historical texts and argumentative discussions

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In nowadays context of science education, we consider that students arrive to the school with a
background of knowledge that, for them, is undoubtedly valid and powerful enough to interpret the
surrounding world. Based on the research of students’ conceptions in science, we know that part of
this knowledge is in conflict with scientific knowledge, and some students are reluctant to
reconsider what they think. Beside the knowledge of these students’ conceptions, the knowledge of
relevant episodes in the development of science can help to better understand the students’ thinking
and some specific difficulties that students have related to some Physics’ topics.
In particular, researches on students’ conceptions in electrostatics have found that students have
ideas and concepts very different from the ones of the scientific models to interpret these
phenomena. One of the difficulties found by teachers and researchers is that students consider
electrostatics phenomena with any relation with the phenomena linked to current electricity.
Students from secondary education and pre-service primary education teachers have answered
some questions about electricity phenomena, some of these about Electrostatics. The results of the
analysis of their answers agree with the findings of other researchers.
To favour the change of student’s ideas and models we have prepared a teaching proposal for
secondary school and pre-service primary teachers that relies on a historical study of electrostatics.
This presentation is the first part of a larger teaching sequence about electricity.
It begins with an exploration of electrostatics phenomena that students would do with everyday
materials. About these phenomena they must draw their own explanations, which means, give their
interpretative models, working in peer. These peer students will present their explanations in front
of the whole class and a discussion about ideas and explanations will be carried on in the group
class. The teacher will try to collect and summarize the ideas and explanations which are nearer the
history of science.
A brief history of electrostatics is introduced then, and some texts from several scientists were
used. Among other, texts in which the model of a single fluid is defended or the one of two fluids.
The activity of students in class is followed by a division of the students between the "supporters of
a single fluid” and “supporters of two fluids” and then, in a roll play activity, each group has to present arguments for their model and/or against the other model, the arguments have to be used to explain the phenomena observed in the exploration phase or new ones. This activity can finish with students writing about the model “defended” detaching now its advantages and inconvenients.

At following, students will read texts related to science applications, the main aim of this activity is to relate electrostatics phenomena with current electricity. The first text explains how Franklin understood the nature of the lightning and the lightning rod and the second is a chapter of a roman about some historical episode related situated in the Barcelona of XVIII, the one about the invention of the telegraph made by Salvà & Campillo in Barcelona (1790). Students will answer some questions and use the historical models of one and of two fluids to explain them, and compare them with the scientific explanation of the “accepted” science of nowadays.

With this type of teaching proposal, conceptual aspect of electrostatics will be understood and also students will learn about the nature and history of science and culture, as well as about argumentation.

What has happened to mass

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“Physical concepts are free creations of human mind, and are not, however, it may seem, uniquely determined by the external world”. [1] Therefore, it is no wonder when physical quantities change their meaning over the course of time. The developments in the understanding of what we call mass, could be divided into 5 steps.

First step:
As any other physical quantity, mass characterizes a special property of a physical system or body. In the beginning it was used to describe the amount of a substance, or it was used to describe what we call the heaviness of something. This is the way students use the word mass not only in everyday life, but also, when they start learning physics.

Second step:
Since the time of Newton there exist two different quantities, both of which are called mass. To distinguish between them, we call one of them gravitational mass and the other inertial mass. Gravitational mass is used in formulas like: F = m*g. Inertial mass is used in formulas like: F = m*a. The masses in the two formulas are different, even though in both cases the same symbol is used. And moreover: the same measuring unit is used in both cases: kg.

Third step:
Einstein wrote: „Gravitational and inertial mass of a body are equal. This was stated but not interpreted by previous mechanics.“ [2] In his Theory of General Relativity Einstein stated that gravitational and inertial mass are equal. They are just two different names of the same physical quantity. No experiment would be able to distinguish between them. The experimental work of Eötvös on gravity is one in a long series of experiments which showed, that there is no difference between gravitational and inertial mass with an accuracy of 10^-10.

Fourth step (Historically, this step came before the third step.):
In 1905 Einstein published his famous equation E = mc^2. In ‘The meaning of Relativity’ Einstein says: „Mass and energy are therefore essentially alike; they are only different expressions for the same thing“ [3]. Or: „According to the Theory of Relativity there is no principal difference between mass and energy. … Is a hot piece of iron actually heavier than a cold one? Now, we must answer „yes‘ to this question“ [1]. The merging of mass and energy into a single physical quantity has the consequence that the energy has the same properties as mass:
- A fast proton is heavier than a slow proton. The inertia of a particle increases with its speed (and energy).
- “The mass density of the magnetic field of a magnetar is $10^4$ times heavier than lead.” [4].
- Objects with energy are sources of gravitational fields: „Geons are electromagnetic or gravitational waves which are hold together in a confined region by the gravitational attraction of its own field energy.” [5].

And vice versa mass has the same properties as energy, as for example the reaction of matter and antimatter shows.

Fifth step:
In particle physics mass is invariant with respect to Lorentz transformation, and therefore mass could be used to characterize a particle. This understanding of mass seems to be in contradiction with the fact that mass increases with velocity. This contradiction disappears if we use rest mass or rest energy instead of the invariant mass.


The discovery of X-rays diffraction from crystals to DNA: a case-study to promote understanding of the nature of science and of its interdisciplinary character

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The advantages of introducing History of Science (HoS) materials into the teaching of science has been advocated by a large number of scholars within the science education community (e.g. de Hosson & Schneeberger 2011, Leone 2014, Matthews 1994). One of the main reasons given for using HoS in teaching is its power to promote understanding of the nature of science (Galili & Hazan 2000, Kipnis 1998). In this respect, the discovery of X-rays diffraction is a case in point for showing that a correct experimental strategy and a favourable theoretical context are not enough to make a scientific discovery (Robotti 2012).

X-rays were indeed discovered in 1895 by Wilhelm Conrad Röntgen while studying the phenomenon of electric discharge in rarefied gases. Röntgen was persuaded of the wave-like nature of the X-rays and soon attempted, after having studied the various optical properties of these new rays, to obtain their diffraction through narrow slits and also through crystals. These experiments, however, proved unfruitful and about twenty years elapsed before the diffraction of X-rays was actually discovered in 1912 by Max von Laue.

The discovery of X-rays diffraction was indeed the final outcome of a lengthy process requiring a number of conditions: the success of the wave theory of X-rays mainly through Charles Glover Barkla’s discovery of the fluorescence rays; the reliable estimate of X-rays wavelengths; the emergence of an interest toward the crystal optics and the crystal lattice structure; and, finally, the development of an experimental expertise on X-rays and the commercial availability of fairly powerful X-rays tubes.

All these conditions were met by 1912, particularly at the Sommerfeld’s Department in Munich, where Laue was working and where the scientific climate was favorable to his discovery.

However, even if the search of diffraction of X-rays was in the air, Laue was the one who had the formidable idea that Nature gave us the right tool, that is a tool of resolving power high enough to diffract the X-rays, the crystal. Differently of Röntgen who failed to find the diffraction by means...
of crystals, Laue succeeded because he understood that the crystal may behave as a diffraction grating for X-rays. In short, he knew what to look for and how to find what he was looking for.

In order to make Laue’s discovery a powerful experimental method, however, another fundamental idea was required, that is Lawrence Bragg’s idea that the diffraction might be seen as the internal reflection by the crystal planes, and also a new instrument was necessary, Henry Bragg’s X-rays spectrometer. By these improvements, a new field of science was born, the X-rays spectroscopy. From the 1920s onwards, this new field developed into a quantitative science and X-rays analysis crossed the frontiers of physics and was applied to more complex inorganic crystal structures and, eventually, also to organic materials. One of the most significant applications of X-rays spectroscopy to biological structures were the first X-ray photographs of DNA. The discovery of the correct structure of this molecule, however, required further steps, i.e. the development of the alpha-helix theory of proteins and the formidable Crick and Watson’s double helix idea.

References
A dynamical model for the rolling cylinder

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In this contribution we present a dynamical model for rolling motion used at high school level. Starting from the observed behavior of a rolling cylinder accelerated in different ways, we introduce a model based on the exchange of linear and angular momentum between the rolling body and the underlying surface. The main point is that in rolling without sliding, the ratio of angular momentum and linear momentum has a constant value which means that their rates of change must satisfy the same condition. Using the canonical dynamical equation of motion (interpreted here as balance equations for linear and angular momentum) we can derive in a simple manner forces and torques originating in the interaction between rolling object and surface. This approach helps students forming a suitable mental image of the processes. Moreover, it effectively supports them in formulating the equations that govern the motion of the cylinder.

In a second step we will discuss the energetic aspects of the rolling motion, both in the absence of dissipative processes and in the presence of rolling friction. Each energy exchange is associated with an exchange of another extensive quantity: for conductive processes, the power of the process is proportional to both the intensity of the flow of this extensive quantity and the associated potential difference. With this model we examine, among others, the motion of a cylinder coming to rest on a rough surface. The model lets us argue that, in absence of gliding, only the angular momentum exchange between the rolling cylinder and the surface is responsible for the dissipative process. Finally, using a dynamical modeling tool, we discuss the agreement of quantitative model predictions with experimental data.

Use your head - in football and in physics education

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Including sports issues in physics education offers an opportunity to increase students’ interest and motivation. Furthermore, it allows for taking into account the methodical and didactic ideas of 'active learning', which here means learning by and in motion. Students can perform athletic activities, they can measure physical parameters of their own movements, and they can analyse the resulting data. However there are a wide variety of possibilities to measure parameters and analyse data concerning the athletic activities of real sportspersons. In any case, there is a definite necessity to develop and apply models in order to interpret and understand the complex human limb movements. This active modelling helps students attain knowledge regarding problem solving. Lastly, by measuring and explaining sports activities, fundamental concepts of physics can be taught.
Football is one of the most popular sports in many countries, which means that a football-themed physical discussion usually arouses great interest. This presumably accounts for the fact that a wide range of (popular) science literature, as well as technical and subject-didactic articles have been published on this subject. Apart from extensive works on football in its entirety, some partial aspects have been singled out for closer scrutiny, such as unexpected trajectories of balls (curling crosses) which impressively show the Magnus effect, the high ratio of coincidence in football results which lends itself to statistical evaluation and the goalie’s (and the penalty-taker’s) anxiety at the penalty kick, which can be convincingly explained with kinematics. Another important component of the game, namely headers, have not yet been analysed as diligently, even though the question of how dangerous a header really is relates directly to the determination of the forces and acceleration involved. In this talk, we will show that headers may enrich physics education experimentally as well as theoretically. Especially, we would like to focus on and present the examination of the interaction of football and head from various different viewpoints. On the one hand, we introduce a wide array of experimental approaches, from simple experiments to video analysis and data acquisition with acceleration sensors. We show the good agreement between data from video-camera and from sensor-based data logging. We also point out that data logging and analysis concerning real situations within a football match are much more difficult than experimental set-ups in laboratory.

We attempt to explain the data by using theoretical models of varying complexity. For instance, simple models may assume certain parameters like maximum force. When applying dynamical models even time-based sequence of action could be simulated. Finally, health aspects with regards to headers are discussed, as especially young players are at a particular risk in this respect and should be fully aware of this fact.

Understanding Physics Concepts at Different Representation Levels. A Mutual Information Approach

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We have analyzed student’s knowledge about physics concepts in kinematics at different abstraction levels. The concepts, we were looking at, were first, velocity as rate and second, velocity as one-dimensional vector. The problems administrated to the students were multiple-choice questions using different degrees of abstraction. Questions at the first level are associated with figures like stroboscopic pictures. At the second level questions are furnished with diagrams and at the third abstraction level motions of object were represented by tables. Some of the questions about velocity as rate could be posed at all three abstraction levels. Of course, now the question arise how the different abstraction levels are mutually correlated.

We designed a multiple-choice concept test in kinematics consisting of 27 questions. An exploratory factor analysis revealed that abstraction level 1 and 3 loaded on the same factors. However, diagram questions (level 2) formed an own set of factors. Therefore, one might expect that level 1 and level 3 data are highly correlated whereas level 2 data is neither correlated with level 1 and level 3 data.

This result is quite surprising since we didn’t expect, that reading data out of tables and analyzing stroboscopic pictures are of the same quality for the student. In contrast solving problems using diagrams (level 2) seems to be something completely different. Since correlation analysis is a linear method it doesn’t take nonlinearities in the data into account. Correlations can be zero although there is an obvious nonlinear relationship in the data. Thus we have used a different method to analyze the data: mutual information. It computes the information of the overlap of two data sets. If the two sets are independent the mutual information is zero. We
arranged the data in a two-dimensional table with the number of correct answers at level 1 in horizontal direction and the number of correct answers at level 2 in the vertical direction. All question were linked to the same concept. The students (in total 56) were now assigned to one of the fields of the table. Mutual information can then be calculated using the definition given in R. Steuer et al. (Bioinformatics, 18 Suppl. 2, 2002, S231 - S240). Our results show that the mutual information between the different abstraction levels is higher than the corresponding correlation (mutual information MI12 = 0.11, MI13 = 0.23 and MI23 = 0.56 versus R12^2 = 0.074, R13^2 = 0.58 and R23^2 = 0.076). Thus we assume that the diagrams (level 2) are not so unrelated to the other two levels of representation although this is suggested by the correlation analysis.

We have also worked out similar analysis between concepts in mathematics and physics concepts. It turned out that mathematics concepts seems to be an essential prerequisite to learn concepts in physics if they are as closely related as in kinematics.

**Students’ views of theoretical models in Physics**

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In the European project, CoReflect (www.coreflect.org), groups of researchers and teachers in different countries have develop, implemented, and evaluated digital learning environments (LEs) using the web-based platform STOCHASMOS. In total seven LEs was developed. All the LEs focus on different socio-scientific issues (SSIs). The LE developed in Sweden addresses SSIs related to astrobiology (Hansson, Redfors & Rosberg, 2011). The LE was implemented with 15-17 years old students. The LE had two socio-scientific driving questions "Should we look for, and try to contact, extraterrestrial life?", and "Should we transform Mars into a planet where humans can live in the future?"

The students working with the LE were in their last year of compulsory school (16 years old), and worked together in groups (2-3 students) in front of one computer. Students’ work included reading texts, working with activities, hands-on labwork, collecting and formulating arguments, chat- and forum-discussions, and the formulation of the final standpoints. Students were expected to: demonstrate a basic understanding of essential concepts of astrobiology, discuss the nature of science, link hands-on lab-work to astrobiology research, provide evidence-based answers to the driving questions, using scientific, social, economical and ethical perspectives. Seven of the 14 groups were audio taped throughout their work with the LE during five weeks with four lessons per week (40-70 min). In addition to this, all computer activities were logged by STOCHASMOS for all student groups, i.e. arguments, final decisions, chat and forum discussions. One or two researchers were present in the classroom during 14 of the lessons. In addition to this the students completed written individual pre- and post-tests. Results from analysis of students’ decision-making and arguments used, in relation to the SSI driving questions, in their written documentation – from the workspace, chat and forum discussions, the final standpoints of the groups and in the pre- and post-tests are discussed in Redfors et al. (2013). The analysis showed among other things that the students often used science related arguments, which differ from much previous research on science teaching with SSI.

The analysis presented at the conference uses data from written pre- and post-test and follow-up interviews concerning questions about theoretical models in physics. Theories and theoretical models in science are used to make sense of, discuss and explain physical phenomena. Theories and theoretical models are developed in an interactive process of discussions, experiments and observations (Adúriz-Bravo, 2012, Giere, 1997). Observations and experiments by necessity are embedded in theory and are therefore "Theory laden" (Hanson, 1958). Hence, there is a complicated relation between what we call a theoretical model with theoretical concepts and real world referents and phenomena. The data is analysed with an aim to answer the research question:
What views of theoretical models do the students hold before and after working with the LE? Through the longitudinal design we are able to analyse the development of the individual students’ responses during the LE, and compare pre- and post-test responses with the follow-up interview. It is possible to trace the impact of the different LE content on the student explanations, and a progression in the use of scientific concepts and model constituents is indicated. Further results from this on-going analysis will be presented at the conference.

A possible implication for physics teaching and future research of the preliminary results is the importance of discussing the nature of theoretical models, compare different models, and to discuss phenomena where one explanatory model does not suffice. This will be discussed and problematized at the conference.

References


High school students’ misconceptions in electricity and magnetism and some experiments that can help to reduce them

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Electricity and Magnetism is one of the topics in high school curriculum which is often perceived as difficult. It is known that even at higher (i.e. university) level the conceptual understanding of students in this area is often rather poor, with many misconceptions.

To identify misconceptions of Czech high schools students we at first tried to use The Conceptual Survey of Electricity and Magnetism (CSEM) [1]. This survey is intended for students of introductory physics courses at universities. The survey was shortened for Czech high school students but some assignments and pictures appeared to be too abstract for students and they didn’t understand the tasks and questions concerning them. So, we have prepared a new Conceptual test from the area of Electricity and Magnetism, which is focused on high schools’ students. This test was presented at WCPE 2012 in Istanbul. After pilot testing in school year 2011-2012, the test was slightly modified and this modification was tested and verified last year. Some examples of typical misconceptions in the area of electricity and magnetism which students participating in the survey have was presented at ICPE-EPEC 2013 in Prague and it will be publish in the proceedings from the conference [2].
The modified test and some typical misconceptions of Czech high schools students in the area of electricity and magnetism will be briefly presented. For example, one topic students seem to have a problem with is a charge distribution on conductors and insulators. A lot of students predict that if we charge just a small part of a body then, after a while, the charge will be present on the whole body in spite of the fact that the body is made of insulator. In the area of electrostatics, there is another problematic part. Students are able to solve a quantitative problems using Coulomb’s law, but it seems that they do not understand it as well as one could expect. Another problematic topic could be electromagnetic induction and magnetic flux – students seem to have a problem to understand what the area “S” in the magnetic flux is, they often do not see a collapsing loop as changing the magnetic flux.

However, to identify misconceptions is not enough. Therefore, in the main part of the presentation, we will show some experiments which can help students to overcome their misconceptions and to better understand not only the topics mentioned above. Most of these experiments can be done with very simple tools and materials. For example, to demonstrate, how the electric force between two point charges depends on charges and on the distance between them the force could be measured using digital scales. As “point charges” we use ping-pong balls. Even more simply, semi-quantitative demonstration of Coulomb’s law could be shown only with plastic straws and paper clips. We will present experience we have with these experiments in teaching electricity and magnetism at high school, too.

coherent internal accounts to develop explanations in the classroom, thus revealing more of the processes by which they develop pedagogical content knowledge from their subject knowledge and the interplay between these. The research also examined the other funds of knowledge upon which pre-service teachers draw, such as general pedagogical knowledge and pedagogical context knowledge, and their perceptions, together with the perceptions of their mentors and tutors, of how they learn to teach and explain physics in the classroom. Interviews were carried out to explore how pre-service teachers plan their lessons; their epistemic beliefs about high school physics; their pedagogical beliefs about the role of the teacher and the nature of learning; their perceptions of their own learning process and their identity as pre-service teachers. This was followed up by observations of the pre-service teachers teaching physics and post-lesson interviews, together with interviews of teacher educators in the university and mentors in school. Initial findings suggest pre-service teachers’ practice is based on complex and nuanced beliefs about the nature of learning and the role of a teacher, with an element of conflict between them. Although only a few months into their teaching careers, it was clear that they had developed a wide pedagogical knowledge basis, much of which was in the process of becoming tacit knowledge: nevertheless they were able to articulate how their learning in university and in school contributed to their professional practice. Implications for pre-service teacher education are discussed from the perspective of learning how to explain physics in the classroom, including the interplay between theory and practice, and the necessity for both situated and decontextualized learning. This work is funded by a Royal Society Education Research Fellowship.


A preliminary look at the educational products developed within a professional master's degree in physics teaching

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Professional Master (PM) is a modality of postgraduate education in Brazil designed to meet the social, political and economical demands of producing qualified workforce. It has been created in the 90s, when higher education had undergone several legal transformations to meet the agenda planted by the World Bank for education in peripheral countries.

On teaching science and mathematics, PM has been regarded as a promising innovation aimed at improving Brazilian science teaching. Actually, it can not be considered ‘an adaptation or a variation of [academic] modalities that already exist in Brazil’. Hence, it has been claimed that PM programs and students should be assessed through means of different criteria. If, on the one hand, academic postgraduate programs are aimed at producing knowledge, on the other, professional masters on science teaching are aimed at developing educational products that may be immediately experienced in the science classroom.

Encouraged by the lack of research on PM and taking into account the distinct importance of educational products in the official assessments of PM programs, the paper reported in this abstract presents an initial survey of educational products published from 2004 to 2012 in a large pioneer
Brazilian PM program for physics teaching that has been regarded exemplar for other programs that have been established recently.

In this period, 70 in-service physics teachers graduated from this program. In addition to the educational product, these graduates are required to write a small thesis presenting the product they have developed and their experience with its application. From these small theses, it was possible to account for the type of school, educational level and theoretical orientation of each educational product. In these small theses, the most cited theoreticians are David Ausubel (40 citations) and Lev Vygotsky (36 citations). Ausubel’s theory on meaningful learning is possibly the most influential theory in the analyzed PM program for some historical reasons. Even when other theoreticians are cited, they are adapted to meet the Ausubelian worldview. Most educational products are oriented toward high school teaching (42 products). Only few are oriented toward primary education (7 products). We also observed that 39 products were experimented in public federal institutions, 28 in private schools and only one in a private-particular institution. Most theses present educational products elaborated under technicist frameworks oriented toward private and federal high schools. It is highly debatable whether these products reach for the most needy strata of Brazilian educational system. Preliminarily, it is possible to ascertain that these products and theses are limited to fulfill the prerequisites for graduation rather than actually transforming science teaching as foreseen by any brief historical analysis of the professional master modality.

The Assessment of Pre-service Physics Teachers’ Misconceptions about Geometrical Optics with a Four-Tier Diagnostic Test

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There is ample evidence that misconceptions in physics are robust and consistent with respect to age, ability, gender, culture or nationality. Generally, misconceptions are thought to be problematic since they affect how individuals understand natural phenomena and their scientific explanation. Therefore, correct identification of misconceptions is crucial in order to overcome or avoid them. Several diagnostic assessment methods have been used including interviews, concept maps, open-ended tests, multiple-choice tests, and multiple tier multiple choice tests (two-tier or three-tier tests), but each has its own advantages as well as disadvantages. The present study describes the development process of a four-tier multiple-choice diagnostic test in order to assess common misconceptions about geometrical optics and presents the results of the test scores. In the current study, the instrument called Four-Tier Geometrical Optics Test (FTGOT) was developed and administered to 243 pre-service physics teachers in Turkey from twelve state universities with physics teacher education programs. The FTGOT was specifically designed to assess the prevalence of twenty one misconceptions about geometrical optics in the contexts of plane mirrors (single plane mirror and hinged-plane mirror), spherical mirrors (concave mirrors and convex mirror), and lenses (converging lens and diverging lens). The Cronbach alpha reliability coefficient of the pre-service physics teachers’ scores was estimated to be 0.59. As a result, six of the misconceptions, which were held by more than 10 % of the pre-service teachers, were identified and considered to be significant.
Examining impacts and shifts in pre-service physics teacher self-efficacy, beliefs about nature of science, and constructivist practice through the NSF Robert Noyce Scholarship Program

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The National Science Foundation (NSF) Robert Noyce Scholarship Program for Science and Mathematics Teachers recruits and prepares middle school science/mathematics and high school mathematics, life science, chemistry, and physics teachers highly qualified to teach in the US, with particular preparation for teaching in economically disadvantaged school districts. This paper presents research on the Robert Noyce Scholarship Program at the University of Texas at Arlington. The Noyce program recruits and awards scholarships to science and mathematics majors seeking teacher certification, and is a collaborative program among the College of Education and Health Professions, College of Science, and urban area partner school districts. The NSF Noyce program implemented a concerted design to promote pre-service science and mathematics teachers’ self-efficacy through constructivist teaching and learning experiences in our UTeach Arlington science and mathematics teacher certification program, along with a strong foundation in science and mathematics content knowledge. The program focuses on promoting understanding of nature of science and mathematics by providing experiences to explore science and mathematics as active and dynamic disciplines. Impacts on pre-service physics teachers is of particular interest in this research due to the severe shortage of physics teachers in the US; shortages that are profound our partner urban school districts. This research is based on the contention that teachers with high self-efficacy toward teaching science and mathematics, and who view science and mathematics as active, changing, and dynamic disciplines may hold a more constructivist philosophy of science and mathematics teaching and use more inquiry-based/problem-based teaching approaches. This postulation is the focus of this study, with the following research purposes: 1) to examine possible shifts in self-efficacy toward teaching science, views of nature of science/mathematics, and primary teaching philosophy and practices from beginning to end of the program, and 2) to investigate relationships among self-efficacy toward teaching science, views of nature of science/mathematics, and primary teaching philosophy and practices at the beginning and end of the program. Results indicated positive significant shifts in self-efficacy and in nature of science/mathematics toward more dynamic views, and significant increases in teachers’ use of constructivist teaching practices including using inquiry-based models, problem-solving and logical reasoning strategies. Specific and unique patterns in these shifts and relationships were found among the pre-service physics teachers in the program. The NSF Robert Noyce Scholarship program in accord with the UTeach Arlington science and mathematics teacher certification program will be described in the context of the findings of this research.

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Teaching inquiry: the European TEMI project involves Italian teachers, first outcomes

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The aim of the European TEMI (Teaching Enquiry with Mysteries Incorporated) project is to help transform science and mathematics teaching practice in Europe, by giving teachers new skills to
engage their students and exciting new resources together with the extended support needed to effectively introduce inquiry based learning into their classrooms.

The TEMI project involves 13 partners of 11 European countries in order to implement innovative training programmes called “enquiry labs” [1]. These labs are based around the core scientific concepts and emotionally engaging activity of solving mysteries, i.e. exploring the unknown.

In the present work, we will illustrate the pilot enquiry lab, performed by the University of Milan, which was addressed to a cohort of 15 of secondary school teachers. The guidelines of each enquiry lab have been fixed by the project to ensure that a certain uniformity is maintained in the implementation of the project by all the participating institutions. Our inquiry lab has been developed for 4 afternoons, during which lab teachers directly experienced a guided inquiry IBSE [2] on their own, in order to become familiar with the method that they will subsequently implement with their students. A mystery to be solved was the engaging part and the pivot of the entire enquiry lab. Therefore, it had to be sufficiently stimulating, but not too much complicated to inhibit the possibility of investigation of the participant. The mystery proposed to the teachers involved in our enquiry lab was the same for everyone and pertained harmonic motion. On the contrary, each of them was let free to choose a particular mystery, suited for his/her group of students, in their classrooms.

All the teachers of our first cohort have been teaching physics for at least three years in secondary school and were following an in-service teachers training course to get a teaching qualification. They did not chose to follow the inquiry TEMI lab for a particular personal interest, and therefore we believe they can represent an “average” Italian teacher sample. Thus, the obtained results may be meaningful to test the effectiveness of the TEMI inquiry labs.

Teachers have been monitored in all their activities from their previous disciplinary competencies to the ability in implementing IBSE in their classes by means of written tests, logbooks, oral interviews, and multimedia materials documenting their classroom practice.

Here we will discuss strengths and weaknesses of the teachers inquiry lab together with the results obtained by teachers in implementing IBSE with their own students. We will also evaluate the effectiveness of TEMI enquiry labs for the dissemination of the guided inquiry method among secondary school teachers.


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**Session 5.3: Pedagogical Methods and Strategies**

Wednesday 9, 14:15-16:15

Room 9 (Aula 9)

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**Good Italian taste: a multidisciplinary approach to pasta cooking**

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In this work we implemented a multidisciplinary empirical approach, involving mathematics, physics and chemistry, to Italian durum wheat semolina pasta cooking mathematical modeling. This work was implemented in a III class of a Scientific High School, combining simple theoretical
modeling of physical phenomena with experimental activities and experimental data processing. We started from simple physical models both for heat and water diffusion into pasta structure. Heat transfer into pasta structure is a diffusion process. In order to obtain a simplified description of this process, we assumed heat transfer into pasta structure equivalent to particle diffusion into a perfect gas, hence time needed to external (100°C) temperature to reach pasta inner is proportional to pasta radium squared. Amount of Water flowing into pasta is limited by external pasta surface. Chemical structure modification is a thermal activated process. With these physical and chemical assumptions, we justified the hypothesis of a quadratic relationship between cooking time and pasta diameter. An experimental procedure was implemented to test the model.

First, other than spaghetti we selected further different both thin and large pasta types. Second, in order to reduce the effects linked to personal cooking procedures and tastes, we adopted a standardized procedure and performed cooking under as much as possible controlled experimental conditions. Each pasta format was cooked for different time intervals. A four people panel of “assaggiatori” tested cooked pasta allowing us to reduce personal tastes drift in determining experimental “al dente” cooking times. Caliber and micrometer were used to measure, respectively, thicknesses and radii of thin and large type pasta. Experimental cooking times and measured pasta diameters were used to found, through a non linear least square fit, a quadratic function describing the cooking process for almost all types of pasta. The obtained function well describes cooking times from various pasta brand. Prediction capabilities of this function was tested on different pasta types whose data were not used in the best fit procedure. We observed deviations from this model both for “bucatini” and large (ziti) pasta. For “bucatini” we introduced a semi-empirical correction to our equation linked to their particular structure (inner hole). For large pasta types we took in count the limitation to water flow into pasta structure linked to the surface to volume ratio. Both corrections allowed the model to fit those extreme cases. This work was realized both during regular and extra school hours. The multidisciplinary approach involved mathematics, physics, chemistry and informatics. Modeling the physical and chemical aspect of pasta cooking helped students to select the appropriate mathematical model. A rigorous procedure was defined and implemented to collect data in as much as possible experimental way. The idea of a “taster” panel was introduced after having realized that well cooked is a rather personal judgment.

Teaching physics with Angry Birds: momentum and energy conservation laws

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Videos are a powerful tool for engaging students to describe phenomena and give the corresponding physical interpretation. Recent software for video analysis are freely available in the web, enabling students to collect experimental data from videos. Physics teachers are interested not only in collecting experimental data, but also how its numerical, graphical and mathematical treatment can enhance learning in their students. Therefore, video modelling is of major importance in education, and is being used for teaching and learning several topics in Physics [1-3]. For this reason, the freeware video analysis software Tracker, which includes the module Data Tool for video modelling, has a great potential in physics education. The conservation of momentum and energy are usually introduced with classical academic examples, like a ball tossed in air, or a collision between two balls. However students can be more engaged when teachers use new and challenging contexts to study these laws. In this work we show
how this can be achieved with the very popular game Angry Birds, from Rovio Entertainment’s [4]. Angry Birds is cataloged as a “physics game” because the motion algorithms are based in the kinematics of projectiles [5-9]. The analysis of the motion of the blue angry bird gives a good opportunity for studying momentum and energy. At a certain point of its trajectory, the blue bird “explodes” and splits into three new birds (it’s a kind of special power the blue bird has…). Is there momentum conservation? And how about energy? Is the physics in Angry Birds’ world similar to that in our physical world? Tracker software provides the tools to obtain the equations of motion of the birds, and therefore their momentum and energy immediately after and before the “explosion”.

The present work is a didactic approach for teaching kinematics in high school and introductory physics courses with an interactive methodology.

References:

SECURE results on differentiation

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The research done within the SECURE project on MST (Mathematics, Science - also Physics - and Technology) curricula in ten European countries (Austria, Belgium, Cyprus, Germany, Italy, The Netherlands, Poland, Slovenia, Sweden, and United Kingdom) was triggered by recognition of the present situation in MST education in Europe. Young people seem to lose their interests for MST sometime before and during their adolescence. Europe is lagging behind the USA and East-Asia in technological development and this trend will continue if not enough young people will chose to pursue their careers in MST. Can we do something on the curricular level to induce the positive change, to keep young people more motivated to study MST? Before one can give recommendations about possible improvements the present situation of the educational system and curriculum should be analyzed.
Within the SECURE project which ended in October 2013 partners from 10 European countries were connected to perform a research on MST curricula for pupils of ages between 5 and 13. The aims of the project were not only to study the formal (intended) curricula as described in available curriculum documents, but also their implementation and the perceptions of their direct users: teachers and pupils. Attention was given to several aspects of curricula, as they are represented in a theoretical curriculum spider web model [van den Akker]. Some general questions asked during the research were permitting to draw conclusions on motivation for example, and also on differentiation.

By the term differentiation all didactic methods which enable individualization of the learning content, process, and product, paying attention to the needs, interests, abilities and learning styles of individual learners are understood [Heacox, Tomlinson: The differentiated classroom], and also organizational solutions, which support differentiated teaching. If we want to keep up with the most technologically developed countries it is very important to find appropriate systemic solutions to the questions of differentiation and individualization, or differentiated instructions. The principle of differentiation is in the core of balancing the needs of future scientists with broader societal needs (the phrase was in the heart of the project’s goals): on one hand to ensure equal rights to education for every child and on the other giving each individual an opportunity to maximal development [Tomlinson: Mapping a Route].

We will present some results obtained from analysis of a huge amount of data, obtained within the SECURE project, on differentiation in MST education. We have also performed a descriptive analysis of national curriculum documents and checked for the presence and type of principles, recommendations and regulations on differentiation in general and also concretely to specific target groups of pupils. We have found much variety in documents of participating countries, extending from very detailed and regulated, for example, in Slovenia, and very general, for example, in the United Kingdom. Additional data from extended teachers’ and pupils’ questionnaires give us a complementary view from the perspective, how principles of differentiation, regulated more or less and written in national documents, influence the actual school practice. We find some significant connections between the nature of records on differentiation in curriculum documents and the school practice in some countries, and in few others the connections are not so conclusive.

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References:
Guiding students to combine partial laws of energy conservation within a scientific context

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In the Netherlands innovation committees for the exact sciences have advised a context-based approach (Boersma et al., 2007; Commissie Vernieuwing Natuurkunde onderwijs havo/vwo, 2006; Driessen & Meinema, 2003). Unsolved problems in context-based education are the difficulty to achieve transfer and the difficulty to develop abstract concepts in contexts (Parchmann et al., 2006; Pilot & Bulte, 2006; Schwartz, 2006; Goedhart et al., 2001). The concept of energy conservation is an abstract concept which is difficult for students to apply to various situations (Borsboom et al., 2008; Liu et al., 2002) and to revise when necessary (Kaper, 1997). The main question for our research has been the following: “How do context and concept interact in context-based education that is suitable to develop a versatile concept of energy conservation?”

To this end we have developed a context-based teaching-learning sequence for sixteen- to seventeen-year-old students in which a versatile concept of energy conservation may be developed. To improve the versatility of students’ conceptions we have chosen a guided reinvention approach (Freudenthal, 1991). The teaching-learning sequence is subdivided into three distinct stages: reinventing partial laws from measurements, combining those partial laws into one combined law, and extrapolating that combination procedure to arrive at the general law of energy conservation (Logman et al., 2014). The first stage of reinventing partial laws has been set in technological design contexts and has been the focus of earlier papers (Logman et al., 2010, 2011). Combining partial laws and the extrapolation of that combination process have been set in scientific contexts and will be the focus of this paper. The more specific research question for this paper therefore is the following: “How can students be guided to combine partial laws and to reflect upon such combinations within a scientific context?” To check students’ skills at the end of the teaching-learning sequence the students were given a scientific assignment in which they had to combine a new partial law into the law which had been established so far and to check whether such a combination would always be possible. About a third of the students were capable of performing such a combination and took steps towards extrapolating the combination procedure to arrive at the general law of energy conservation. Half of all the students concluded that it is always possible to expand the conservation law when necessary and thus that it is generally valid. None of the students stated that expanding the law would not be possible.

Students’ results on a test on applying the general law of energy conservation were comparable to the results for eighteen-year-old Dutch exam students in traditional education. In the learning process students showed scientific skills such as describing suitable experiments to combine partial laws of energy conservation, deriving physical laws from data, combining such laws, and reflecting on the procedure of such derivations and combinations. In traditional teaching of the subject these skills normally are not addressed. A fruitful combination of reinventing a concept and the use of authentic practices therefore seems possible even for an abstract concept such as energy conservation.

References
ENEM and physics learning in Brazilian high school

Marta F. Barroso, UFRJ - Physics Institute, Brazil
Marcelo S.O. Massunaga, UENF, Brazil
José Christian Lopes, UFRJ - IF & Colégio Pedro II, Brazil
and Gustavo Rubini, UFRJ – IF, Brazil

The entrance to most of the public universities in Brazil, and student financing to private universities, depends on the scores obtained by students in ENEM, Exame Nacional do Ensino Médio (Brazilian National Assessment of Upper Secondary Education). This exam consists of four tests, in the main areas of Language, Mathematics, Natural Sciences and Social Sciences, plus a written composition, and the methodological framework is Item Response Theory supported by a reference matrix involving competencies, skills, disciplinary knowledge and cognitive domains. This exam is a high stake one for students, and typically around 4 to 5 million submit to it every year; from these, around 1 million declares to be completing high school in the year of the exam. So, the analysis of the results of this exam may provide conditions for monitoring high school learning and quality of education in Brazil.

We present a study of the Natural Science Test of ENEM, specifically the physics part of it, over the years 2009 to 2012. Based on some qualitative categories, we classified the questions of these tests: disciplinary content, number of words, qualitative/quantitative aspect, contextualization, cognitive operation involved in solving them, necessity of science knowledge, and others. Some of them allow us to provide a profile of the Natural Science test: a disciplinary exam (physics items are about one third of the total), with a qualitative character, long and time consuming items, only a few of them demanding more complex reasoning and assessing some problem solving skills, and
The distribution of content in the test is not aligned with the traditional high school program, and this can eventually promote an undebated change in high school teaching in the country.

The answers of the students were analysed, based on the microdata available at the federal government site. This study was carried using basic statistical exploration and Item Response Theory to draw the item characteristic curve of the physics items.

A comparison was made between the qualitative analysis, via the classification of the questions, and the quantitative analysis, the exploration of the responses of the students in the physics questions.

The study of student performance reveals that the learning of basic high school physics is not attained, with a percentage of correct answers on items that is almost always small, and that items that require some type of disciplinary knowledge or require use of basic mathematical reasoning present a performance significantly weaker.

Also, it is possible to observe the impact of two subsets of groups: female students perform worse than male students in most items, and students that come from federal and private high school perform significantly better that those from state high school (75% of students in high school attend state or regional schools). We observe also DIF (differential item functioning) related to the type of financing (federal or state budget) of public schools, in both directions, and this can be explained by analysing the text of the question.

In conclusion, the combined analysis of student’s performance and content of the items reveal some of the characteristics of student’s learning in Brazil, at around 18 years, that can impact in the physics education system.

Session 5.4:  ICT and Multi-Media in Physics Education
Wednesday 9, 14:15-16:15
Room 10 (Aula 10)

Video-based lecture demonstrations and activities in introductory physics

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Studies on students learning in science and engineering disciplines consistently demonstrate that the students learn much better in an active learning environment rather than in a traditional didactic “transmission” lecture classroom. Many innovative activity-based science curricula that were developed over the last few decades demonstrate excellent results in a controlled research environment with limited enrollment, but this success is much harder to replicate once these curricula are adopted on a larger scale by typical science departments in large research-intensive universities. One of the major reasons for this is the lack of resources, the logistics support and sometimes expertise for a proper implementation of the teaching innovations in a typical science department that does not focus specifically on science education research. Lecture demonstrations remain one of the very few (sometimes the only one) vehicles to bring a real-world connection to a large-enrollment introductory science courses. Videoanalysis [1.2.3] brings additional opportunities to broaden the choice of the demonstrations in the lecture setting and beyond. Most modern digital cameras, cell phones and tablets allow the recording of video clips that can be downloaded to a computer (while camcorders can record directly to the computer in real time), while a special software allows obtaining motion data (both time and position) from each time frame (30 frames per second for a typical camera). The videos offers feasible, cost effective alternative to live experiments when the measuring equipment is unavailable, visible changes are too fast to be
observed in real time, or the event takes place outside of the classroom or laboratory. The videos can be shared through a course management system for the students to view the videos on demand. Student learning can be extended beyond the classroom by creating meaningful homework assignments based on these video demonstrations. In addition to the videos recorded by the instructors and students, relevant videos for demonstrations can be easily found on YouTube. Video-based demonstrations can be a very attractive option for the distance/online education courses, interest for which has been on a steady increase. For the in-class demonstrations, we follow the Interactive Lecture Demonstrations (ILDs)[4] protocol that is proven to be particularly effective in combating students’ misconceptions. This approach employs elicit/confront/resolve cycle where the students are required to make written predictions before they see a demonstration, then observe the demonstration, and have to reconcile their ideas with the results of the experiment after the experiment is completed. However, a common complaint about using ILDs in large classes is that the written predictions need to be marked or at least recorded for credits. Our approach combines Peer Instruction pedagogy, where the clicker questions are designed to probe students’ understanding of the underlying concepts and to collect the predictions about the experiment to be performed, as well as the result of the follow-up questions after the experiment and the discussion that follows. Although the research show that “clicker ILDs” are not as effective as the traditional ILDs with written predictions, we find that asking clickers questions related to the demonstration is an acceptable alternative to the standard ILD procedure, in particular, for large-enrollment classes. We will provide several examples of lecture demonstrations and follow-up activities.


Operating System Independent Physics Simulations

Osvaldo Aquines, Héctor Gonzalez, Pablo Pérez
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In his research on the cognitive development, Jerome Bruner[1] proposed three modes of representation: Enactive representation (action-based), Iconic representation (image-based) and Symbolic representation (language-based). These modes occur sequentially in the natural learning process. The Enactive representation is particularly important since it implies many senses. In the context of physics the Enactive representation would be the direct interaction with the phenomena, namely a laboratory. Unfortunately, in most physics courses due to classroom size, time, budget, etc. the course is centered in the development of the theory and solving equations (covering mostly the Iconic and Symbolic representation) and if there is a laboratory, it occurs at a different time and place. By this the student gets in a highly abstract reasoning process without a physical reference to relate it.

Computer based physics simulations offer the teaching process the opportunity to integrate the three modes of representation in the same classroom session, providing a more solid and integral learning process for the student. Nevertheless, nowadays there are many types of computing devices and several operating systems, and most of the actual simulations are operating system dependent and require specific libraries. These requirements limit their use to a certain type of devices and platforms. The offered complimentary alternative is a set of Java coded cross-platform physics simulations which can be used in any computing device on any the available operating
systems: from personal computers, tablets and smartphones on Linux, Windows, iOS or Android. They enable the student to interact with the desired phenomena at all times and places. Learning games and challenging scenarios can be proposed and left as homework, since the simulations can be accessed continuously and by this engaging the student in the development of knowledge. Since they help him become the center and administrator of his own learning process, they contribute to active learning and knowledge ownership. As well, making the interaction with the phenomena more persistent, a deeper insight of the concept is reached. This cost effective solution is intended to full the needs of the modern education system from elementary to college level. They can be used for illustrative purposes or to predict results using theory.

References


Video problems in recitations of experimental mechanics and electrodynamics courses

Sebastian Gröber, Pascal Klein and Jochen Kuhn
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The improvement of students conceptual understanding in introductory mechanics and electrodynamics physics courses is a relevant topic in higher physics education since many years. In our calculus-based courses (separated lecture, recitation and laboratory), we focus on recitations and replace a part of the weekly theory-based paper and pencil problems by video problems of equal content and level of difficulty.

A video problem consists of a given prerecorded video of an experiment (video experiment) and an accompanying sequence of single tasks. In video experiments, the well known video motion analysis is combined with sensor-based measurements. Not only kinematic quantities are directly or indirectly measurable, but also data of all by sensors measurable quantities can be displayed in such video-based real experiments. This enables the experimental representation of nearly the whole mechanics content and up to now of essential parts in electrodynamics in one and the same media format video.

Video experiments are designed to visualize physical processes and to illustrate the problem as well as to measure and analyze in a video analysis program easily dependencies between quantities with a few pairs of measured values. The use of video problems and especially the introduction of video experiments in recitations have two added values:
1. It is possible to establish relations between theory and experiment through a combination of well-designed theoretical and experimental single tasks. The simplest form is a comparison between a calculated and a measured value.
2. In contrast to paper and pencil problems it is possible to establish not only narratively but also experimentally connections between physical content and the context fields nature, everyday life, technique and physical applications. Therefore, video experiments are designed as model experiments (with laboratory equipment) or as outdoor recorded experiments (without laboratory equipment).

In general, video problems balance experimental and theoretical activities in recitations and first semesters might gain a more realistic insight in physical methods. Students development of conceptual understanding is fostered by visualization of problems in video experiments, by different forms of relations between theory and experiment, by representations of experimental and theoretical data in diagrams and by connections to different fields of context.

The talk gives reasons for the chosen approach, explains the structure of video problems and presents examples from statics and dynamics, geometrical and wave optics, electro- and magneto-statics, linear DC- and AC-networks, … to demonstrate the suitability of video problems in
recitations of mechanics and electrodynamics courses. Here we focus on the instructional design of video problems and seek to present empirical evidences next year.

**New Media Experimental Tools (N.E.T.): Using Smartphones and Tablet PC for Experimentation in Physics Education at School and University Level**

*Jochen Kuhn, Pascal Klein and Sebastian Gröber*

*University of Technology Kaiserslautern, Germany*

Smartphones and tablet computers (tablet PC) have increasingly become everyday tools for adults and especially for students. Their impact on our daily lives is rapidly increasing. Besides the well-known negative effects of these devices in schools or university courses (e.g., writing text messages in courses), the increasing use and technical development of, for example, a Samsung smartphone or an iPhone can enrich lessons, too. These devices in particular serve as suitable experimental tools in science (especially in physics) because they are usually equipped with a number of sensors. For example, most of the smartphones involve a microphone as well as acceleration sensors and field strength sensors, a light intensity sensor, a gyroscope, a GPS receiver, and a camera (CCD-/CMOS-Chip). As all the sensors can be read by appropriate software (apps), a large number of quantitative experiments in physics classroom and university courses can be conducted with smartphones and tablet PC. Within the scope of the research project New Media Experimental Tools (N.E.T.) we develop experiments using especially smartphones and tablet PC for conducting experiments in physics education and study their influence on students learning abilities. In this talk, we give an overview about the theoretical framework of the N.E.T.-project and present examples of using smartphones and tablet PC as experimental tool in different topics at school and university level such as mechanics, acoustics, (electro-)magnetics, radioactivity and so on.

We further discuss a quasi-experimental pilot study on acoustics in German 10th-grade classes. A number of control variables such as using the same teacher in the treatment and control groups, identical learning sequences and learning contents (except for the experimental material, viz., mobile devices vs. conventional experimental material), and the consideration of potentially influential cofactors and covariates are considered. This empirical design allows to investigate effects of experiments with smartphones in physics education (N.E.T.) on students learning and motivation in comparison to traditional experiments of the same content (but different learning material). The results of the pilot study shows that students learning with N.E.T. have a significant and larger effect on achievement in comparison to its content-identical conventional counterpart. Although no influence on total motivation can be discovered, data provide evidence that N.E.T. has a positive influence on the perceived self-concept (as a subdimension of motivation).

We end with a brief overview about a first study on the use of tablet PCs for mobile video motion analysis in introductory mechanics physics courses at university.
Non-relativistic moving frames of reference - Building a bridge between mathematics and physics with video analysis problems in experimental physics

Sebastian Gröber, Pascal Klein and Jochen Kuhn
University of Technology Kaiserslautern, Germany

Experimental calculus-based mechanics physics courses treat the topic “Moving frames of references” predominantly in a mathematical way: In lectures much effort is spend on deriving the formula for the transformation of the acceleration in a fixed frame of reference \( C \) into the acceleration in an accelerated frame of reference \( C' \) by use of vector analysis methods. An overall qualitative understanding should be that in \( C' \) additional inertial accelerations of the object appear to describe and explain motions in \( C' \) by Newton’s fundamental law. However, only a few traditional problems in experimental physics deal with this transformation because either inertial linear and centrifugal accelerations seem to be too easy or problems concerning Coriolis’ and Euler’s acceleration lead to coupled differential equations, which are difficult to solve.

Today’s video motion analysis programs offer the feature to set origin, direction and orientation of a coordinate system after each video frame new. These features allow to measure the trajectory of an object relative to a moving frame of reference. We use moving experimental carts or rotating discs to represent moving coordinate systems in a recorded video experiment. This enables us to realize special or combined cases of the transformation formula (e. g. for translated \( C' \): Galilean transformation and linear inertial acceleration) in model experiments. In addition to trajectories, acceleration vectors of the object can be displayed in the video dynamically.

With video analysis problems (video experiment plus problem statement) in recitations we try to foster student’s conceptual understanding of the transformation formula and of moving frames of references in general. Learning elements are:
- Identifying mathematical with experimental quantities
- Quasi simultaneously comparison of motions in \( C \) and \( C' \)
- Comparison of theoretically calculated and measured trajectories in \( C' \)
- Comparison of value and direction of total accelerations in \( C \) and \( C' \)
- Differentiation between trajectories and displacement-time-functions
- Variation of motion patterns in \( C \) (body at rest, body moving with constant velocity or acceleration) and parameters (velocity of object, angular velocity of \( C' \))

In the talk we present analyzed model experiments of increasing complexity which cover inertial accelerations. For example: Experimental verification of Galilean transformation, falling rain observed stationary and from a moving car, study of Coriolis’ acceleration and inertial accelerations during a looping drive.
The speed of sound in singing pipes

Giuliano Zendri, Stefano Oss, Luigi Gratton and Matteo Valdan
Università degli studi di Trento - Dipartimento di fisica, Italy

Physics of sound is a challenging field of investigation despite its apparently well-settled origins. Among others, we depict, as an interesting case study, the behavior of acoustic waves in a corrugated pipe. This is quite an intriguing situation, since it constitutes the working bases of a well-known "musical game", i.e. the singing "dragon" tubes which, upon their rotation, emit sounds with certain frequencies. As it will be discussed at the conference there are several parameters which are involved in this phenomenon: the geometry of the pipe is crucial for the pitch of the generated sound, thermodynamic properties of the air inside the tube also play an important role for its fluid dynamical behavior. We will show that such conditions require a deeper and deeper understanding of several acoustical and fluid dynamical subjects of study that, for many student, is a very demanding, often too much difficult treatment of basics of sound and its scientific representation. A complete description of this way of producing sound involves the study of nonlinear second order differential equations (of the Van der Pol kind) which are addressed only in specific academic courses. Despite it is impossible to analyze the whole problem with young students, one could easily deal with these aspects at different levels, without sacrificing scientific accuracy, with specific attention, as it is quite obvious, to the specific education context. The possibility to set up an experiment with young pupils, placed somehow halfway between physics and music, can show them a funny, rather unexpected way to play a sound and allows to observe that the higher the rotation speed of the tube (i.e. the speed of the air inside the tube) the higher the pitch of the sound will be. It is as well a sensible way to introduce them to the world of science, by showing them that physics can be (but is not automatically) fun and closely related to everyday life. With high school students it is possible to investigate more quantitatively the sound generation by means of a corrugated tube. This can be done by analyzing the relation that exists between the pitch of the tone and the length of the tube. The same result is also achieved by measuring the velocity of the air that travels into the tube. Furthermore, it is even possible to discuss the fundamental and overtone frequencies of an open tube and to relate them to the measured speed of sound in air. As said above, a deeper understanding of the whole phenomenon is left to an higher education level, in which it is possible to analyze and discuss the mathematical description of the propagation of a pressure wave. This should not prevent from dealing with complex phenomena with younger students. Sound is part of such a complex, yet fascinating world and students should be introduced to it as soon as possible, in such a way also to avoid more extended and demanding difficulties afterwards.
LED lamps and energy consumption: where is the power factor?

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Speaking of energy is more than an abstract, formal necessity of technicians and scientists. Energy is the sustenance of our society and as such it would be very much appropriated to be discussed and widely known at various, even non-formal, levels, including school activities and other educational contexts. In the present contribution to the conference, we discuss how, by means of simple electrical circuits, the idea of energy/power consumption should be properly addressed at the aim of obtaining correct evaluations and figures at quantitative level. In fact, despite its importance, in some experiments at didactical level wrong procedures are carried out for measuring the energy usage of home appliances, such as light bulbs. As it is well known, appliances behave quite differently if direct or alternate current are used: any appliance using inductors in their power circuitry (i.e. washing machines, personal computers etc.) are unable to work when powered with direct current. Moreover, speaking of energy consumption, it has to be taken into account that in AC current the electrical power is obtained multiplying the current, times the voltage, times the so called power factor (the "cos phi"), a coefficient that depends on the phase that may exists between the electric current and the voltage themselves. Several appliances have in their power circuits capacitors or inducances which indeed cause a phase shift between current and applied voltage. Electric power consumption will be then changed according to the aforementioned power factor. As it will be discussed at the conference, certain LED bulbs devoted to domestic illumination can lead to an higher current utilization because of their power factor induced by the AC phase shift. The magnitude of this shift, as well as that of the reactive energy produced, is determined by the design of the supply circuit that these LED bulbs typically have in their sockets. We have observed that certain LEDs have an indeed good power factor (almost an unitary one) and some others behave quite poorly in this respect. As we will discuss at the conference, the reactive energy, generated in our houses, is an important factor in the local distribution system because it increases the energy losses. Reactive energy could also trigger blackouts if the network is not capable to sustain its effects. The proposal of some intriguing experiments about energy consumption in didactical laboratories, like the one allowing students to measure the energy actually required by a LED bulb, will lead to a better understanding of the way in which domestic appliances used in our everyday life really work. This is an important step for becoming educated citizens, i.e. users aware of this tools and of a proper way of reducing energy consumption.

The Results of a Questionnaire about Spacecraft Flights and Tidal Phenomena

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Spacecraft flights and tidal phenomena are not a usual part of high school physics course in the Czech Republic although these topics are very interesting and offer many opportunities to attract students to physics and also to practice various parts of physics when explaining these two topics. A questionnaire about spacecraft flights and tidal phenomena was prepared, pre-tested and a main research was accomplished afterwards. It was focused on high school students which had already got through classical mechanics course (especially gravitation). The age of students was typically between 16 and 18. In our research took part 800 high school students from 13 schools from the
Teaching the basic concepts of the Special Relativity in the secondary school in the framework of the Theory of Conceptual Fields of Vergnaud

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In this work, we investigate the conceptualization of basic aspects of Special Relativity (SR) at secondary school level. Despite its importance, research on this topic has been limited, although it is worth mentioning in this direction the works of Saltiel, 1980; Hewson, 1982; Posner, 1982; Villani & Arruda, 1998; Pietrocola, 1999; de Hodson, 2013.

In our case we have conducted our research along the lines of the Theory of Conceptual Fields (TCF) proposed by Vergnaud (Vergnaud, 2013). It consisted in the design, implementation and evaluation of a didactic sequence specially elaborated to conceptualize the basic aspects of SR. The proposal is composed by eight situations, complemented with a set of exercises. It was carried out in two classrooms with students of the last year of secondary level (17 years old). N=(43)

The conceptualization was analyzed in a classroom context, where the selected situations are essential to promote the emergence of the relevant concepts.

The TCF defines Concepts as a list of three different, non-independent sets (Vergnaud, 2013: 156) “Concept = def (S, I, L), being S the set of situations giving sense of the concepts, I the operational invariants integrating the schemes advocated by the situations and L is the set of linguistic or symbolic representations (algebraic, graphics etc.) that allows to represent the concepts and its relations”. There are two kinds of operational invariants: concepts in action, that are pertinent categories; and theorems in action, which are propositions, considered true by the students.

The didactic sequence has three main parts. The first one referred to the classical kinematics and the principle of Galileo's Relativity, involves the following concepts: system of reference, observer,
measurement of length and time, relative motion, inertial reference systems, the Galilean law of addition of speeds (much smaller than c), and the principle of relativity.

In the second part the postulates of the SR are presented: P1) Indistinguishability between rest and the rectilinear uniform motion for free bodies in inertial reference systems, and P2) the speed of the light in the vacuum c is a universal constant of physics, independent of the source motion.

In the third part the most relevant kinetic results of the SR are considered. At the beginning the postulates of the SR would seem “acceptable” from the point of view of the intuition, based on our low speed world experience compared with c. Students do not conceive the counterintuitive consequences of the above mentioned postulates. The aim is to arrive as directly as possible to a situation where the direct application of the postulates reveals the relativity of the simultaneity. The choice is based on the fact that the existence of a universal time is one of the most deep-rooted idea of students. After conceiving the invariance of c, measured by different observers, the students analyze the incompatibility of this fact with the Galileo’s law of speed addition. Then, situations where the phenomena of time dilation and length contraction are manifest are proposed. This leads to the analysis of the relativistic law of speed addition. The range in which the relativistic aspects are observed has been emphasized. The large value of c, compared to the speeds of our ordinary experience, is the origin of our difficulties to understand phenomena like time dilation or length contraction. The sequence also proposes hypothetical situations where c is of the order of ordinary speeds. In such a case, the relativistic effects would be observable in everyday life and would not represent a contradiction to the intuition.

Data analysis shows the effectiveness of this small set of situations to introduce basics of SR in high school. They also reveals the process by which at the beginning, students naturally accept both, the relativity principle and the invariance of c, separately, but not the counterintuitive consequences of direct application of both together, like non-universal simultaneity, time dilation or length contraction.

How students conceptualize absorption of infrared radiation when interacting with matter? Findings from a research study and implications for an instructional design

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This study has been carried out within the REVIR scenario, which is an initiative in which secondary school students have access to a computerized laboratory at the Faculty of Education of our university and work in small groups during four hours with specific instructional material. One of the sessions included within the REVIR project deals with light-matter interaction, which is addressed to post-compulsory secondary students (16 - 18 year-old students), and promotes the use of different ICTs such as MBL technology connected to temperature sensors, and simulations. In particular, this session is aimed to make students understand the effects of absorption of infrared (IR) light on the part of matter, and the underlying processes, at a macroscopic and at a molecular level.

Within this framework, we have conducted a research study to analyse students’ conceptions of the effects and processes involved in matter - IR radiation interaction. Various authors have analyzed students’ understanding of greenhouse effect [1], global warming [2], and phenomena involving interaction between metals and electromagnetic radiation [3]. Our research study focuses more on students’ conceptualizations of absorption of IR light in terms of energy, and its effects in terms of physical changes (temperature increase) and internal structure of matter (molecular vibration).
For data collection, a question was posed to all students at the end of session. It was preceded by a text describing the application of an IR laser for acne treatment. During the academic year 2012-13, students were asked to relate what was described in that text to what they had learnt throughout the session. The analysis of the 67 students’ answers collected to that question revealed that many students explained the effects of the laser in vague terms, often repeating information included in the text, and so without providing evidence on their conceptions of absorption of IR light. In a consecutive version of the instructional material, two more specific questions were added after the text. From the analysis of 168 students’ answers to these questions, we found that less than 15% of students explicitly explained absorption in terms of energy associated to IR light. Rather than focusing on explaining the processes involved in absorption, most students’ answers focused on describing the effects at a macroscopic level or at a microscopic level. Students’ answers to questions posed during the instruction (after carrying out a real experiment and after using a computer simulation) and at the end of the instruction have been collected during the academic year 2013-14. The results of the ongoing analysis of these data and implications for further developments of the instructional design will be discussed in the presentation during the conference.

References

Session 6.2: Physics Teaching and Learning at University Level
Friday 11, 14:15-16:15
Room 8 (Aula 8)

Laboratory activities and the perception of the students

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The perception that students have towards laboratory activities has been analyzed on the basis of the results of a questionnaire that was distributed to a sample of 99 students from high school and about 270 university students from the Physics Bachelor degree course at the University of Torino. The objective of laboratory activities is not only the demonstration of concepts, laws and procedures: very important are also the attainment of a greater maturity and autonomy of thought and an increased capacity of cooperation and of using various types of instruments by the students. Nevertheless, the students (and on occasion also some members of the teaching staff) often give greater importance to the subjects more closely related to didactic on-face activities.
In this context, it has been considered interesting to analyze the perception that students of different ages and school levels, from the last years of high school up to the third year of university, have towards laboratory activities.

After a preliminary phase of study on the expectations and on the perceptions of the students relative to the laboratory activities, it was decided to conduct a more detailed analysis of the evolution of the student opinions. The objective was that of following the temporal evolution of the approach to the laboratory, starting from the students of the IV and V years of high school and going on to students in the III year of the degree course in Physics at the University of Torino, where 6 obligatory laboratories are in operation, 2 for each year of the course.

The questions can be grouped together into some main streams:
- The usefulness of the laboratory to attain a greater comprehension of Physics;
- The interest in and the complementary nature of laboratory activities and classroom lessons;
- Implementation in the capacity to use other instruments, whether of an informatics type or others;
- The usefulness and ease of use of the informatics instrumentation.

The questionnaire also included two open questions on “What I like” and “What I do not like” in the laboratory activities.

An analysis was then conducted for each question, on the basis of a chi-square test, considering a null hypothesis, which followed a simple uniform statistical distribution. Therefore, the non-acceptance of the null hypothesis shows the presence of a diversified response, which points out, according to the context, a change in opinion over the years, or a more positive opinion (or more negative) that that foreseen for a pure proportional distribution for all of the years, or for some of the years of the course.

The analysis work carried out on the responses to the questionnaire has pointed out some considerations, which had already been shared by the teaching staff, and offered some food for thought, which could inspire future didactic programing.

Overall, it is possible to state that the analysis of the responses has made it possible to point out some critical points on which to work, over the next few years, in order to maintain the educational aspect of the laboratory courses and, at the same time, to broaden the educational capacity and the positive acceptance of the students.

An investigation of contextual gender bias of FCI questions

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At the University of Manchester we have been using the Force Concept Inventory (FCI)(1) for the past six years to evaluate first year physics students’ conceptual understanding of Newtonian mechanics. We have collected data on about 1400 students, approximately 20% of whom are female. Analysis of the data reveals a consistent significant difference in the mean scores obtained by male and female students, both pre- and post-instruction, with the males outperforming the females by 10-20%. A similar gender gap has also been observed elsewhere in the UK(2), and the USA(3-6).

When we analyse the answers to individual questions we find that male students perform better than females on nearly all of the questions on the FCI. This is consistent with other data in the literature(6,7). However when we compare our data with similar data obtained in the US we were surprised to find that the gender gap is particularly wide for some of the same questions, especially questions 14 and 23. Such a gender gap might arise due to a male context of some of the FCI questions, and McCullough(8) has created a version of the FCI which uses a more female context for each of the thirty questions. An early study using this version (9) on a group of non-physics students showed no change in the overall scores for males and females. In a more recent study (10) on students in a calculus based physics course, McCullough concludes that changing the context of
the questions can affect how students respond but the patterns of change were very variable. However, the average scores obtained by the students in both these studies were between 22-46%, well below the 80% regarded as the threshold score for Newtonian thinking by Hestenes (1). In contrast, the average scores obtained upon entry by University of Manchester physics students range from 72-78%. This raises the question whether students performing at this level are affected by changes in the context of the questions. In 2013 we made context changes to questions 14 and 21-23, which had previously shown the greatest gender differences. We used a slightly modified version of McCullough’s questions, trying to avoid changing the nature of the physical concepts being investigated. Our analysis has revealed a reduced gender gap for question 14 but no change for questions 21-23. We conclude that significant gender differences in conceptual understanding of Newtonian mechanics remain independent of context. This implies that further research is still required to resolve the issue of the gender gap obtained by the FCI and the next stage of our investigation will involve the introduction of an intervention into our teaching of Newton mechanics, in an attempt to reduce the gender gap post-instruction.


Investigating student understanding of operational-amplifier circuits in upper-division analogue electronics courses*

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Until very recently, the physics education research community has focused relatively little attention on upper-division laboratory courses [1]. In particular, the analogue electronics courses offered by most physics departments have remained largely unstudied. While electronics courses have many learning goals, the development of a functional understanding of circuit behavior is typically an expected outcome. The limited prior work in such courses has generally either focused on student understanding of introductory circuits concepts or used the course content as a launching point for studying other phenomena. (Some relevant work, however, has also been conducted in electrical engineering courses.)

We describe a systematic investigation of student understanding of the behavior of basic operational-amplifier (or op-amp) circuits, which are ubiquitous in electronics. This multi-year investigation, which began at the University of Washington, was subsequently extended to include the University of Athens and the University of Maine. The study participants were undergraduates enrolled in upper-division physics courses on analogue electronics at all three institutions. To date, we are aware of only one published study of student learning of op-amp circuits; it was conducted
in an introductory electrical engineering course, and detailed insights into student thinking were not provided [2].

This investigation was designed and conducted through the lens of the specific difficulties empirical framework [3]; the goal was to characterize student thinking in sufficient detail to inform effective instructional interventions. The investigation was guided by the following research question: To what extent do students develop a functional understanding of basic op-amp circuits after lecture and hands-on laboratory instruction in an upper-division electronics course? In particular, we sought to determine: (1) the extent to which students are able to reason productively about op-amp circuits that correspond to “perturbations” of canonical op-amp circuits, and (2) the extent to which students are able to correctly describe the currents and voltages in a basic op-amp circuit such as the inverting amplifier. Data primarily came from several written tasks administered as both graded and ungraded questions. Additional data were obtained from clinical student interviews. Data were analyzed using modified grounded theory.

The findings from this investigation indicate that many students leave analogue electronics courses without developing a functional understanding of the behavior of op-amp circuits. We will discuss the most prevalent conceptual and reasoning difficulties identified, including the lack of a function understanding of both op-amp Golden Rules as well as tendencies to: (1) generalize Golden Rule II inappropriately, (2) overlook the role of the power rails when applying Kirchhoff’s junction rule to the op-amp, (3) ascribe a voltage drop to a resistor through which there is no current, and (4) reason locally and sequentially about the behavior of op-amp circuits. Specific examples will be used to illustrate important implications for instruction, including, for example, the need for greater emphasis on the power rails and the application of Kirchhoff’s junction rule to the op-amp itself.

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Probing the influence of the teaching method on students' ability to identify real forces in diagrams

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When solving physics problems, students often fail to identify real forces acting on the body under consideration [1]. This problem is mainly due to the abstract nature of the force concept, but it can also result from the traditional teaching methods. Typically, the mathematical approach to physics problem solving is characterized by introducing additional, nonexistent forces, thus leading to a loss of physical clarity.

Vector calculus, in most physics courses, is carried out by the traditional algebraic methods, i.e. by resolving the forces into components and then summing up the components of the same direction. In this procedure the number of the vectors appearing in the force diagram is significantly
increased. Although this procedure facilitates the calculation, it potentially leads to the misconception that the components are also some real forces. In addition, the procedure is not entirely in accord with the concepts of the Newton’s laws which state that the motion of the body is determined by the vector sum of the forces, usually not considering the components. The question arises: is the direct vector method [2] or application of the polygon rule for vector addition more successful in teaching mechanics?

In this study, we have developed an instrument that aims to measure the extent to which students can identify the real forces in different diagrams. Unlike the FCI test, which mainly checks for preconceived notions, our test checks for didactogenic misconceptions. In addition, our multiple choice questionnaire is based on the visual representation, where the students have to choose the diagram that correctly presents only the real forces. Using this instrument we made an initial study of the effectiveness of the two different problem solving methods.

Our test, consisting of 12 items, was administered to the two groups of first-year physics students at Rijeka (RG) (n = 27) and Split (SG) (n = 25) University, after the “concept of force” had been covered in class. We found the pretest item difficulty index ranging from 0.12 to 0.83, with the discrimination values from 0.21 to 0.93 and the KR-20 reliability estimate 0.72. Afterwards, both groups exercised additional force diagrams tasks for a period of two class hours. The only difference was that RG used the polygon rule and SG the vector components method. Posttest showed a shift in the average rate of correct responses which was larger for RG. The normalized average gain in RG was 0.46 compared with 0.24 in the SG. The ANCOVA showed a statistically significant difference (p=0.009) in favor of RG.

Based on these initial results we formulate the working hypothesis for the future investigation: If we apply the teaching method where the force diagrams are solved, not by separating force vectors into the components, but by adding them by using the polygon rule, we foster students’ ability to identify real forces and we improve their understanding of Newton’s laws. Further tests of this hypothesis are the subject of our future work.

References

Gender Differences in the Peer Instruction

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Peer Instruction (PI) is one of the simplest active learning methods to increase students’ engagement in lectures. We have implemented PI into introductory physics lectures in our University and the high school affiliated to our University. For evaluating the effectiveness of each PI we have used the Peer-Instruction efficiency (PIE), of which definition is given in analogy with the Hake normalized gain (H. Nitta, PRST-PER, 6 (2010) 020105). Combining PIE data with pre-post FCI results one obtains information about students’ naïve conceptions as well as the effectiveness of lectures.

In this presentation we concentrate ourselves on the gender difference. From our FCI results it is found that, before studying high-school physics, there was already a gender gap and the gap did not decrease after the lecture. For PI, both for the high school and the university, we found that the rate of female students giving the correct answer before discussion is smaller than that of male students. However, the averaged PIE for females is higher than males. This result indicates that females change their answers during discussion more likely than males. We also found that some clicker questions represent drastic gender difference.

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A large body of research has been carried out on physics and science education, investigating the difficulties that students face in studying motion and its causes. According to several researchers, many students are convinced that a constant force is required in order to sustain motion at constant speed and if the force is removed, the object will surely stop. This kind of reasoning has been recognized as stable patterns called ‘misconceptions’ or ‘naïve beliefs’ (McCloskey, Caramazza, & Green, 1980). Other researchers noted that students explain motion and its causes by invoking different resources that depend on the context of the situation. This phenomenon has been called ‘knowledge in pieces’, where the pieces involved in reasoning are ‘phenomenological primitives’ (DiSessa, 1993). Various conceptual change theories have tried to address these problems so as to find out causes and possible solutions.

In this paper we wish to contribute to our understanding of students’ difficulties with motion concepts. We ask if there is at least some continuity between lay and scientific forms of understanding of motion. To this end we will investigate how naïve beliefs (in the form of phenomenological primitives) are constructed in laypersons’ minds, and we will compare these beliefs to concepts as they are used by scientists.

The main tool used here is an investigation of the role of language involved in the description of motion and its causes. Lakoff and Johnson (Lakoff & Johnson, 1980, 1999) underline the deep and strong connection between language and mind. According to these authors, the nature of the conceptual structure that we use to think, speak and act is metaphorical; in other words, we understand something in terms of something else we already know. As a consequence of this, metaphor is no longer seen as a mere linguistic and aesthetic feature. The cognitive role of metaphor emerges in the process of structuring and acquiring new knowledge. Lakoff and Johnson also claim that our understanding of abstract concepts is ultimately grounded in experiential image schemas. Both Amin (Amin, 2009) and Brookes (Brookes & Etkina, 2009) argue that if we want to understand lay and expert comprehension and reasoning we should look at the metaphorical structure of language.

What we are going to illustrate here is the presence of image schemas and conceptual metaphors that ground lay and scientific language used to describe and interpret motion. We are going to investigate the research question by analyzing the language used in a large set of lay and scientific linguistic sources (lay language corpuses, scientific texts, secondary school physics textbook, etc.). Our approach allows us to identify some metaphorical structures which demonstrate the existence of aspects of continuity between lay and scientific conceptualization of motion. Furthermore, our results suggest that further research is necessary to find additional figures of mind involved in the conceptual structure of motion and its causes. In conclusion we believe that our research significantly adds to the understanding of the problems students encounter when learning scientific concepts.
Introduction

The results of the last PISA test are evidence of the low level of scientific competences of Chilean students. This raises the need to implement methodologies that suit the needs of the students in this country. The objective of this research was to determine whether the use of active methodologies in physics classes affects the scientific competences level of the students. The active methodologies used were: Peer Method (PM) and Inquiry Based Science Education (IBSE). The research was carried out under a quasi-experimental design, where the pre test and post test results were compared with a control group, in which was applied the traditional methodology.

Classroom Methodology.

The experiment was developed with Chilean students between 15 and 17 years old (secondary school) in the physics program. The unit worked was “Heat and Temperature”, implementing the methodologies previously mentioned.

The IBSE consists in exploring the contents in a laboratory experiment, where students are actively involved, planting hypothesis, asking relevant questions, analyzing results and proposing conclusions. In this particular case, this activity was implemented before each lecture, to activate student’s previous knowledge.

The PM consists of brief classes of no more than 15 minutes where the content is presented. After that, is shown a series of multiple choice questions. These questions are answered in pairs using clickers. After this, a software displays the results automatically, making possible to know the voting statistics. From these results, the teacher may choose one of the next three options: a) allow the group discussion, b) review the concepts again, and c) continue with the next concept. The advantage of this method is the information feedback during the development of classes, allowing to immediately recognizing the progress of the students.

Both pre and post test were composed of 21 questions adapted from the PISA science test. The results of the experimental group were studied using the Wilcoxon W and the comparison with the control group by the Mann Whitney U.
Results
A slight increase (2.7 points) was observed in the performance of the experimental group. Moreover, the previous gap between experimental and control group decreased from 4.5 to 2.7 points.

General conclusions
It is expected that, in a longer intervention in time, the results obtained by the experimental group increase significantly.
On the other hand, when a new methodology is chosen, the characteristics of students must be considered. Both the PM and the IBSE, require interaction and discussion between students, so it is required that there is mutual trust between them, that allows them to express their ideas freely.
If necessary, it is recommended that, prior to class, the group develops some activity to strengthen the communication and relationships among students, to make the methodologies more effective and favorable for them.

Bibliography

Exploring the physics of senses

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Our knowledge of nature relies on the basis of sense experiences. The five traditional faculties of sight, hearing, touch, taste, and smell, and the means by which bodily position, temperature, balance, etc, are perceived enter in our modelling of reality. The everyday thinking of reality is often far away from the description that emerges from the scientific knowledge taught in school.

Exploring the physics of senses can be an effective way to improve the students’ motivation and connect science to the real world that they experience. Moreover, revealing the mechanisms that allow to perceive reality can make science interesting and useful because it satisfies questions that are deeply rooted.

On the other side, many topics are involved in the physics of each sense both to characterize the physical quantities that the sense perceives both to understand the physiological mechanisms that allow the perception. Furthermore, it is not unusual that advanced topics, such as resonance, can be introduced in this context in a very natural and easy way. In order to achieve a deeper student involvement, specific learning paths have been developed and tested. These paths are usually interdisciplinary and rely on many lab activities in order to favor active learning in students. Examples of this motivational strategy for some senses are given (sight, hearing and touch). Preliminary tests with vary groups of students (full classes, small groups in optional laboratory and in a summer school) are presented. The main results indicate the effectiveness of these learning paths. Some difficulties emerge in expanding them at school whereas there is little habit of teachers
to work closely together in interdisciplinary projects. Some suggestion to develop this attitude in school contexts is given. Actually curricula in secondary school allow to select topics by teachers and specific projects which enhance motivation are encouraged. How to promote and realize this motivational strategy in this context are discussed.

**Nature of Science Fiction Education with a Blind Student**

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In order to understand the nature, science is invented and constructed in a long period. Scientists developed and learned lots of laws, theories, methods, and materials from huge number of experiences. Some thoughts from these experiences may bring science to science fiction which may be seen unrealistic first. Science is related with nature but scientists find unnatural or extreme solutions, discoveries and explanations which are natural according to human mind.  
The purpose of this study is about nature of science fiction education. In other words, explain how to interact the learner for better extreme thinking. Defining the science and science fiction in terms of the literature and figure out the principles of science fiction education are two main parts of this study.  
To integrate the suggestion gathered from students with special needs, a blind student is included the study. With the help of blind students’ suggestions, it is aimed to make the educational model for Science Fiction Education more universal. Universal educational models should reflect universal design principles. These principles let different learners learn through course or material designed for all. After the interview with blind learner, the decision about how a science fiction education should be designed to make it for all is turned around four principles; consistency of fiction, relation with our life, understandable by everyone, avoided from discriminative expressions.  
Additional to science fiction education is necessary for learners to make decision what is scientific or not; science fiction resources are important sources of information. Newspapers, novels, cartoons or other resources are not only for formal learners but also for informal learners.  
At the beginning of science fiction education, to talk about science fiction you do not need to be an expert as for about the science. Following the inductive and deductive methods of science fiction education is enough to construct a new fiction. For instance, choose an extreme condition and make it a general rule. This is a deductive strategy and you may predict that everyone’s electricity in the world was cut off at the same time in the future. The fiction continues through this context; how our daily life changes or how irremediable damages occurs. The nature of science fiction education includes this kind of low, medium and high possible predictions about future or explanations about the history.  
The possibility and time graph for each fiction reflects the nature of science fiction. Time explains the condition of fiction in terms of today, future and history. Possibility explains in which percentage of possibility a human may face to the fiction. This possibility also presents the scientific level of fiction. Therefore, science fiction education should let learners produce a view about their future and it is also possible that this view will become a purpose of learners’ research area.
Development of teaching materials: a course for geometrical optics for lower secondary students

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Geometrical optics is one of the core topics in physics instruction in lower secondary. Numerous learning difficulties and students’ conceptions have been identified by physics education research during the last decades (Duit, 2009). This knowledge about domain specific learning problems has hardly been used for the rearrangement of instruction. Physics education research shows that conventional instruction is in many cases not able to enable students to explain basic optical phenomena with the help of adequate scientific concepts (Andersson et al., 1983; Chu et al. 2009). Reasons for this may be manifold: Conventional instruction is frequently not oriented on students’ alternative ideas, or at least does not address them appropriately. On the other hand, daily confrontation with optical phenomena reinforces ideas which are frequently not in harmony with scientific concepts. These everyday concepts are deeply rooted in students’ cognitive frameworks and conceptual change is thus difficult to achieve (Gallili, 1996). What seems to be another frequent problem is that instruction in geometrical optics treats optical phenomena quite soon on an abstract level focusing on the construction of ray diagrams without taking the actual phenomena and related beams of light holistically into account (Herdt, 1990; Wiesner et al., 1995; Wiesner et al., 1996).

There are however, a few learning environments and content structures which were empirically evaluated and proved to be significantly more successful than conventional instruction in geometrical optics. We based our Design-Based-Research project on lower secondary teaching materials for geometrical optics on the ideas of Wiesner and others (Wiesner et al. 1995; Wiesner et al. 1996) and on the results of the empirical evaluation of these ideas by Herdt (Herdt, 1990). Our contribution reports two facets of this project on geometrical optics in lower secondary (year 8). Firstly, the research based development cycles of teaching materials and the accompanying evaluation of this development process with qualitative research methods like interviews and teaching experiments (Komorek et al., 2004; Haagen et al., 2013) is described. Secondly, first pre- and post-test results of the implementation of the developed teaching materials in N=3 year 8 treatment classes are reported. The results of this pilot study are contrasted with test results of N=16 conventionally instructed year 8 classes. The results show a positive impact of the materials on the learning processes.

References
A metacognitive approach for professional development of experienced physics teachers

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This research is focused on design and study of a metacognitive approach to professional development (PD) of high-school Physics teachers. We designed and studied a course that is part of a two-year M.Ed. program designed for experienced high school science teachers. Four metadesign principles from the Design Principles Database were implemented in the course: a) learning from and with peers. This enables the teachers benefit from the ideas of their colleges and introduces new perspectives and motivates them to interpret their ideas, b) making thinking visible. This allows the teachers examine their own knowledge integration processes and engage them in linking, distinguishing or reconciling their ideas, c) make contents accessible. The course setting included a variety of components: labs, simulations, media resources, academic materials and lectures. These components expose the teachers to a rich learning environment and enable them to scaffold their inquiry process and generate new connections within their science content knowledge, and the last principle was d) Promoting autonomy so students can become lifelong learners. This involves establishing a rich, comprehensive inquiry process that teachers can apply to varied problems both in science class and throughout their PD process.

The teachers were asked to develop teaching units in physics and were given the opportunity to teach and apply their units to children participating in an enrichment program in the college. The goals of our study were to characterize the design principles of the teaching units, and to examine the changes in the design that followed the interactions between the participants in order to understand the teachers’ meta-cognitive knowledge about designing teaching units in physics. The data included interviews with the teachers, reflections of the researchers, the teachers’ teaching units and activities, observations of the teachers' physics lessons, and the children's reflections after each lesson. The data was analyzed using qualitative methods. We found that all four principles were expressed within the teachers’ units. Teachers related to their meta-cognitive knowledge as a key component in the development of their unit. They mentioned learning from colleague feedback, from the children's reactions, and from the facilitator of the course. It seems that listening to the voice of the children was a new experience for the teachers, and could change their views about teaching and learning. This study strongly encourages teachers to develop and design activities and to test them in a supportive environment, that can help them in understanding their own beliefs as well as promote their meta-cognitive knowledge about teaching, learning and designing learning activities.
Preparing Future Physics Teachers in the UTeach Model

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In the United States, secondary school teachers who teach physics often do not have physics degrees since common certifications are for physical science (teaching physics and chemistry) or a combined certification for mathematics and physics. These composite certifications are due in part to the desires by schools to employ teachers who can teach more than one subject, to allow maximum flexibility in teaching assignments. The UTeach model for secondary science and mathematics teacher certification requires that teacher candidates earn a degree in science or mathematics along with required courses in education in order to receive teacher certification. In this presentation we will discuss the specific degree plans that future physics teachers must satisfy. In particular, we will discuss a required course called “Research Methods” in which students carry out original research, with most mathematics students doing a project in physics. Finally, we will examine UTeach student content knowledge using instruments such as the Force Concept Inventory and the PTRA assessment. We will identify gaps in knowledge that future physics teachers might have and present ideas for how to remedy those gaps.

Revisiting derivatives in physics with pre-service physics teachers

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This study is part of a larger, ongoing project on how best to prepare undergraduate physics students to become teachers in secondary schools. We report on our attempt to help pre-service students link concepts from different curriculum areas through the mathematical tool of derivatives. The focus of the study was not only to document physics teachers’ conceptions about derivatives in physics teaching and learning, but also to develop a course for teacher education. The theoretical framework of the study is based on teacher learning and transfer of learning from mathematics to physics across different curriculum areas. The physics curriculum areas were those of kinematics, thermodynamics and electromagnetism. We worked with thirty-two pre-service physics teachers during one academic year. The study investigated how the designed tasks and our study groups supported physics understanding. We conducted interviews with students based on their marked coursework and audio-taped discussion between instructors and students. We also collected students’ coursework and homework. Data analysis aimed at identifying their reasoning, difficulties and changes in performance on physics tasks. Students improved their understanding of derivatives, taking the derivative with respect to a different variable in various physics contexts and the associated physics concepts. However, some of the designed tasks were challenging even for the highest achieving teachers. It is argued that students’ difficulties with derivatives are due to lack of a deep conceptual understanding of physics and a sound understanding of the mathematical processes involved. We conclude with some recommendations for initial physics teacher education and physics education research. The next step will be to evaluate the proposed course for physics teacher education.
Science teachers’ transformations when implementing inquiry-based teaching-learning sequences

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Research has pointed out that teachers, when implementing innovative teaching-learning sequences, often transform original designers’ objectives. While some transforming trends may lead to fruitful modifications/enrichments to the original sequence, others may impact on implementation of the sequence in such a way that the original approach may be overall tuned down. To investigate the extent to which teachers transform innovative approaches may provide insights about factors that may impair the spreading of such approaches in school practice. Inquiry-based approaches are acknowledged as central in many curriculum reforms documents since mid-nineties. However, implementation of such approaches is still slow, especially in countries where curriculum is content-oriented. Previous studies have investigated the impact of professional development (PD) programs that could provide support for teachers about inquiry-based approaches. However, the transformations that teachers necessarily do in their practice when they implement inquiry activities deserve more attention to identify possible factors that may favor/hinder their adoption. To gain insights about these transforming trends may help teachers’ educators in developing more effective PD courses. In this study, ten in-service teachers (biology, chemistry, physics) with about 20 years of teaching experience, were involved in a 27-hours training course aiming at familiarizing them with inquiry principles. During the course, the teachers were trained using an “experiential” PD rationale. According to this rationale, the teachers are engaged in the same activities of their students to trigger the same cognitive processes under both disciplinary and professional viewpoints. Moreover, videos of expert teachers are shown in order to trigger discussions about benefits and pitfalls of the proposed teaching approach. The activities were organized along nine 3-hours sessions: during the sessions, the basic principles of inquiry teaching were addressed using seven inquiry-based teaching modules as training contexts. The modules were focused on the following topics: factors affecting heat transfer by radiation; collisions and momentum conservation; role of the light wavelength on the photosynthesis process; volcanoes on Earth and solar system planets; fossils and origin of life on Earth; chemical composition of soil and rocks. The modules shared the same objectives: - to use scientific ideas and models to explain phenomena and generate research questions and test research hypothesis; - to plan and carry out practical investigation in small groups; - to collect and analyze data; - to use experimental findings to provide evidence for scientific explanations. The modules all featured real-life examples as contexts for the investigation activities. After the training course, the teachers chose two or three modules to implement in their curriculum hours. The teachers were then observed when implementing the chosen modules. In this study, we report the findings related to three observed teachers (two biology, one physics). Collected data were: - video recording of the classrooms activities; - teachers’ interviews at the end of the activities; - audio recording of the debriefing sessions carried out after each school activity; - teachers’ portfolios filled in on a weekly base. The observed transformations are related to a limited interpretation of inquiry potentialities. In particular, the following trends emerged: - introduction of the concepts related to the module before doing laboratory activities; - scarce attention to aspects of scientific inquiry as students’ generation of the research questions; - forcing class discussions to get the “right” answer from the students; - scarce importance given to group work. From the interviews and collected portfolios, it seems that these trends may be reasonably related to factors as teachers’ ideas about teaching/learning processes and their experience with open-ended teaching approaches. As an implication, these findings suggest that PD courses should explicitly point out possible transformations that could occur when implementing an innovative teaching approach.
Interactive Whiteboard (IWB) and Classroom Response System (CRS): how can teachers use these resources?

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International literature showed that students have to face and overcome many difficulties in order to reach a deeper comprehension of Newton Laws (even though these laws are related to everyday life phenomena). In particular, teachers have to consider two different aspects:

(a) novices’ spontaneous ideas according to which there is a direct relationship, more or less linear, between velocity (rather than acceleration) and force in the motion of a body - what is called “motion implies force” concept (Clement, 1982; Viennot, 1985);
(b) learners’ difficulties related to graphical representation of physics laws and phenomena - for examples, space vs. time and velocity vs. time graphs, related to linear motion and to uniformly accelerated motion (McDermott, 1993).

In order to help students facing these difficulties, innovative learning paths based on ICTs technologies and real-time experiments play a crucial role. In fact, international literature highlighted the advantages of using new technologies in conjunction with laboratorial activities, as regards students’ engagement and skills’ development. A wide literature showed that ICTs can be used as “cognitive tools” as well as instructional media (Baek, Jung, & Kim, 2008), by employing mobile or integrated devices and different easy-to-use software. Interactive White Board (IWB) represents an example of these technologies (Al-Qirim, 2011). Although it is relative new technology in education, most of researchers in science education acknowledged its value, showing all the advantages of using it in teaching activities. IWB allows teachers to plan innovative learning activities, integrating real experiments with a wide range of ICTs resources.

In addition to IWB activities, many researches demonstrated that the use of Classroom Response System (CRS) with appropriate set of questions improves classroom dynamics (Reay, Bao, Li, Warnakulasooriya, & Baugh, 2005) and interactivity.

In this paper we present an experimental learning path on linear motion and on uniformly accelerated motion, combining IWB activities, real experiments and video-analysis (by using Tracker free software). We planned our learning path in order to address (in particular) students’ difficulties related to graphical representations, by using different ICTs activities (i.e. IWB practices, video-analysis of real experiments and Multi-Choice response activities through CRS).

We involved a sample of third-year science education students (University of Calabria). The obtained results lead to interesting conclusions, regarding engagement of students and improvement of graphical representation skills. In particular, the comparison between pre-test and post-test results shows that our learning path helps students to improve their abilities regarding graphs representation and analysis (related to linear motion and to uniformly accelerated motion).

This work shows in particular that Classroom Response Systems (CRS) are highly attractive for students and allow teachers both to involve the whole class in proposed activities and to analyze their responses in real time, encouraging discussion among students, as well as between students and teachers.

Bibliography


The nanolab project: educational nanoscience for high schools

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The growing role of the nano-perspective in contemporary technologies naturally calls for the inclusion of nanoscience in high school curricula[1,2]. In addition to the huge technological interest, which naturally appeals to students, nanosciences are a natural playground to introduce modern physics in a hands-on interdisciplinary way. Indeed, owing to the fact that nano-systems set themselves between the intrinsically quantum scale of atoms and the classical macroscopic scale, they can be easily probed and manipulated by several controllable external fields (temperature, pressure, visible light, electrostatic fields, etc), often responding, due to their quantum nature, in different, or even opposite ways with respect to ‘classical’ materials. This opens the possibility to explore intrinsically quantum phenomena in school laboratories, probing the properties of matter at the nanoscale by means of simple “macroscopic” experiments.

NANOLAB[3,4] is an educational project aiming at introducing nano-inspired didactical paths, exposing the main ideas of current Nanoscience and Nanotechnologies, into high school curricula. Through the use of carefully chosen nanomaterials, which are now available off-the-shelves and relatively cheap, great effectiveness can be reached at very low cost. Within the project a few key-ideas of Nanoscience and Nanotechnology have been selected and each has been linked to a relevant thematic area: nanoparticles, smart materials[5], conducting polymers, nanostructured surfaces. For each area, a small set of integrated experimental protocols have been developed which probe matter at the nanoscale.

In the existing panorama, most of the proposed nano-activities for young students are actually based on what we may call the “wow-effect”, i.e. in high impact spectacular but qualitative demonstrations, exploiting some of the peculiar properties and behavior of nanomaterials to fascinate and stimulate discussion. With the NANOLAB project we show that it is actually possible to go beyond this, exploiting wow-effects to capture student attention and give them the motivation for pursuing further, more quantitative investigations, and to interpret results within their own school labs. The NANOLAB activities are in fact designed as much as possible as the didactic counterparts of experiments performed daily in research laboratories; that is, students play with the real stuff, and explore the Physics behind the phenomena in an inquiry based approach.

Tools and methods in NANOLAB have been specifically developed to target teachers and their professional development. The aim is to make teachers confident and fully capable of independently testing and implementing the proposed themes and related activities in their own courses, without the need of a specialized assistance. For this reason, a great effort has been spent in training and supporting teachers by providing high quality and user friendly resources, networking possibilities and adequate professional development both on-site (two summer school, held during spring 2011 and in September 2013) and on-line (website and on-line community). Moreover, a kit with consumables has been currently made available for teachers to experiment with their classes.
Students’ misconceptions regarding everyday thermal phenomena

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Thermodynamics on every school level often deals with phenomena which have macroscopic manifestations, but microscopic explanations. Such an abstract approach can form or strengthen students’ intuitive incorrect beliefs – misconceptions. This contribution describes a research focused on secondary school students’ misconceptions in the context of common, everyday thermal phenomena.

In order to identify typical students’ misconceptions in this field, the Thermal Concept Evaluation (TCE) test was chosen. This concept inventory was originally developed by Yeo and Zadnik at Curtin University in Perth in 2001 and later it was used in other countries such as the United States, Turkey or South Korea. In order to use it for this research, the test was translated into Czech, adapted to the Czech environment and finally reduced into its present form which includes 19 multiple-choice questions regarding topics such as reaching the thermal equilibrium, heat conductivity, development of temperature during phase transitions etc.

In May and June 2013, piloting of the Czech version of the TCE took place and some minor revisions were carried out. Since September 2013, more than 500 secondary school students from 24 classes have filled in this test twice – for the first time (as a pretest) before they started the thematic unit of thermodynamics in physics lessons, for the second time (as a posttest) after they finished it. The results show that some misconceptions are quite successfully reduced in physics lessons, while some others are very resistant and in some classes they even strengthen. It is also interesting to compare the results in the Czech Republic with these in other countries where the TCE test was administered. In my contribution, the results will be discussed in greater detail.

Besides the questions regarding thermal phenomena, the test includes a few items which find out additional information about students – on the scale from 1 to 6 students should choose how they enjoy physics, whether they find physics useful for them and for the society and whether they expect they will need physics in the future. The possible correlations between the test results and the results of this attitude mini-questionnaire will be presented.

In the next school year, the testing will continue in order to involve schools in regions further from the Czech capital Prague. The most problematic topics will be identified and investigated due to qualitative methods; in addition they provide an inspiration to develop suitable simple experiments designed to face misconceptions in the field of thermal phenomena.
The task of the experiment that we intend to present is the effect of the presence of air and the evaluation of physical phenomena variation decreasing the pressure: the central topic of this work is therefore vacuum, its meaning and its effects. The choice of the topic was driven by the fact that the concepts involved are often explained by the theoretical point of view without an experimental evidence; for example, of particular interest is the study on the fall of a grave in the air and in vacuum. This work has been tested with a group of high school students at the university laboratory and subsequently developed in the classroom by teachers.

In the first part of the laboratory activity we present some qualitative experiences about the balance of forces; before the experiment we ask students to make a prediction of what will happen and to give a physical motivation of the response. Observing the Magdeburgo hemispheres, the effect of the vacuum on a balloon and on the baroscope behavior inside the vacuum chamber. Students discuss about forces involved and how these forces change decreasing pressure. The baroscope in particular allow to reflect on the effect of the air on buoyant force pointing out that in vacuum only gravity is involved. In the vacuum chamber is also possible to show that the sound wave needs a medium to propagate using the bell inside the vacuum chamber. This experience underlines the difference between mechanical waves and electromagnetic waves and how the first one require a medium for propagation.

In the second part of the laboratory activity a quantitative measure relative to the phenomenon of the fall of a grave is shown, using a tube and four photocells. This experimental apparatus allows a measure of the acceleration of gravity in vacuum and a measure of the speed of fall at different intervals of pressure. This measure allows students to quantify the buoyant force and the force of viscous friction.

In the third part it is possible to observe the phase transitions of water that occur at different temperatures changing the pressure; in particular it’s possible to observe the temperature of the boiling point. The use of internal energy decreases the temperature of water with its subsequent freezing; this observation allows an interesting discussion with the students on the phenomena involved. The curve of the boiling temperature as a function of pressure is plotted and it is compared with the theoretical curve for the distilled water: a fundamental educational point of view is the calibration phase in which the student evaluates the right time of reading of temperature and pressure. Using a solution of water and salt it is possible to compare the boiling point of distilled water and of the solution at the same pressure. The interdisciplinarity of physics and chemistry in this measure is relevant.

This course enables students to understand some fundamental physical concepts, important also in everyday life; it is mainly intended for high school students.
Integration of Historical Vignettes into Physics Instruction at the Secondary School Level in Nigeria.

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This study investigated the influence of historical vignettes on Secondary School Students’ Achievement in Physics. The integration of history of physics (HOP) in physics teaching and learning has been advocated by researchers such as: McComas, Clough and Almazora (2010); Justi and Gilbert (2000); Galili (2010) and Okoronka and Adeoye (2011). This is based on the obvious gains which experts such as Galili (2010) believe would accrue to physics education by so doing which include among others;
(i) creating deeper understanding of the subject matter of Physics;
(ii) helping Physics teachers to recapitulate and compare learners (novices) and experts conceptions by identifying and interpreting students misconceptions with those recorded in HOP;
(iii) revealing the nature of Physics; and
(iv) to express the culture of Physics i.e. the ethos, mythos and pathos of Physics so that it can become more attractive to the learners.

Historical Vignettes are part of the HOP strategies of instruction already suggested and applied by Wandersee, 1995 and Chan, 2005. These researchers are of the strong opinion that when HOP has been appropriately integrated into Physics instruction through the use of historical Vignettes, the ultimate gain would come by way of improved performance of learners in the subject. This underscored the need to experiment on the influence of Historical Vignettes on some secondary students’ achievement in electrostatics.

The study involved a Pre-test, Post-test, control group design. Use was made of two groups of learners namely the experimental and control groups. In the experimental group, historical vignettes (stories of the life, times and temperaments) of the three key scientists in electrostatics namely Alessandro Volta, Michael Faraday and Charles De-Coulomb, in addition to the electrostatic content was applied to some 29 senior secondary (SS II) Physics students. The control group simply involved teaching the same electrostatics content to another set of 41 senior secondary (SS II) Physics students without the vignettes.

Data on achievement were collected using a 20 – item objective test instrument adopted from past West African Senior School Certificate Examination (WASSCE) questions which are standardized items. A preliminary analysis of data collected using the independent sample t – test showed no significant difference between the pre – test mean scores of the two groups. However, the independent sample t – test analysis of the post – test mean scores revealed a significant difference between the experimental and control group. This is a possible indication of a positive influence of historical vignettes vis-à-vis HOPs on the achievement of students in Physics.

References
High school students face the magnetic vector potential: some relapses in their learning

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Although the magnetic vector potential is currently treated at university level in electromagnetism and modern physics courses using differential operators, in secondary school it is never introduced. But a quite important place is, instead, given to the electrostatic potential, often in connection with electrical circuit, thus creating a certain asymmetry in the didactical presentation of electric and magnetic fields.

Here we present an experimentation carried out in secondary school in which we have introduced the magnetic vector potential in analogy with the electric scalar potential, using the integral tools of circulation and flux [1]. Since these mathematical tools are the same that students use writing the Maxwell’s equations, our strategy for the introduction of the vector potential can be very useful, from the one hand to highlight students’ difficulties in electromagnetism, and on the other hand to stimulate students’ understanding of this topic [2].

The educational path for the vector potential that we describe, starts from the concept of scalar potential, in mechanics and electromagnetism, and subsequently introduces the concept of the magnetic vector potential. We propose a definition of the vector potential in close analogy with that of the electric scalar potential and its properties [3]: by means of this properties, students are able to calculate and represent the vector potential generated by some simple, but meaningful, current distributions just as they are able to do in the case of the magnetic field [4].

The last part of the path pertains the concept of gauge invariance, that is discussed starting from an example in which students determine two different vector potentials for the same magnetic field. Despite the gauge invariance could be considered too difficult to be faced by the high school students, we believe it is instead a great stimulus in order to reflect on the physical meaning of physical quantities. It is just in this context that we have developed the physical meaning of the magnetic vector potential in our path.

Besides the description of the educational path, we will present the outcomes of its experimentation in a high school science course of 25 students [1]. From the preliminary test and the oral interviews, the difficulties that students had in understanding the concepts of flux and circulation clearly emerged. During the sequence, we avoided every reference to the questions proposed in the pre-test, while the lessons were entirely focused on the vector potential. At the end of the path we submitted a post-test identical to the pre-test that showed a marked improvement in students’ abilities in dealing with the mathematical tools of flux and circulation.

Playing with (super)hydrophobicity: An interdisciplinary learning path on physical properties of water through high-speed visualization and software modeling

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The increasing complexity and pervasiveness of technological applications of the empirical sciences more and more suggests the opportunity of finding significant moments of integration of the physics’ teaching/learning process with that of other sciences, especially chemistry and biology. This need is highlighted by the success of educational initiatives at an international level (such as for example the “Co-ordinated Sciences” curriculum within the Cambridge General Certification of Secondary Education). There is no doubt that, in such a context, physics preserves a peculiar epistemic status, as it provides to the other empirical sciences the key, both conceptual and instrumental, for the success of the reductionist approach often taken by these sciences. In this context, great importance is assumed by the identification of teaching topics, within the physics curriculum, that lend themselves well to the preparation of interdisciplinary learning paths allowing learners to grasp a unitary perception of science.

In this perspective, a very interesting argument is represented by the physical properties of water, in particular those concerning its interaction with a large class of surfaces known as “hydrophobic” surfaces. Hydrophobicity, in fact, is a kind of “emerging” force driving many important processes, either in the biological realm (let’s think as an example to the self-aggregation of molecules giving rise to cells membranes) or in the development of technological applications (let’s think to the development of water-repellent clothing). In this context we have developed a consistent series of activities, both real and simulated (or visualized), including high speed video-analysis of fast phenomena, such as for example the interaction of water drops with some superhydrophobic surfaces easily achievable in a teaching laboratory.

Most of the real experiments we propose can be carried out with simple teaching equipment and are well suited to undergraduate students. Moreover, some well-known toys (such as, for example, the “Aqua Drop” and the “Magic Sand” games) inspire our didactical activities, whose playful nature allows teachers to construct learning paths at different levels, ranging from undergraduate students to primary school pupils. In particular, as regards the latter teaching target, proposed activities are complemented by some simulations made with the free software Scratch, aimed to illustrate in a purely visual way the property of hydrophobicity and the role of water in determining auto aggregating structures in the biological realm. On the other hand, the use of commercial grade photo/video cameras, together with freely available video analysis software, allows undergraduate learners to explore unfamiliar phenomena related to fluids, allowing them to get in touch with the principal theoretical concepts and practical applications pertaining a context located at the boundaries among physics, chemistry and biology.

Finally, the multimedia learning path aims to give students and teachers methodological and practical hints to independently conduct and analyze their own teaching experiments on such systems. Moreover, activities and documental materials presented give teachers significant examples of the role of video-analysis either in education or in empirical research.
The braced string - a simple system to discuss dispersion and elliptical polarization

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When talking about dispersion, phase and group velocities, the question we often encounter with students and teachers is this: "so the crests travel with phase velocity, but the group does not. The first crest then still reaches its destination with phase velocity, right? So how is it that information can not be transmitted this way?"

The system we describe provides an answer and is arguably the simplest system with a clear mechanism of dispersion and, therefore, the perfect playground for the topic. We define the braced string as a rope that is suspended on elastic strings - 'braced' in elastic material. The addition of strings results in dispersion and it can be observed and measured. We show that the dispersion is due to segments of the rope having their own natural frequencies, because they are connected to external springs and thus form oscillators. The phase velocity depends on the frequency of these oscillators.

We can see that a wave with well defined frequency travels at phase velocity by producing standing waves. We can also see that a pulse, made up of many frequencies, travels with group velocity. The pulse appears like a wave inside an envelope. It can be seen that the crest (phase) travels with a velocity higher than that of the envelope (group). The crest appears to be overtaking the envelope, but is still limited by it so it vanishes at the front as a new trough appears at the rear of the envelope. Mathematically we describe the phenomenon by decomposing the pulse into its component waves via Fourier transform. The actual physical mechanism for the disappearance of the crest and the appearance of the trough is rarely discussed. We show that this system offers the opportunity to do exactly that - identify the physical reasons for the phenomenon. This way we provide students not only with the phenomenon and the formalism to describe it, but also with physical reasons behind it, at least in this particular case.

The individual oscillators made from a segment of the rope and the string attached to it have different natural frequencies for vertical oscillation (they act as spring oscillators) and horizontal oscillation (they act more like pendula). This difference in natural frequencies causes a difference in phase velocities, which makes wave propagation anisotropic. In other words, the vertical and horizontal polarizations have different phase velocities. As with other cases where this occurs, a polarization of 45° is gradually transformed into elliptical, linear at -45°, elliptical again and back to linear at 45°. These are the same types of polarizations that occur for light in birefringent materials. We do not attempt to make a comparison, we just offer a system that shows the mechanical version of the phenomenon.

How close can we get waves to wavefunctions, including potential

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When first encountering quantum wave-functions, students often come into cognitive conflict when trying to compare the behaviour of a wave-function to the behaviour of a particle it is supposed to describe. We aim to diminish this cognitive conflict by providing a purely classical wave system that can reproduce waveforms of the same shape as most wave-functions encountered in introductory quantum mechanics. We provide the mechanical wave equivalent of a 'potential' which
takes the same role in the wave equation as potential does in the Schrödinger equation. We show that we cannot achieve this by changing the properties of the medium (e.g. linear mass density etc.). Instead an external force has to be used. Springs connected to the waving medium from a fixed frame can achieve this. Each of these springs and the segment of the medium it connects to now form an oscillator with a natural frequency. We show that this natural frequency determines the 'height' of the potential. This natural frequency is due to the external springs and cannot occur due to a change in medium properties.

The system is meant as a stepping stone that offers adequate classical wave experience to students, from which they can start building the quantum picture. We treat the system as a purely classical wave system and discuss the reasons, why a certain shape occurs. We discuss especially exponential tails in too high 'potential' and show that they are an inherent feature of waves. We believe that in the case of mechanical waves, it is intuitive, why a wave penetrates a 'potential' that is not infinitely high, and this can be exploited to diminish the cognitive conflict about tunneling, since quantum particles are described by wave-functions.

We are aware that opinions among teachers of quantum mechanics about making comparisons between classical waves and quantum wave-functions are very different, but we believe that students will make the comparisons anyway, because it is natural to try to relate a new topic to what one already knows. Therefore, we suggest how the comparison can be guided to be as close as possible to the quantum case and clearly point out the crucial differences.

With this system we were able to reproduce standing waveforms of the same shapes as the wave-functions of stationary states of the finite potential well, the infinite potential well, the potential barrier with 'potential' lower and higher than the 'particle energy' (the latter includes tunneling), and the parabolic potential of the quantum harmonic oscillator.

Reflection of the changes in modern physics curriculum on School Textbooks and Evaluation of these changes by pre service teachers: Turkey Sample

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When we take a look at how physics has been taught in the last twenty years, we can spot three main changes in physics curriculums. The 11th grade modern physics topics within the program applied between 1992 and 2010 are “theory of light” and “theory of atom”. With the reconstruction of secondary schools in 2005, the education span was elongated from 3 to 4 years and the 11th grade topics were continued to be taught in 12th grade with the same titles. Reconstruction also led to a new curriculum that was put into practice gradually after 2006-2007 educational year. While modern physics topics were given under modern physics unit in 11th grade with 2010-11 educational year, they were transferred to 12th grade by decreasing the functions with the new curriculum dating from 2013.

School textbooks are concrete sources introducing the curriculums to teachers and they are expected to cover activities that will lead the students to gain knowledge and skills determined in the curriculum. The purpose of the study is to investigate how changes in modern physics teaching as part of education programs affected the school books. Study group is composed of 18 5th grade pre service teachers attending physics curriculums of educational faculty who have received modern physics and modern physics teaching courses. Pre service teachers were asked to fill in book evaluation forms determined to be the data collection tool for the research. The form had two sections; one examining how functions and skills based on them are handled in present program and the other covering 19 statements related to “teaching-learning conditions; content and
assessment-evaluation” features of both the old and the present schoolbooks. The obtained data have been analysed quantitatively. It was found as a result of data analysis that 83.3% of pre service teachers didn’t regard - the questions testing knowledge functions; and 89.9%, the skills that need to be built on these functions- in sufficient levels. While 33.3% of pre service teachers thought the questions testing “skill functions “were adequate; 61.1% thought they weren’t sufficient albeit there were some. 72, 2% of pre service teachers were found to think that, old books didn’t have authentic examples; whereas 83, 3% considered the new books to partly have authentic examples. Pre service teachers have been found to think; in both course books modern physics sections were open to misconceptions. In terms of their ideas about assessment-evaluation features; old books were found more sufficient in terms of number of questions. Pre service teachers indicated, supplementary assessment-evaluation methods were poorly covered in both books however; old ones were mentioned to have assessment-evaluation methods with classifying while new ones, to have evaluation questions based on performance. In consequence it has been found about course books while teaching modern physics that; Authentic contexts are poorly covered, whether the expressions, pictures, figures or diagrams are going to lead to misconceptions or not is not taken into consideration, supplementary assessment-evaluation methods and pre-learning of students are underestimated. Present course books can be said to have performance-based activities, albeit insufficient. While preparing books about abstract subjects like modern physics in addition to having true, clear, understandable and up-to-date content, examples from daily life should also be included. It is also recommended that expressions, pictures, figures and diagrams leading to misconceptions not be covered; while examples, activities and questions that will improve students’ skills in different areas be included.

**Recasting particle physics by entangling physics, history and philosophy**

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The main goal of the paper is to present the design process we followed to recast particle physics so as to make it conceptually relevant for secondary school students. Since the first draft of the designed materials, the concept of symmetry was assumed as core-idea because of its structural and foundational role in particle physics, its crosscutting character and its epistemological and philosophical value (e.g. Brading & Castellani 2003; Hill, Lederman 2000; Van der Veen 2013).

The first draft of the materials was tested in a pilot-study which involved 19 students of a regular class (grade 13) of an Italian school. The data were collected through: a) a questionnaire on a selection of the teaching materials; b) audio-recordings of a lecture (2 hours) and of a classroom discussion (1 hour); c) individual written essays. 

The data analysis, whose details are reported elsewhere (Bertozzi et al 2014), showed that the students were in their “regime of competence” for grasping subtle nuances of the materials and for providing important hints for revising them. In particular, students’ reactions brought into light that the ‘foundational’ character of symmetry was appreciated for its potential of evoking connections among different domains of knowledge (music, visual art, physics, maths, …) but it was too vague from a conceptual and philosophical point of view. A more precise meaning for contextualizing symmetry in XX century physics and capturing its foundational role was missing.

The delicate step of re-thinking the materials required the researchers to articulate the complex relationship between researches on physics teaching, history and philosophy of physics. The new design process led to:
- identify, among the different meanings for the foundational character of symmetry in XX-XXI physics, the key-concept of 'symmetry as normative principle', that is a principle which provides constraints (norms) for defining particles as well as the shapes allowed for the physical laws (Toraldo di Francia 1978; Brading & Castellani 2003);
- explore the formal, linguistic, philosophical and historical aspects of ‘symmetry as normative principle’;
- draw out communication strategies (examples, metaphors, narratives…) for giving back the essence of the new key-concept.

This analytic phase resulted in a version of the materials which implies the students to be guided to grasp the meaning of symmetry as normative principle in XX century physics, throughout the exploration of the different meanings symmetry gained in science from antiquity to nowadays.

The whole process led also to the production of an essential, on-line version, of the materials targeted to a wider audience. This version is available as virtual exhibition on the website of ‘Museo Officine dell’Educazione’ of the University of Bologna (http://omeka.scedu.unibo.it/exhibits/show/simmetriafisica)

In the exhibition, the visitor is guided through three different virtual spaces (‘rooms’) where the historical meanings of symmetry are put in connections with different roles of concept. In particular: a) the room of poliedra explores the ancient meaning of symmetry as proportion; b) the room of crystals addresses the modern, group-meaning of symmetry as transformation; c) the room of the fundamental laws and objects presents the contemporary meaning of symmetry as normative principle.

References


Session 7.3: In-Service and Pre-service Teacher Education
Saturday 12, 09:00-11:00 Room 9 (Aula 9)

The Roles of Visual Perception and Interpretation of Interference Fringe Image in Pre-service Physics Teachers’ Model Development of Standing Waves in a Pipe

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Many pre-service teachers have only micro-abstract models among 4 kinds of model types and have a difficulty to connect phenomena and abstract models. Therefore it is needed that studies for developing pre-service teachers’ macro-concrete models and developing whole model through model transformation. Pre-service teachers’ prediction through initial models cannot be compared with phenomena, because standing waves in pipe is ‘visually unperceivable in fact’. Therefore pre-
service teachers have a difficulty to develop models. Electronic Speckle Pattern Interferometer (ESPI) visualizes pressure variation that is macro domain of phenomena. Pre-service teachers’ macro-concrete model can be developed by ESPI. 29 physics pre-service teachers were engaged in 4 hours activity. Entire activity was recorded, videotaped and analyzed with questionnaire and worksheets. Questionnaire and worksheets were analyzed by model type, model organization and model structure.

Pre-service teachers have a difficulty to have scientific macro-concrete model type as former study. However it is seemed that they can develop their macro-concrete model type with visual perception and interpretation of interference fringe images. It is seemed that pre-service teachers who use model transfer in scientific way may develop their model organization. It suggested that model transfer from concrete to abstract is effective at development of model organization and development of concrete model is essential for development of model organization. In particular non-scientific model transfer was more appeared in model transfer from concrete model to abstract model compared to model transfer from concrete model to abstract model. When variation of micro-concrete, micro-abstract, and macro-abstract model types which were acquired by model transfer from variation of macro-concrete model was different from variation of model types known before, they abandon variation of mode types which were acquired by model transfer. And then they write down variation of model types know before. Therefore non-scientific model transfer was occurred. This hindered development of model structure. It is important that making interference fringe images visual perceive easily for development of model structure.

The result of this study suggests that pre-service teachers’ development of macro-concrete model type is essential for development of model organization and model structure. And development of macro-concrete model type may be occurred by visual perception and interpretation about visualization of phenomena. This emphasis of importance of macro-concrete model type development may have implication for current instruction about standing wave in pipe concentrated in abstract domain.

Are the teachers left alone? The SECURE comparative study across ten European countries

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Wim Peeters, Dienst Katholiek Onderwijs vzw, Antwerpen, Belgium
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SECURE was founded as a collaborative project under FP7 to provide research results of current mathematics, science and technology (MST) curricula across Europe. The research focused on the MST curricula offered to 5, 8, 11 and 13 year old learners in ten European countries. The consortium invited 60 schools from each partner country to participate in the project. Altogether almost 9000 pupils, 1500 teachers and 600 schools took part in the study.

The research framework was constructed upon the curriculum spider web (van den Akker, 2003), in which curriculum is represented on a spider web with Rationale located in the center and nine other components (Aim and Objectives, Content, Learning activities, Teacher Role, Materials and Resources, Grouping, Location, Time, Assessment) placed around it, becoming the nine threads of the spider web, yet extended with the eleventh item: Attitude and Motivation, crucial for future scientists as well as broader needs of modern, knowledge-based society. The instruments used in the study consist of a transnational comparative screening instrument for MST curricula and of the school data collection instruments: teacher questionnaires, learner questionnaires and interview
protocols for all age groups of pupils and their teachers. A mixed method approach for the analysis of the MST curricula has been applied throughout three different representations of the curriculum: the intended curriculum (formal curriculum documents), the implemented curriculum (the actual process of teaching) and the attained curriculum (focus on learning experiences of the learners). Selected results have been already presented in several conferences and published elsewhere (Sokolowska at al., 2014a, 2014b).

In this contribution we particularly focus on the teachers’ perception about their professional development. During the presentation we will show the outcomes of the research comprising the need of professional development among MST teachers, the accessibility to the in-service courses and the time availability. The results show that large majority of the teachers express the need of the courses but they admit having no time for that. Moreover, when asked about the support received in their teaching, most of the teachers highlight receiving help from their colleagues and at the same time they barely see any support from the professional entities. The conclusion is that MST teachers across Europe need better in-service courses, tailored to their necessities, more attention from the professional education organizations and more systemic solutions, giving them time for the professional development.

Acknowledgement: 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

interactive methodologies in the training of physics teachers in a context of curriculum innovation: the peer instruction method

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Research on curriculum innovation in Physics in the High School confirms the need to shift from a teaching style focused on content transmission, to an interactive mode that addresses the needs of students, thereby altering current classroom dynamics to promote not only conceptual learning but also the development of cognitive and social skills. However, despite these advances in research, teaching based on content transmission has resisted change, largely due to limitations of teachers' knowledge and their beliefs surrounding the nature of their disciplines and their personal and professional identities in the teaching and learning of specific content (Pintô et al., 2001). In other words, how teachers learn to teach what they know, how they form their knowledge, as knowledge changes over time etc., are factors that need to be better understood during the process of curriculum innovation (Davis, 2003).

Our goal was to advance the professional development of future physics teachers by introducing topics of Modern and Contemporary Physics during their initial training, using an interactive
teaching method called Peer Instruction (Mazur, 1997). This work aims to map and evaluate the professional training of the prospective Physics teachers in Brazil, with emphasis on (I) the teaching methodology proposed and (II) the limits and the scope of the teachers' actions once the Peer Instruction approach has been implemented in their classrooms.

The research methodology was of a qualitative, case study type, and the tools used for data collection were: i) semi-structured interviews, ii) questionnaires and iii) the recording of video lessons. To categorize the data we used an analytical tool proposed by Mortimer and Scott (2002) to analyze the discourse and the production of meaning in the classroom.

Data was collected from a group of 12 pre-service teachers on the Physics Teacher Training Course of the São Carlos Institute of Physics, at the University of São Paulo/Brazil. The prospective teachers attended weekly meetings with a studying/reading group on topics of Quantum Physics, aimed at providing them with conceptual tools and preparing them to work with the proposed topics, specifically the Mach-Zendher interferometer and the photoelectric effect. Subsequently, the future teachers were asked to analyze the content studied and to adapt and organize it into a 16h-teaching module which was applied to a group of 20 Brazilian High School students.

The data analysis focused on the professional development of the student teachers with regard to the manner in which the content and meanings were shared in the social context of the classroom. The research provided insights into understanding the functions of the teacher-pupil interaction, indicating the alternation in the discourse of future teachers of a pattern between an authoritative communicative approach, with an IRE model of interaction and an interactive dialogic communicative approach, with an IRF model of interaction and. (Wertsch, 1991; Mercer, 2010; Mercer & Howe, 2012). The results show that the Peer Instruction method may be an efficient tool for preparing future teachers and enabling them to deal with methodological aspects in a context of curricular innovation, while actively engaging students in their own learning process.

The discursive aspect relating to the communicative approach, in the interactive/dialogic and interactive/authoritarian patterns, promoted between future teachers and High School students demonstrated how the discourse was conducted.

Our hope is to contribute to the advances in research on teacher training research in a context of curriculum innovation, expanding our interpretation of the mechanisms and processes involved in the initial training of Physics teachers which deal with interactive teaching methodologies, in particular, the Peer Instruction method.

**Views of Nature of Science of New Physics and Other Science and Mathematics Teachers: Traditionally Prepared versus Traditionally Prepared With Enrichment versus UTeach-Model Prepared**

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Until the fall of 2010, the undergraduate pathway to secondary science and mathematics teaching at The University of Texas at Arlington (UTA) was very traditional. Pre-Service secondary math and science teachers were majors in College of Science departments, and they had to seek advising towards teacher certification from the College of Education on their own. These traditional pre-service teachers did not have any pedagogy coursework until their junior year at the earliest, the pedagogy coursework served all secondary pre-service teachers (science, mathematics, history, language arts, etc.), and they did not have any field experience until their student teaching experience. Beginning in 2009, some of these students were awarded large National Science Foundation sponsored Robert Noyce Teacher Scholarships(1), and they received additional mentoring specifically for science and mathematics pre-service teachers. Beginning in the fall of
2010, all new pre-service science and mathematics teachers at UTA were enrolled in UTeach Arlington, a UTeach replication(2) science and mathematics teacher preparation program. In the UTeach Arlington program, pre-service teachers are actively recruited even before they start their freshmen year, receive instruction from Master Teachers with expertise and substantial experience as secondary science and mathematics teachers, and begin their pedagogy coursework and field experiences as a freshman. UTeach coursework is specifically tailored to science and mathematics pre-service teachers. In addition to pedagogy coursework, UTeach students also take a course in the history and philosophy of science and mathematics as well as a course called Research Methods. Students in Research Methods design, execute, evaluate and report on four inquiries. Once the initial cohorts of UTeach pre-service teachers became juniors in 2012, some of them also began to earn Noyce scholarships and receive additional enrichment.

The first students will graduate from the UTeach Arlington program in May 2014. The graduates will be given the Views of Nature of Science Questionnaire (VNOS)(3). The VNOS is designed to measure a subject’s understanding of concepts such as the tentative nature of scientific theories, the role of creativity in scientific experimental design, and the affect of social and cultural values on science. In addition to these first UTeach graduates, recent graduates of our traditional undergraduate program, both Noyce Scholarship winners and regular program completers, and recent completers of UTA’s post-baccalaureate science and mathematics teacher preparation program will also be given the VNOS.

The data will be analyzed to determine if there are statistically significant differences in the understanding of the nature of science between the physics, other science, and mathematics teachers produced by the traditional programs at UTA, the traditional programs at UTA with Noyce enrichment, UTeach Arlington, and UTeach Arlington with Noyce enrichment.


Do teachers’ conceptualization of key aspects of quantum mechanics really help to overcome the comprehension difficulties students have?

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There are several difficulties faced by undergraduate students in understanding some central ideas in quantum physics. These ideas are part of a worldview that presents assumptions and interpretations to give new meanings to phenomena that are interpreted in other way in classical physics. Thus, many difficulties students faced in comprehend physical problems could be attributed to the overlap or lack of differentiation between classical and quantum ideas (Johnston et.al., 1998; Kalkanis et.al, 2003; Baily and Finkelstein, 2010). In this sense, not being able to differentiate classical and quantum fields could be considered an epistemological obstacle to the acquisition of quantum physics concepts. These difficulties could arise from: use of analogies with classical interpretation of quantum phenomena; no distinction between classical and quantum objects; a deterministic interpretation of the behavior of quantum objects; the need for a probabilistic interpretation of quantum phenomena and the classic interpretation of the measurement process.

In order to overcome these obstacles in understanding students need to be aware of the conceptual difference between classical and quantum physics. Furthermore, this gap in knowledge has to be
addressed with the way we teach them. For that reason, a couple of question must be answered: Is this lack of differentiation between classical and quantum ideas well addressed in regular textbooks used for teaching in undergraduate level? And, a more important one: Are teachers aware of the way they conceptualized these quantum mechanical ideas?

One of the most thought-provoking parts of quantum mechanics is the Heisenberg’s Principle. It provides the opportunity to contradict the everyday experience, a way to discuss the probabilistic interpretation and measurement process in quantum mechanics. A previous study carried on with textbooks and research papers[1] (e.g. Sears et.al, 2009; Alonso and Finn, 1992; Kalkanis et.al., 2003; Johansson and Milstead, 2008) show us that many authors assign different meanings to this principle. The use of words like uncertainty, indeterminacy and accuracy is leaving place for a polysemic understanding of them, mostly related with classical usage. Furthermore, no mention is made about the different interpretation of those words in the quantum mechanical point of view.

In this work we focus on teachers’ conceptualizations of some of these basic features that could serve as an underpinning in constructing a comprehension of quantum mechanics. It is part of an ongoing project aimed to design and validate a didactical sequence for teaching the Heisenberg’s Principle.

Data were obtained from a survey conducted with Brazilian and Argentinian physics teachers as well as undergraduate physics students in a pre-service course of physics education. These survey were built on a few fundamental issues to differentiate classical and quantum objects and the interpretation of the Heisenberg’s Principle and the measurement process. It was implemented in a voluntary, anonymous and online written questionnaire. Participants were supposed to give explanations and meanings based on their own comprehension and experience. Specific questions were prepared in a manner to allow detecting contradictions between them. It was possible to access the questions in groups and only move forward once all the questions were answered and with the impossibility to return to previous answers.

It is noticeable that the initial phenomenographic data analysis has revealed that participants often depend on the classical worldview to describe and explain quantum systems. This is highly analogous with findings reported in studies carried on with students[2] (Cataloglu and Robinett, 2002; Mannila et.al., 2002; Ayene et.al., 2011). In case of physics teachers, this situation would be considered highly inadequate to teach quantum mechanics since they could reinforce the classical picture that students normally have. For that reason, new findings and some implications for instruction are discussed.

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Session 7.4: Pedagogical Methods and Strategies
Saturday 12, 09:00-11:00
Room 10 (Aula 10)

Investigating the Implementation of Hands-on Introductory Physics Curriculum at Abu Dhabi Men's College

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The popularization of flipping the classroom, blended learning and purely online courses, online video lessons (khan academy etc.) and interactive lessons (ALEKS) have shaped the landscape of teaching-learning dynamics which drives self-directed learning or independent learning. The pursuit to engage learners more actively in their own learning would then lead to modifying the instructional model; learners now can be tasked to do a mix of instructional activities (problem based learning, PHYSLET applets, PHET simulations, laboratory and classroom experiments) prior to the introduction of the theory or concepts in introductory physics. At Abu Dhabi Men’s College
where, traditionally, lecture dominates the semester long College Physics 1, the introduction of Applied Physics in the Diploma program which introduces the new mode of inverted instructional delivery is a novelty.

This investigative study will focus on the implementation of Hands-on Introductory Physics curriculum (ETD 1072) at Abu Dhabi Men’s College. Thus, there is a need to assess the implementation model; to gain insights on the appropriate calibration ratio (number of contact activity hours to number of lecture hours) and on the proper sequencing of varied instructional activities suitable to Emirati diploma students. The system approach (Input- Process- Output system) will be used in describing the conceptual framework of the study.

The study will employ both quantitative and qualitative methods of analysis in finding out the appropriate implementation model. Participants of the study will include two sections of Engineering Technology Diploma Emirati students of the second semester of Academic Year 2013-2014. The treatment will be administered in alternate mode. For section 1 (70/30 ratio), the first half of the course will employ PBL first while the second half of the course will have other activities first. For section 2 (50/50 ratio), the first half of the course will have other activities first and the second half of the course will have PBL first. Data on academic performance of ETD 1072 students and the attendance percentages, students’ perception on learning experiences, teacher evaluation and issues in implementing hands-on learning instruction will be generated, analyzed and interpreted. Qualitative data will include selected videotaped classroom sessions, interview of selected students, students’ portfolio and memos/notes of the instructors of the course. Quantitative data analysis will utilize descriptive statistics while qualitative data analysis will make use of ATLAS.TI software. Based on research findings, instructional model suitable to Emirati diploma students will be proposed. Implications of the study will border on applying the model to other Physics courses being offered at seven colleges of Higher Colleges of Technology.

Using existing inquiry based learning materials: is it really straightforward?

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Chain reaction is a project that spans 12 European countries. The aim of the project is to engage and motivate both students and teachers with the Inquiry Based Science Education (IBSE) approach and resources over a three-year period. In each country, students in the 14-16 age groups work together to research scientific scenarios, using and developing critical thinking, reasoning and problem solving skills. Source materials for using the IBSE approach are 11 selected Pupil Research Briefs (PRBs) that fit in “the Earth and the Universe” topic areas. These are being updated and modified by each partner country to come in line with the most current research outputs, curriculum developments and local contexts. We adapted two of the original PRBs for Slovenian students. The first one is “Green Heating”, where students try to improve the efficiency of a solar collector, while the second one is called “Plants in Space” that considers possible life on a space station. Two faculty members adapted the two PRBs and tested the modified materials by carrying out workshop activities in the form of “technical days” or “nature-sciences days” that are an integral part of lower-secondary education in Slovenia. Each activity was divided into three whole-day workshops. On the first and second day students learnt about research and proposed different ideas of how to improve the efficiency of a solar collector or of how to improve the photosynthesis rate with plants in space. They subsequently tested these ideas. On the last day they prepared presentations and reported on their findings. Green heating was carried out in 5 schools.
with approx. 100 students altogether, while Plants in space was performed on 3 schools with approx. 60 students altogether. Although the project’s written materials contained guidelines for various inquiry-based activities, an implementation in real circumstances was not straight-forward. This contribution analyses problems that occurred while adapting existing inquiry-based learning materials to local needs. It is a case study based on a reflection of two faculty members who adapted the two PRBs for Slovenian schools and tested them.

Several studies suggest that instruction is more effective when it connects new ideas to existing knowledge in a student's mind [1, 2]. The first problem we were confronted with was that PRBs were not designed with respect to knowledge of the target group of students in Slovenia. Consequently, materials contained a lot of data that required different level of students’ knowledge. We have noticed that connecting existing knowledge to a designed problem requires also its flexibility that allows for in-situ adaptations. Problems arose with adaptation for the appropriate level of students’ scientific skills and their cognitive level, with integration into the curriculum, and other contexts related to social or educational circumstances. For some examples(1) we suggest possible approaches for dealing with such problems. We analyze them in the framework of inquiry based activities Green Heating and Plants in Space.

The results of our study may help others who adapt existing inquiry based learning materials to the specific educational environment to predict possible difficulties in advance and to better estimate the time needed for such an adaptation. This is especially true for some time-limited projects where certain materials need to be modified. Additionally, the solutions we present here may serve as an accessory for solving common problems with adaptation of learning materials.

(1) Accompanying materials to Chain Reaction project

Some tasks to develop metacognition and evaluate students in Physics classroom

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A lot of research studies all over the world explicitly emphasize the importance of metacognition to learn science (White & Frederiksen, 1998; Schraw, Crippen & Hartley, 2006). In a review of researches on metacognition in science education, Zohar and Barzilai (2013) found that “the field of metacognition in science education is in a state of growth and expansion, and that metacognition is increasingly integrated into research addressing the core objectives of science education” (p. 121). According to those authors, developing metacognition can improve teaching and learning process. This idea is based on the belief that when students think about what they know (or not), what their doubts (or potentialities) are or how they can study in order to get their learning goals, it becomes easier for them to manage their own learning processes. Besides, if the teachers know such perceptions, it will be possible to develop instruction for the purpose of helping the students learn. However, how can the students develop metacognition in the classroom? Science education research provides a large set of activities to improve it (Beeth, 1998; White & Frederiksen, 2000; Koch, 2001). In this paper two metacongnitive tasks to evaluate the students are presented. In the first task, the student has to create a question involving some contents s/he has previously learned, to solve it and to explain why s/he made the question that way, with those characteristics. The question may involve writing explanations and/or calculus and shouldn’t be a multiple-choice one.
The second task is a self-evaluation. At the end of the semester, the student is requested to write a text (some phrases or a paragraph) individually. S/he has to report his/her impressions about his/her learning and development during the classes. S/he also has to identify difficulties, contents on which s/he had doubts, and possible causes of those problems. If the student wishes, s/he can also point out some ways to overcome the problems identified. Both tasks have been carried out since 2009 in a public High School in Brazil, during Physics classes. Analyzing the texts the students wrote in 2009 to evaluate themselves, four themes were identified: the student, the teacher, the teaching and the content. Mentions about the students themselves were related to metacognitive knowledge (person and strategy categories) (Flavell, Miller & Miller, 1999); the metacognitive knowledge (task category) was identified with the sentences about the content and the teaching. The presence of the teacher in the texts was related to the way she taught and it suggests that the students and the teacher established an affective relationship during the classes, which improves students’ learning. It is possible to conclude that self-evaluation can act as a monitoring and a cognitive self-regulation strategy, supporting learning, and also as an instrument of research on metacognition (Maximo-Pereira & Andrade, 2012). Considering the questions, their answers and what the students wrote to justify their questions in 2010, 2011 and 2012, one characteristic stood out: concerning the contents, most questions were about Mechanics, no matter whether this topic was been studied at the moment of the task or if it had been studied some time before that. A lot of students also considered that it is important to know a topic to choose it for creating (and solving) a question, which means that they realized the importance of thinking about what they know or not. Integrating both results, it is possible to conclude that the students seem to think they know themes in Mechanics, and curriculum and teaching characteristics have to be considered in order to understand this result completely.

Just-in-Time Teaching and Peer Instruction methods in the learning of Electromagnetism in a Brazilian high school

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Cognitive and emotional engagement is a necessary condition to achieve meaningful learning and substantial efforts have been made to develop didactical strategies that favor this condition. Just-in-Time Teaching (JiTT) and Peer Instruction (PI) are examples of methods which have been successfully used in the international scenario especially in the university level. This is not the case at Brazil, where very few didactical experiences exist with these methods, although there are many teachers willing to know and adopt new pedagogical resources, mainly at high school level. The combined use of JiTT and PI requires students to engage with the subject to be learned even before the class through Reading Assignments (RA); and during the class they are motivated to interact with their colleagues and the teacher through ConceptTests. The main goal of this paper is to present a didactical experiment which has been done in a Brazilian high school with the combined use of JiTT and PI to promote a meaningful learning of Electromagnetic concepts. We attempted to answer the following questions: What are the students’ attitudes toward the methods? What is the conceptual gain achieved by the students in Electromagnetism using these methods? Our proposal was implemented in a fourth semester class of a public high school, at a Brazilian city (Pelotas, Rio Grande do Sul). The instructional materials (including texts, videos, conceptual tests, experimental demonstrations) that compose the reading assignments and the ConceptTests presented in class were developed based on the main principles of Ausubel’s meaningful learning theory. The didactical unit was organized in 12 meetings of one hour and thirty minutes each. Seven of these meetings were intended for conceptual learning via Just-in-Time Teaching and Peer Instruction; three meetings, to solve traditional problems and two meetings for application of a pre/post-test. There
were two sections of high school students enrolled, one section with 29 students in the first semester of 2011 and the other with 15 students in the second semester of 2012. A control group with 18 students (2012) had traditional classes, but they could access all the instructional material worked with the experimental group, if they want. A qualitative analysis of the student’s receptivity to the teaching methods revealed very positive results. The most important one was their consciousness about the relevance of the reading assignments. They recognize that by reading some materials and answering a few questions in advance, they were able to make better use of the time in class to learn the physical concepts. They appreciated so much the method that they suggest it should be used in some others courses and classes. A conceptual test was applied as pre and post-test to measure the performance of the students enrolled in the courses. The average normalized gain for the groups with JiTT+PI method(0.65) resulted larger than for the controlled group(0.32). A t-test for independent samples shown a statistically significant difference for the averages (p<0.001). We conclude that it is worth to apply this combined method (PI+JiTT) to other subjects and to investigate its effect on the students’ self-efficacy and their habits of study.

Session 7.5: Physics Teaching and Learning at Primary Level and Pre-Service Teacher Education
Saturday 12, 09:00-11:00
Room 11 (Aula 11)

Education of pre-service primary school teachers for teaching the physics part of science in Slovenia

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Curriculum of primary education includes substantial part of science topics starting with in kindergarten in Slovenia. Therefore the teaching of science in a primary school is very important. The quality of teaching depends on teachers that have to have good education in scientific concepts and its didactics as they have to be skilled in experimental work appropriate for younger students. Primary school teachers in Slovenia finish 5 years university study program for the primary school teaching on Faculty of Education. They absolve the science classes (separate subjects: physics, chemistry and biology) and an intertwined didactics of science. Each subject has lectures, experimental classes and field work. Science subjects are considered as difficult by pre-service students.

Science curricula for pupils of age 6 - 10 in Slovenia prescribe that pupils should assimilate the following physics concepts: heat, temperature, density, viscosity, electricity, shadows, weather, movement of liquids, etc. It is evident that substantial physics knowledge is required by a primary school teacher that he or she is able to teach well both, the knowledge-seeking pupils and weak pupils.

We believe that it is very important that pre-service primary school teachers gain experimental experiences besides a theoretical knowledge of physics. The comprehension of physics concepts takes time and students understand physics better with having experimental experiences. Therefore we developed a set of simple hands-on experiments that support physics concepts studied at the University but can also be adapted for future work in school.

The contribution focus on heat and temperature. The experiments students study within this topics are presented. The results of the study of a development of conceptual understanding for three concepts: a temperature, a heat and an energy during the obligatory experimental labs will be reported.
The persistence of the alternative conceptions: the case of the unipolar model

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Several studies achieved among others in France, in England, in Italy, in Finland, in Australia and in the United States demonstrate that the conceptions of the teachers of the primary schools, as well as their pupils, on the basic notions in fields of physics, chemistry and biology are erroneous, compared to those commonly accepted by the scientists (Métioui and Baulu-MacWillie, 2014; Pilatou and Stavridou, 2004; Kruger and Summers, 1998; Newton and Newton, 1996; Kruger and Palacio, 1992; Webb, 1992; Webb, 1992). For example, in the case of the working of an electric circuit constituted of a battery, a bulb and two electric wires, several of these works demonstrate that majority of students explains its working while referring to the following models: (1) the model of the current that wears out (a part of the current consumes itself in the bulb), (2) the model of the two antagonistic currents (two currents leave the two boundary-marks of battery simultaneously) and (3) the unipolar model (the current leaves from the battery and arrive to the bulb; thus, the thread back toward the battery is considered useless is passive). These spontaneous models are relatively erroneous to the scientific model postulated that every portion of a closed circuit is crossed by the same current. Other works led this time on high school students having followed scientific teaching with regard to the working of electric circuits demonstrated that the unipolar model continues to nourish the speech of these students (Shipstone, 1985; Closset, 1983). It seems that this model lasts among some students frequenting the first academic year (Fredette & Lochhead, 1980). About the persistence of this model, Tiberghien (1988) underlined that the majority of the pupils abandons this erroneous model during the training of the electric circuits and that the one that persists the more to the teaching is the model of the current that is attenuated. Let's note to this topic that very few research have been done in order to insure that in fact, the pupils abandon this model more easily. The present research, of qualitative type, appears in this view and serves to identify the conceptions of future teachers on this unipolar representation. Besides, the survey of electric circuits been part of the curriculum in the primary school of Quebec in Canada, as in several countries.

SAMPLE, CONTEXT
Research has been achieved in the setting of a formation carrying on the didactics of the sciences. The sample was constituted of 88 students; their majority are female and registered in second year of the program in primary education. The middle age was of 22 years and the majority followed a course on the electric circuits during their secondary studies. They are all possessors of a diploma of collegiate studies in liberal arts.

METHODOLOGY
To identify the conceptions of the students with regard to the unipolar model, we distributed them a questionnaire of a length of 60 minutes including six questions. For each, they had to answer by true or false, while justifying their choice of answer, what was indispensable to identify their conception. Thus, in a first time, we compiled the answers, a question at a time, each taken separately. Then, we conducted their regrouping in distinct categories, the number of which being variable from one question to the other, according to the different advanced answers. Let's note that the analysis of the answers started by the distinction between those that are correct or erroneous and those that are incomplete or indecipherable. To qualify the answers of just or of erroneous, we compared them to those presented to the section "construction of the questionnaire."

CONSTRUCTION OF THE QUESTIONNAIRE
The questionnaire included six questions carrying on the notions of open circuit and closed circuit. Several of these questions have been presented in other research and we rephrased them slightly.
The first served to know if there is an electric current that circulates in the electric wires leading to a lamp, knowing that its filament is broken and that the switch is in position "on". In these conditions, no current circulates in the wires since the circuit is open. The second was about a circuit composed in series of two bulbs in series of which a bulb that normally illuminates and another one that doesn't illuminate. One wanted to know if, the bulb that doesn't illuminate is burnt. This situation concerns two bulbs that don't have the same features, what explains that one functions and the other no. This last "cannot be burnt" since the circuit is closed. The third question was about a circuit composed of two branching of which one is closed and contains a bulb and the other is open and contains two bulbs. The question was to know if the three bulbs could shine with the same intensity if they were identical. Evidently, it is not possible since in the open branch, the bulbs will be extinguished.

ANALYSIS OF THE RESULTS
The analysis of the results allowed us to demonstrate at the majority of the participants the persistence of the unipolar model. As illustration, we present the analysis of the first two questions. Of the electric current has in the case of first question, for 83% of the students, in the wire leading to the bulb, even though its filament is grilled. For several, the current is present in the wires since the switch is open. To justify the presence of this current, it is sufficient to remove the bulb, to put our fingers there and one will feel its effect: "The current reach the lamp. For proof, if one wants to change a burnt bulb, it is necessary to make it after having closed the current because this one is always present and one risk to electrocute them." (e39). As for the second question, 24 % advanced a just answer; to know that the bulb cannot be burnt otherwise the circuit would be open. On the other hand, most didn't specify that it was joined to the features of the bulbs and advanced erroneous justifications in referring to the model of the current that is attenuated: "It is just that the bulb A consumes the whole current coming from the battery and that there is not some unfortunately enough to light the B bulb." (e18).
For the majority, the bulb doesn't function, either because it is burnt or contacts between the wires are bad (62 %). Finally, according to 16 %, the bulb can be burnt but it also can happen that it is not grilled and that it doesn't illuminate because the bulb A takes the whole current (or a big part) and it doesn't remain any anymore (or not enough) to the B bulb.

CONCLUSION
In the setting of a formation program for the teachers in exercise and in formation, the conceptions identified in this research are applicable to develop strategies of teaching centered on the notion important of conceptual conflict.

Floating rules and Archimedes’ principle in middle school: Where to start?

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CFP e Departamento de Física e Astronomia, Portugal

Teaching the Archimedes’ principle and floating rules in middle school is a challenging assignment, due to the alternative conceptions of students about floating and sinking, and to the advanced reasoning skills required. Furthermore, many elementary physics textbooks explain Archimedes principle (floating and sinking) through incomplete or over complicated explanations. According to the researchers, it is fundamental that students have a correct and solid understanding of the concept of density before any formal instruction. On the other hand, a proper understanding of the floating and sinking phenomena requires an analysis of the relationship between buoyant force and gravity force. Therefore Newton's law must be part of the instruction of this subject, more specifically to understand how the immersed volume of the object and its buoyancy changes with the liquid or the object's density. Without this fundamental approach, students lack a sound understanding of buoyancy, which can probably explain why students remain, after the formal instruction, with their previous wrong ideas.
We designed and implemented two middle school lab sessions, though lab stations model, for a 9th grade group with 60 students. To promote an intelligible and rational teaching instruction of Archimedes Principle and of floating and sinking process, the laboratory activities were designed to help students realize the limitation of their own predictions, creating cognitive dissonance and surprise, thus facilitating the mental readiness to learn and to apply correct scientific concepts. The lab sessions were part of a module developed for three lectures (lasting 90 min) and two lab sessions (90 min). The analysis of previous research provided the outline of the main objectives of the module. The lectures, the lab sessions and the teaching materials were carefully prepared with rigorous content and skill objectives in order to develop relevant physical concepts and scientific reasoning skills.

To evaluate the effectiveness of the module, an instrument was devised to assess the students’ knowledge before and after instruction. The knowledge assessment questionnaire, simultaneously pre and post-test, was administered individually to the students to evaluate the general effectiveness of instruction in modifying the students prior common sense conceptions. Preliminary results indicate a significant educational gain specifically concerning the concept of density and floating conditions. But we also detected difficulties in the correct application of Newton’s second law and in relating buoyancy force and weight. The results of this pilot study will be used to reformulate the lab stations to address the difficulties revealed in this study.

References

Using digital teaching and learning tools with pre-service teachers for our modern primary science classrooms.

_Maeve Liston_

_Mary Immaculate College and the NCE-MSTL, Ireland_

The Irish Government’s Strategy for Science, Technology and Innovation 2006-2013 states that ‘if we aspire to build a sustainable knowledge economy and become world leaders in STI we must build strong foundations in primary and second level education and our system needs to develop to make this happen (Government of Ireland, 2006). Therefore Initial Teacher Education (ITE) programmes must not only provide the opportunities for pre-service teachers to develop a strong pedagogical content knowledge (PCK) but also a strong matter knowledge (SMK) in science by strengthening their conceptual understanding and investigatory skills in science to enable them to teach science concepts in a meaningful manner. Colleges of Initial Teacher Education (ITE) also need to ensure that all newly qualified teachers enter the teaching profession with the ICT knowledge and skills to be able to teach effectively, incorporating ICT into their teaching and learning strategies (NPADC, 2001; Lim, Chai, & Churchill, 2010). The Teaching Council’s Policy on ‘Initial Teacher Education: Criteria and
Guidelines for Programme Providers’ sets out a list of Learning Outcomes for Graduates of Programmes of ITE in Ireland, stating that graduates should be able to use technology, including multi-media resources, effectively to aid pupil learning (The Teaching Council, 2011). While pre-service teachers today are more skilled ICT users than their predecessors (Richards, 2004; Albion, 2003) it is often incorrectly assumed that they have developed sufficient skills outside their teacher education courses. European priorities for improving teacher quality and teacher education, state there is a need to improve teacher competencies in the use of ICT, linking knowledge and information about ICT to curriculum delivery (BECTA, 2006). Many studies in the past have highlighted that teacher education needs to diversify and all ITE programmes need to place a greater emphasis on the pedagogy of technology rather than focusing on the technical aspects of technology (EACEA, 2007; Pelgrum and Plomp, 1993). Teachers need to understand the potential of ICT, how to integrate ICT into their classroom teaching and be taught how to revise their pedagogical practices and so develop their Technological Pedagogical Content Knowledge (TPACK) (NPADC, 2001).

In ITE, one must also consider that our world is changing with an increase in the amount and variety of different digital teaching tools readily available to all. The National Strategy for Higher Education to 2030 stated that ‘in the coming decades, the delivery of higher education in Ireland must be characterised by flexibility and innovation’ (DES, 2011). This project is answering the calls from the above mentioned reports and requirements from the Government and Department of Education and Skills.

This research involves an integrated approach to science education modules, where technology is used to further develop pre-service primary teachers’ PCK and their TPACK to prepare teachers to teach where technology significantly impacts and changes teaching and learning methodologies in primary science classrooms. The overall aim is to use a variety of teaching and learning tools to (IpoDS and video editing, software) in Science Education Modules for pre-service primary teachers with the aim of enhancing the teaching and learning of science and strengthening their SMK, PCK and Technological Pedagogical Content Knowledge (TPACK) for the modern world.

The use of avatar animations in teaching physics to elementary school children

Angel Antonio Rojas Garcia, Universidad Cooperativa de Colombia, Colombia
Gustavo Alberto Atehortua Rico, Sena, Colombia
Cesar Eduardo Mora Ley Instituto Politecnico Nacional, Mexico
and Sonia Yaneth Lopez Rios, Universidad de Antioquia, Colombia

The teaching of physics and your particular interest in the teaching and learning processes of this discipline from the conceptual, experimental and problem-solving perspective, should redirect your efforts toward a better understanding of the elements of a scientific discipline. One possibility consists of focusing on the way the emotional and intellectual commitment is combined with the wonder of students for natural phenomena by promoting critical thinking and a scientific perspective.

In this work we present a proposal for teaching that involves the use of avatar (animated drawings) to approach the process of teaching mechanical physics to children between the ages of 5 and 7, using as selection criteria, a positive attitude toward academic, primarily scientific processes. The main purpose of the study is to determine the contribution of a teaching proposal focused on the use of video (based on avatar) to the understanding of mechanical physics concepts of a group of children.

Methodologically, the study is based on qualitative research with a collective case study, where each of the participating children constitutes a case analysis, to analyze the impact the proposal has
on each of the subjects in a particular way. Some of the main results suggest that children acquire an important motivation towards learning concepts from physical interaction with these potential tools, an essential condition for meaningful learning, which is also evident from the understanding of concepts and the relationships established between them.

**Session 7.6: Physics Curriculum and Content**
Saturday 12, 09:00-11:00
Room 12 (Aula 12)

**PROFILES Approach to Teaching and Learning Physics in Slovenia**

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Faculty of Education from University of Ljubljana collaborates in the project Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science (PROFILES). The PROFILES project is a four-year project funded by the FP7 programme of the European Commission which has started in December 2010. It promotes Inquiry-Based Science Education (IBSE) through raising science teachers’ self-efficacy and promoting a better understanding of changes in teaching science in schools and the value of stakeholder networking. The PROFILES consortium is composed of 21 institutions from 19 different countries.

In Slovenia 56 invited science teachers from primary schools and from secondary schools participated in the project. The national PROFILES group organized a Professional Development Programme that was designed to meet the criteria of the PROFILES philosophy according to which students are presented with a motivating, socio-scientific problem and engage in discipline-specific but also general skill-developing inquiry activities in order to solve a problem. Teachers formed groups according to the level of education (primary and secondary) and according to the subjects they teach (biology, chemistry or physics). In school years 2011/12 and 2012/13 9 primary school physics teachers and 2 secondary school physics teachers participated. The teachers worked in groups and each group developed PROFILES modules (3-6 school lessons each) taking into account the PROFILES philosophy and the aims from the national curriculum. The topics of the modules refer to the following physics concepts: pressure, density, air resistance, friction, motion with constant velocity, electricity and simple machines. Most of the modules were applied in the school environment.

Based on the collected and analyzed data and after three years of PROFILES experience, we can conclude that, the IBSE approach has been well accepted among Slovenian physics teachers involved in the project. Teachers report that this approach presents a positive challenge for them as well as for the students. However, there were also some disadvantages of IBSE approach detected, which must be reflected on and elaborated.

The focus of the contribution will be on the presentation of the PROFILES project in general as well as on the activities of physics teachers regarding to the designing of the modules and its evaluation. The advantages and disadvantages of IBSE approach in practice will be discussed as well.
Teaching physics with context in Polish schools – mission impossible or mission accomplished?

Agata Długosz
NCU Toruń, Poland

In the last school year (2012/2013) less than 10 percent of 365,000 Polish students chose the matriculation examination in physics. Other items of the group Science: geography – 80,000, biology – 77,000, chemistry – 47,000. This trend continues for the few past years and does not seem to be improved, in spite of curriculum has been changed in 2009. This prompts us to seek ways to increase interest in physics, show its attractiveness and pull it into practice. To achieve these purposes, physics teachers look for solutions adopted in other countries to replace the commonly used expository method (plus some practical elements – solving tasks, carrying out the experiments). The advantage of this method is undoubtedly providing new material for group of 30 or more students during 45 minutes once a week. So should an effective (considered as realization of the required curriculum) way be replaced by new form called teaching with context? The main objective of this project was to consider and evaluate this solution from the viewpoint of university student, who includes not only the pedagogical framework and the physics syllabus, but also relevant specifics of education system in Poland.

Teaching with context consists in combining real-life situations with the curriculum. The use of the latter allows to understand the former. This methodological proposal is relatively simple to implement. At the beginning of the lesson the teacher poses questions about the phenomenon or experiment: What happened? What would happen if? In this way, the teacher sparks students’ curiosity and they reflect on poser. The lesson is subordinated to capture answers to nagging questions. The climax of the class is formulating a response to a question from the beginning of the lesson. The lesson conducted in this way shows the usefulness of science. Even if the classes take the same form, the students do not fall into a routine, because they consider another research problem. They acquire not only knowledge, but also an array of social skills. In addition, the important elements are: deformalizing physics and focus on adoption of conceptual physics. This approach is very natural, so the teachers should put a lot of effort into preparing materials in this way. Increasingly, the authors of books for students start preparing the chapters in the shape of research questions. It is to be hoped that a large group of educators will be convinced to adopt such a model as soon as possible, because the results surpassed all expectations.

Nature of Science in science education: from ‘tenets’ to ‘themes’

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This theoretical paper addresses some issues related to “nature of science” in science education, in general, and in physics education, in particular. Our main aims are: a) to challenge the existence of a “consensus view” about Nature of Science (NOS) in science education research literature; and b) to suggest a more open and pluralistic/heterogeneous approach to deal with the “knowledge about science” in school science curriculum. We start by problematizing the question “what” knowledge about science to teach, drawing upon the existing science education research literature. This leads us to identify the existence of a “consensus view” about nature of science that has emerged in recent years and has dominated discussion in this area. This consensus view is based, mainly, on eight official science education standards documents, whose analysis led to the creation of NOS tenets. This list of NOS tenets contains short, direct and domain-general statements about science.
We argue that, despite its relevance to science education, the consensus view hides some divergences that should not be overlooked. In particular, we challenge the idea of the existence of a consensus, showing that there are different routes, terminologies, starting points and conclusions when we analyse literature elaborating this ‘consensus’. Moreover, some aspects of the consensus view are intrinsically problematic, and could, eventually, contribute to construct an exaggerated relativism. Thus, tenets such as “science has a subjective element” are criticised. Some other weaknesses of the consensus view are also briefly identified (e.g. that the consensus view does not represent sufficiently the differences between scientific disciplines). All of this leads us to the conclusion that there is limited consensus about what to teach about the nature of science in the science education research literature. In the second part of this paper we explore another approach to deal with the question of “what to teach” related to the “knowledge about science”. We argue that a better consideration of this issue in the school science curriculum would start from a more open and pluralistic/heterogeneous perspective. In particular, we argue for a different approach to think about curricula, based on NOS themes rather than NOS tenets. We present a proposal classifying these themes along two main axes: the sociological and historical axis and the epistemological axis. Each axis would group themes that function as guides for curricular choices (with subsequent definition about NOS content) which would be built in a more contextualized manner. The implications for science/physics education research and curricula development are presented. In particular, this approach contemplates, to some extent, the flexibility necessary to incorporate the plurality of views on aspects of NOS, especially with respect to the various scientific disciplines. Additionally, it prevents premature formulation of “general principles” on NOS and would avoid many problems associated with the consensus view and the NOS tenets. We finish by calling attention to the difficulties of design a more informed curriculum about NOS issues, due to the strong link between curricula, assessments and teacher education programs.

Methodology for a new project -Teaching and learning nanoscience and nanotechnology in Swedish secondary school with a risk education perspective

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The nanoscience and nanotechnology field is still diversifying in many scientific fields and industrial sectors, and the number and nature of applications is expected to increase rapidly. The nanoscale properties that make nanomaterials so appealing for the development of new applications could also convey risks to health and environment, as the toxicological properties of the nanomaterials most likely also will change compared to the bulk material. Risk has become a widely accepted concept in the public discourse on issues involving science, for example in the public debate about socioscientific issues (SSIs) such as GM foods, vaccinations, nuclear radiation, and is an essential tool when dealing with uncertainty and decision-making (Christensen, 2009). This project aims to link the expanding body of research on the public’s risk perception of NST to research within science education on SSIs, and to develop an approach to NST, which includes risk education. In the project we will explore how nanoscience and nanotechnology can be meaningfully included into school science curricula, particularly with a focus on developing appropriate educational practice. We also want to explore teacher- and student perspectives on the risks and benefits of NST, and let their comprehension, views and standpoints influence the educational design ( Jones et al, 2013; Wickman & Ligozat, 2011).

Research questions from three main areas:
I) Risk perception as a ground for risk education in school:
1. What are the teachers ‘and students’ perceptions of risks and benefits of NST, and how can this inform the development of teaching sequences in secondary school?
II) Student learning of NST and risk understanding from a research-informed teaching sequence:
2. How does a research-informed teaching sequence affect students’ learning of nanotechnology, risk understanding and the ability to discuss NST as a socioscientific issue?
III) Students’ and teachers’ evolving use of disciplinary representations of NST and risks:
3. How can different disciplinary representations in NST (for example computer models, transmission electron -, scanning tunneling -, atomic force microscopic images) be used to inform teaching about NST and how do they affect the learning outcomes?
4. How do students create their own representations in NTS?
In research area I risk perception studies will be undertaken in two schools with 50 teachers and 100 students through questionnaires and focus group studies. The analysis will provide information about Swedish teachers’ and students’ knowledge and awareness of risks and benefits of NST, which will be compared with international studies. This will also give a ground for understanding the demands of this topic in science education.
In research area II, researchers will work together with two teachers to develop a teaching sequence on NST. The teaching sequence will include a discussion on a socioscientific issue (SSI) (nanoparticles in consumer products), finished by a debate, in which the students participate in decision-making concerning NST. During 2014 a pilot project will be conducted in an upper secondary school, in which 12 students will take a course designed in collaboration with a science teacher, and researchers in the project. The teacher will orchestrate the talk in the classroom with awareness of the communicative approach, leading an SSI discussion on positive and negative aspects of nanoparticles in consumer products (e.g. cosmetics) and applications from biomimetics (e.g. gecko tape, shark skin swimming clothes) (Enghag et al. 2013). The course continues, inspired by the textbook Big ideas of Nano (Stevens, Sutherland, & Krajcik, 2010) - and ends with a student debate on NST and risk aspects (Simonneaux et al, 2011). During the main study an improved teaching sequence will be implemented in two schools.
During the conference methodology questions will be discussed and high-lighted.
In research area III the focus will be on disciplinary representations of NST. How representations are chosen or created by the teacher and students will be explored, as well as student responses to the representations (Hubber et al, 2010). Students’ conceptual understanding of nanoscience and nanotechnology will be investigated by analysing the use of argumentation in the video recorded lessons, and in the debate, which will finalize the teaching sequence. We will also analyse the students’ use of representations for both NST and risk.
In time of the conference some first results from the pilot study will be discussed.

HOPE: Horizons of Physics Education

Ivan Ruddock
University of Strathclyde, UK

Physics education is crucial for our understanding of the world around us and for the advancement of science in general. It also results in graduates able to contribute to economic growth through technological innovation as well as through advancing scientific understanding. In particular, physics plays a vital role in our responses to the major challenges facing the world such as climate-change, electrical energy production and new technology for health care. Physics graduates are also prized for their training in problem solving and generic or soft skills and are found in a broad range of non-technical careers in which they can apply and exploit these abilities. Good physics education is the bedrock of a technologically advanced economy and is vital for producing the highly trained workforce that Europe needs. And yet, in many European countries physics is not well appreciated.
by young people and there are still serious shortages of well-trained physics teachers and professionals.

The creation of a skilled physics workforce has a number of linked elements - inspiring physics teaching by properly qualified teachers must take place in schools, school leavers must decide to study physics at university, physics students must be trained in skills that make them employable, and there must be an awareness of physics and its contribution to society among the general public.

To investigate these strands, a new academic network HOPE - Horizons of Physics Education - has been funded by the European Commission’s Lifelong Learning Programme for three years from October 2013. It is effectively the physics education thematic network for the European Higher Education Area and is the sixth in a series of large networks beginning in 1995 with EUPEN (European Physics Education Network, 1995-2004) and its successors STEPS (Stake Holders Tune European Physics Studies, 2005-08) and STEPS TWO (2008-11).

The 71 full partners are from 31 LLP-eligible countries of the European Union along with Norway, Serbia, Switzerland and Turkey; they comprise 65 academic partners and also 6 non-academic partners including CERN, the European Physical Society and the Italian Physical Society. Collaborating physics departments range in profile from research intensive to those focusing on physics education research and the training of physics teachers. The consortium is further enriched by 10 associated partners including the United Kingdom’s Institute of Physics, the American Physical Society, IBM Zurich Laboratory, GIREP, and various universities in both North and South America.

HOPE is co-ordinated by Nadine Witkowski (Université Pierre et Marie Curie, Paris), Marisa Michelini (Udine) and Ivan Ruddock (Strathclyde). The network is researching and sharing good practice within four themes managed by four work groups: (i) the factors influencing young people to choose to study physics, (ii) physics graduates’ competences that enable them to contribute to the new needs of the European economy and society, particularly through innovation and entrepreneurship, (iii) the effectiveness and attractiveness of physics teaching in Europe’s university physics departments and their competitiveness in the global student market, and (iv) strategies for increasing the supply of well-trained physics school teachers and for developing links between university physics departments and the teaching of physics in schools.

This paper will describe HOPE in detail and the methodology used and present some preliminary results.

### Session 7.7: ICT and Multi-Media in Physics Education
Saturday 12, 09:00-11:00  Lecture Room B (Aula Seminari B)

**Performance Task using Video Analysis and Modelling to promote K12 eight practices of science**

*Loo Kang Lawrence Wee and Tze Kwang Leong*

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We will share on the use of Tracker as a pedagogical tool in the effective learning and teaching of physics performance tasks taking root in some Singapore Grade 9 schools. We discuss the pedagogical use of Tracker help students to be like scientists in these 6 to 10 weeks where all Grade 9 students to be conduct a personal video analysis and where appropriate the 8 practices of sciences (1. ask question, 2. use models, 3. Plan and carry out investigation, 4. Analyse and interpret data, 5.

We will situate our sharing on actual students’ work and discuss how tracker could be an effective pedagogical tool. Initial research findings suggest that allowing learners conduct performance task using Tracker, a free open source video analysis and modelling tool, guided by the 8 practices of sciences and engineering, could be an innovative and effective way to mentor authentic and meaningful learning.

actual tracker files down-able via dropbox links on this links:
http://weelookang.blogspot.sg/2014/05/tracker-koaytzemin-student-video-roller.html
http://weelookang.blogspot.sg/2014/05/tracker-deeakdev-student-video.html
http://weelookang.blogspot.sg/2014/05/tracker-wangyuxing-student-video.html
http://weelookang.blogspot.sg/2014/05/tracker-dianielleteo-student-video.html
http://weelookang.blogspot.sg/2014/05/tracker-camelialim-student-video-ping.html

**Enhancing the effectiveness of remote and virtual experiments for teaching undergraduate physics: lessons learned from students**

*Marcus Stefan Brodeur, Nicholas Braithwaite, Ulrich Kolb and Shailey Minocha*

*The Open University, UK*

With the recent rise of MOOCs refuelling interest in distance learning approaches, more academic institutions are exploring the use of online laboratories for teaching undergraduate practical science. Compared to maintaining traditional facilities, computer-mediated practical investigations offer cost and space savings and hold the promise of providing broader access to rare or expensive scientific instruments than is currently possible.

Two promising technologies are remote experiments (REs) and virtual experiments (VEs). REs permit students to operate tangible – albeit geographically distant – devices from anywhere in the world via an internet connection. By contrast, a VE dispenses with the physicality of a scientific facility altogether and allows students to interact with a computer-generated representation of a real-world apparatus.

While the uptake of REs/VEs has seen a gradual increase in recent years, research in this area has not yet addressed how student perceptions of these online experiments directly impact their effectiveness as teaching and learning tools. A review of the pedagogical literature – particularly regarding the application of situated learning theory and experiential learning to practical science activities – indicates that RE/VE effectiveness will be strongly influenced by concepts of authenticity and sociability.

Thus our first research question aims to establish which elements of REs/VEs lead students to perceive them as authentic learning experiences. Our second seeks to determine which aspects of these technologies affect their overall suitability for collaboration, as typified by face-to-face interactions in traditional lab settings. A third question – unique to VEs and not yet explored in the literature – concerns ‘metafunctionality’. Instead of viewing the intangibility of virtual experiments as a handicap, how can we take advantage of their non-physicality to enhance student understanding? Do students appreciate the inclusion of ‘meta’ features (e.g., alterations of scale or temporal flow) that would be impossible to implement on real-world instruments, or do they consider these to be unwelcome distractions?

We discuss the design, implementation, and findings of a 2013 study into how students engaged with REs/VEs as part of two undergraduate physics courses at The Open University (UK). A mixed-methods approach was employed to triangulate quantitative and qualitative data, which allowed us to determine student priorities for REs/VEs and to correlate their assessment outcomes with specific pre- and post-engagement attitudes.
Our analysis identifies distinct contrasts in the perception of REs/VEs between: 1, males and females; 2, students at different stages of their qualification; and 3, those who actually used REs/VEs versus a control group that did not. Females, higher-level students, and those who had no direct RE/VE contact were more likely to: 1, exhibit more positive opinions of these technologies; 2, consider them authentic tools for studying practical science; and 3, believe they promote collaboration while accommodating solitary learners. These three groups also tended to achieve more positive assessment outcomes.

Our results suggest linked priorities for physics educators and designers of REs/VEs. Educators should be proactive in countering any initial student scepticism regarding VEs by incorporating and highlighting the use of real data wherever possible. They should also devise backup strategies to ensure that students using REs are not denied an effective learning experience if connectivity issues arise. Practical activities relying upon these technologies should explicitly ‘build in’ opportunities for collaboration during the planning and data acquisition phases, rather than postponing teamwork until the data analysis phase. Designers of REs should focus on ensuring ease-of-use, stable connectivity, and supplemental information channels that help students visualise the immediate environment of the remote instrument. For VEs, design priorities should be verisimilitude in both the control interface and in data presented to students.

**Rolling motion: experiments and simulations focusing on sliding friction forces**

*Pasquale Onorato, Massimiliano Malgieri, and Anna De Ambrosis*

*University of Pavia, department of Physics, Italy*

As it is well known, rolling motion is a complex phenomenon whose full comprehension involves the combination of several fundamental physics topics, such as rigid body dynamics, friction forces, and conservation of energy.

Recently a number of papers have investigated students’ ideas on the relationship between friction and rolling motion, and identified typical difficulties. For example, students believe that kinetic friction acts on a body that is rolling without slipping. Furthermore, students perceive friction solely as a passive and dissipative force, and have difficulties in identifying its role in pure rolling. With the objective of spotlighting such role in detail, we propose an activity sequence based on both real experiments and computer simulations, and aimed at both high school and undergraduate students. Measurements are performed through the Tracker Video Analysis (TVA) open source tool; while interactive simulations are designed and run within the freeware 2D simulation environment Algodoo. The main steps of the activity sequence are:

(i) Students measure and analyze the motion of a rolling disk through TVA. The velocity of a point on the edge of the disk is tracked in both the centre of mass and lab reference frames. The typical cycloidal trajectory in the lab frame is observed and compared with simulation data.
(ii) Using interactive simulations, the role of friction in the dynamics of the rolling disk is studied, when no other accelerating force or momentum are applied. Simulations help students recognize the null role of kinetic friction in rolling without sliding, and show that, in absence of external forces, no sliding friction (either static or dynamic) acts on a disk that is already in pure rolling condition.
(iii) Using simulations of a disk rolling down a plane at different inclination angles, students investigate rolling motion with an additional force applied. They identify the pure rolling condition using the trajectories of a point on the disk edge; in these conditions, students compute the total mechanical energy of the disk, demonstrating its conservation and confirming that static friction does no work.
A case study is proposed: the comparison between the elastic collisions of two carts on a guide, and of two rolling spheres. For rolling spheres, the laws of conservation describing the collision between carts are no longer sufficient, since rotational motion and friction play a crucial role. Students are invited to explore several variants of the experiment by designing and manipulating Algodoo simulations.

The activity sequence has been proposed for preliminary testing to eight undergraduate students. In particular, the following research question was investigated:

- Is a combination of real experiments and interactive simulations effective in sustaining students’ understanding of rolling motion?

We conducted a pre-post test study, comparing results of our group with those of a sample of graduate and undergraduate physics students, who did not attend the course. We also collected data on the work done by each group of students during step (iv) and from final reports. Comparison of pre and post test results shows a sensible improvement in students’ performance after instruction. Moreover, analysis of qualitative data on students’ reasoning in step (iv) suggests that working with the modelling software helped students in de-structuring the initial complex problem, in analyzing the role of different factors and then in constructing correlations between them. In the conference presentation we will discuss some examples of Algodoo simulations created by students, highlighting the role that modelling activity had in scaffolding students’ knowledge.

**Physics Teachers’ Inventions Fair – a long-time source of teaching ideas**

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The Physics Teachers' Inventions Fair [1] is an annual conference of Czech physics teachers of all levels – from basic school teachers to university professors. They share ideas about new demonstration and laboratory experiments, long-term projects and how to make their lessons more attractive. There are about 100-150 participants and more than 40 papers presented each year. The tradition of the conference went back to 1996 when the first conference took place in Prague. Even though the impact of the conference is mostly national, every year there are more than ten participants from foreign countries who are also inspired. [2]

Papers from the conference are a very good source of teaching ideas because they are mostly ready to be used in the classroom. To offer these ideas to people who didn’t attend the specific conference we built the database of selected papers [3] which is freely accessible for public. Up to now, all 18 years of the conference are covered. Not all papers presented on the conference and published in individual proceedings are in the database. Apart from quality of papers our selection criteria demand that the papers have to be oriented on experiments, especially on the experiments with simple stuff and easily accessible equipment, or present ideas how to make learning more attractive and active.

The very best papers were translated into English and are also freely available [4]. After this was announced in the last year, a positive feedback from the international community led us to the decision to transform a simple list of English version of the papers into a form more comfortable to the readers. Therefore, a separate database of English versions of the papers is being built that will offer the same possibilities as the original Czech version. (The database is fully searchable, enables to find papers according keywords etc.). Also, the number of English versions of papers is increasing, now being about 60.

The presentation will introduce the conference as well as describe some technology details about database contents and statistical data of its utilization.


[3] Database of selected contribution: Inventions Fair for Physics Education
http://vnuf.cz/sbornik/
Abstracts of Posters
In the last few decades, products of scientific development have become increasingly more present in people’s daily lives so that students, nowadays, have easy access to information. However, the educational context is visibly less affected by the latest technological advancements than the rest of society. The current Brazilian school model barely differs from the one in use decades ago. On the other hand, it is easily perceived that basic education plays a crucial role in this society, within which, though, such model seems out of context. This paper approaches an investigation about how society grasps knowledge of Astronomy assuming that social groups have distinct representations of Astronomy as they do about any other scientific subject. The theory of social representations is used as a theoretical framework for getting clues on how Astronomy concepts are affected by the individuals’ social context. Essentially a Social Representation is built upon the influence of the individuals’ social environment as they try translate unknown things into familiar ones. The role of the media is emphasized here in relation to their way of addressing concepts borrowed from science and to the pressure they exert on individuals that construct their representations for such concepts. Social representations for a given subject might radically differ from the parameters of scientific knowledge so that they pertain to a consensual universe domain. In this sense, an experiment using mind mapping to search for possible social representations held by four 6th grade groups of students was carried out at a school in the outskirts of the metropolitan area of one of the main Brazilian cities. Additionally, a didactic strategy was developed according to the meaningful learning tenets and applied to the four groups of students, ages between 11 and 12, aiming at providing an approximation between the representations of Astronomy the students had expressed in their mind maps and those scientifically accepted and, above all, at formalizing a scientific contact between children and Astronomy. It was verified that although these students lived in a relatively well-delimited social group, they presented very few regularities in what concerns the relationship between Astronomy concepts and other terms. It seemed possible to conclude that the students’ concept of “sky” was limited to flying objects and atmospheric phenomena and the meaning they attached to “planet” suggested an intense relationship with daily life activities, such as playing or swimming, which could point out to comprehension of “planet” as synonymous with “earth” as “star” had strong linkages with “night”. In their representations in mind maps, not even the “sun” was understood as a “star”, or at least a common star”. In spite of mentioning “black” and “hole”, these learners did not seem to have already constructed a concept for “black hole”. Apart from attempting at identifying students’ social representations and from classroom activities, a research was carried out with the students’ parents with the use of word recall tests to increase understanding of the relations between what students had shown in the mind maps and their social relationships. Identifying a social representation can be a hard task, especially when the study goal is to ascertain to what extent information expressed by the students might mirror the influence of social context and/or poor scientific background. However, it must be emphasized that identifying social representations may offer a promising topic for science learning research, since it is directly
connected to representational obstacles that can hinder the scientific learning of concepts and to the scarcity of studies in this area.

Teaching astronomy in an Italian vocational school: a case study

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Since many years, the astronomy and physics education research group of Milan-Bicocca University is designing and testing longitudinal proposals for a coherent physics teaching in terms of framing ideas and practices (Rossi & Giordano 2013; Catalani et al., 2008). Although the research was traditionally directed to primary and middle school (K-8 grades), recently the group’s attention turned to vocational school. Since last October, indeed, it is conducting an astronomy teaching experience at the “Cometa Formazione - Oliver Twist” vocational school of Como (Italy), in collaboration with one of its math and science teachers.

This vocational regional school is a particular learning context arising and supported by a specific social, industrial and economic reality. Students, often at risk of dropping out of school, can select a professional training pathway in one of these levels: wood worker and property maintainer, furniture textiles operator, operator catering and room attendant bar. The school strongly supports and encourages teachers training and cooperation in motivating and guiding students in their educational path. All these characteristics make this school a particularly interesting context where investigate two research questions:

- How can science support the development of career competencies?
- How can skills and motivation of vocational school students support science learning?

To this aim, the authors chose to design and test a teaching proposal to engage students in an astronomy knowledge construction process. This approach relies on previous experiences and results of the Milan-Bicocca and the Italian research groups (Levrini & Guidoni, 2008). Moreover, it is coherent with the approach suggested recently by the theoretical framework for K-12 science education (NRC, 2012).

The experience involves 25 students (23 male, 2 female) of the first year of wood worker level. Two main reasons guided the topic and context selection. Students motivated and skilled in woodworking can be involved in the process of astronomy and physics learning by designing and constructing astronomical tools and models. At the same time, this way to enter the physics’ discourse can positively interfere with a growth in the mastery of career competences.

The teaching experience, which began in October 2013, will conclude at the end of this school year with a total intervention of about 30 hours. One of the university researchers is actively participating to all the science lessons and is working with the teacher to test and revise the proposal by the on-going analysis of the real students’ responses on cognitive and metacognitive plans.

The learning environment is designed taking into account multiple aspects: students’ prior knowledge, needs and reactions; teacher’s teaching style; known difficulties in understanding basic astronomy and suggestions to overcome them (Lelliott & Rollnik, 2010). Moreover, it is rich and interactive, introduces multiple tools and multi-representational forms (drawings, graphs, gestures and body movement, physical models, diagrams). Finally, particular attention is given to the use of several technological instruments for path development and documentation (the classroom multimedia whiteboard, a tablet available for each student, an audio-recorder, a digital camera).

The methodologies used in this study aim to investigate:

- Students’ learning outcomes and teaching effects through questionnaire and individual interviews proposed at the beginning and the end of the teaching intervention
- Students’ knowledge construction process through qualitative data collected along the entire experience (lessons' audio recordings; activities' pictures; students' notes, drawings, tools and models).

The authors will present a preliminary analysis in terms of growth in mastery of scientific practices, concepts and ability to perform scientific investigations by students. Moreover, they will present a preliminary discussion about the relationship between the scientific competences developed along the scientific learning pathway and the career competences students need for their vocation.

Bibliography


Determination of the Earth Radius by Observations of the Sun

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Though the computer-based technologies are developing rapidly in the teaching process, real physical experiment still has an important place, especially for understanding of fundamental natural laws and phenomena.

Astronomical observations may be considered as a kind of experiments using the contemporary level of optical and electronic devices, specialized software in row with the traditional equipment and data processing methods. Some of the experiments in this field may be done using ordinary devices which can be found in many universities.

As an example of setting up such an experiment, we measured the Earth radius using a theodolite for observations of the Sun in two separated points.

It is well known from astronomy, that the maximal angular height of any celestial object at its upper culmination can be derived from the formula:

\[ h = 90^\circ - \varphi + \delta, \] (1)

where \( \varphi \) is the latitude of the observation point, \( \delta \) is the object’s declination.

So, if we consider two observation points of equal longitudes, with the known distance \( d \) between them, we can derive the Earth radius as

\[ R = \frac{d}{\Delta \varphi} = \frac{d}{\Delta h}, \] (2)

where \( \Delta \varphi \) is the difference of latitudes, which is equal to the difference of the object’s heights \( \Delta h \) at the culmination moment, measured in radians.

We choose the Sun as such an object, and two observation points located on the same longitude 83° 46' 53" E (one in the city, another to the North of it). A modified approach was used for measuring the difference of latitudes, because our angle-measuring instrument (theodolite) could not measure heights about 60°, which is the height of the Sun in upper culmination on summer solstice at our location, when its declination is very slowly varying.

We had to measure less heights of the Sun before or after its culmination at the noon moment, and then derive the latitude by solving numerically the transcendent equation:

\[ \sin h = \sin \varphi \cos \delta + \cos \varphi \cos \delta \cos t. \] (3)
Here $h$, $\varphi$, $\delta$ mean the same values as mentioned above, and $t$ is the hour angle of the Sun:

\[ t = T - \eta + \lambda \pm 12 \text{ hours}, \quad (4) \]

where $T$ is the measuring moment (UTC), $\eta$ is the time equation value for the measurement date, $\lambda$ is the longitude of the observation point (all values presented here in time units have to be converted into radians according to: $24 \text{ hours} = 2\pi \text{ radians}$).

The experiment was set up on June 26 and 27, 2013. First row of measurements was done in the first mentioned point at $09:08 - 09:32$ UTC on June 26, the second row – in the second point at $09:08 - 09:36$ UTC on June 27. The height of the Sun was measured by a digital theodolite equipped with a special AstroSolar safety film filter with the 2-minute time intervals.

The distance between the measurement points was determined from a topographical map (54.6 km). All measured values and parameters were put into the calculation program, and the values of latitude for both measurement points were derived by solving the equation (4).

The obtained value of the Earth radius, taking the measuring accuracy into account, appeared to be very close to the real one.

We are sure that such an experiment can be performed at any location in the world.

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**On the comprehension of astronomical distances**

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The accuracy of astronomical conceptions of upper comprehensive school students (ages 13-16) in South-Western Finland was studied, with the focus on differences between the results of students following either the international MYP, or the standard Finnish national curricula. The interest in space related issues was also surveyed, and its connection to i.e. gender and grades was studied.

The results were compared to those of upper secondary school students in an IB program, physics teachers and teacher trainees, and astronomy students. The study was conducted as a survey, based on similar query conducted by Miller and Brewer (2010).

Astronomical distances were grossly underestimated. The median of the distance estimates for the Moon was about one sixth, and that of the Sun one hundredth of the correct value. The approximated stellar and galactic distances were in the range of one millionth and one billionth.

The students following the MYP international curriculum were the group with the best understanding of the distances. Gender differences in favor of the males were detected in both interest on space issues and in comprehension of astronomical distances.

As a conclusion it is noted, that teachers should use the travel time of light to describe distances, emphasize the multi-level hierarchy of cosmological structures, and underline the difference between a star and a planet. The need for development of space toys targeted for girls was also recognized.
Regardless of nowadays widespread use of satellites in navigation, communication and earth observation, they are still often considered as “mysterious” objects, mostly because they travel in space where most of us have never been, so that developing an intuitive understanding of satellite motion remains out of our scope. That’s probably why the dynamics of orbital motion, although being central to proper understanding of many aspects of physics, proved to be conceptually difficult for students. Being aware of conceptual difficulties of this kind, Newton wrote a popular text to explain the orbital motion of the Moon, that was published a year after his death. In this paper he demonstrated the significance of the velocity of the satellite as equally responsible for the orbital motion as the attractive gravitational force of the Earth [1]. Besides, the gravitational force is directed to the center of the Earth so that the center of the circular satellite orbit and the center of Earth should match.

In this paper we present students’ ideas about these important issues. For this purpose, we surveyed 276 high-school and university students from Croatia. Students were presented a nontraditional problem [2] with a diagram of the motion of the Earth satellite in different orbits and were asked to choose the one which is the best to receive satellite TV channels in Croatia. Implicitly students were expected to recognize the only possible orbit, for which the gravitational force is directed toward the center. The students were also asked several questions to explain their choice. In order to gain insight into teachers’ awareness of student's knowledge, we asked 48 physics teachers to predict how their students would answer the given problems.

The results of our study suggest that most students have difficulties with providing physically based explanations. They tend to use phenomenological primitives [3]. Specifically, they tend to use the “closer is stronger” p-prim when attempting to identify the satellite orbit which would ensure the receipt of satellite television signal at a certain location, paying no attention to the direction of the gravitational force.

Our results also show that students across different educational levels and curricula in Croatia lack deep understanding and functional knowledge related to the concepts of circular motion, gravitational force and first cosmic velocity. This conclusion is supported by the fact that only 4 % of students provided complete answers regarding the causes of satellite’s motion. Moreover, the teachers considerably overestimate students’ abilities.

Based on this study we believe that the use of diagrams could facilitate designing an interactive classroom environment, especially when it comes to promoting of a creative classroom discussion. However, further experimental studies are necessary in order to additionally reinforce the effectiveness of the proposed approach.

References:
Surveys of elementary training teachers' and pupils' conceptions of Newton's laws of motion

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The works of numerous researchers demonstrate that among the pupils of the elementary school (7-12 year-old), their conceptions of the force and motion concepts are naïve and similar to some theories developed during history and that have been refuted since the advent of the classic mechanics developed by Newton (Watts & Zylbersztajn, 1981; Gunstone & Watts, 1985; Kruger, Palacio & Summers, 1992, Sequeira & Leite, 1991). These misconceptions should normally be changed following formal training, but several works demonstrated that they persist in spite of teaching (McCloskey, 1983; Driver, Guesne & Tiberghien, 1985; Sequeira & Leite, 1991; McDermott, 2003). The present communication is related to this problem and aims to uncover the conceptions of 58 pupils (aged between 10 and 12 years) and 85 students in a teacher training program for elementary school (aged between 19 and 23) with regard to the Newton's laws of motion. To identify their conceptions, we proceeded with classical methods such as paper-pencil questionnaire. It should be noted that the questions asked (N = 7) were based on the researches done worldwide in elementary schools and their teachers' misconceptions on force and motion. We also took into account the notions prescribed in the school program of the ministry of the education of Quebec (MELS, 2002) such as: (1) identification of the situations where the force of friction is present (to push on an object, to make an object glide, to make it roll); (2) identification of the presence of a force (ex. : to push, to throw); (3) to describe how a force acts on a body (ex. : to put it in motion, to modify its motion, to stop it); (4) combined effects of several forces on an object (to foresee the effect combined of several forces on an object at rest or in a straight line motion (ex. : addition, opposition); (5) to describe the features of motion (ex. : speed) and (6) to describe the effect of the gravitational attraction on an object (ex. weight). As illustration, we present three of the retained questions and their analysis. For example, the first question is related to the Newton's third law of motion: "Someone tries to move his car (engine not working), but unfortunately, the car is not moving. According to you, is there a force on the car? Explain your answer". By this question, we wanted to know if the students and the pupils would explain that when one is not able to move an object, it is related to the presence of other force equal and opposite to the muscular force applied. 7% of the children and students affirmed the presence of a force that opposes the one of the person ["Yes, wind pushes the car on the other hand, then this one prevents to make the auto moves" (answer of a child) / "One could say that there is a force that applies because there is resistance on behalf of the car against the force applied by the person" (answer of a student)]. In the same way, 36% of the children affirmed that no force applies since the auto doesn't move. Among the students, this conception is only shared by 7% among them. The second question had for object to know the relation that they establish between force and the speed. Therefore they had to indicate, while justifying their answer, if when one applies a constant force on an object it will move to a constant speed. 52% of the children and 54% of the students answered by the affirmative. Let's note that in the case of the students, they affirmed that in addition to the golfer's force, there is the presence of other forces such as gravitation. It is about a conception that is like the one developed by Buridan (1300-1358) stating that the motion requires the application of a continuous force. In conclusion, the analysis of the data of a questionnaire that we distributed to them demonstrates that they share many false conceptions such as: (1) the motion requires the continuous application of force, (2) a
force produces a motion; and (3) in the absence of a force the objects are at rest. These false conceptions and those developed during history are very interesting to create many constructivist environments for teaching (Dedes & Ravanis, 2009).

**Determining the orbit of Mars: a didactical activity based on Kepler’s method of triangulation**

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In Brazil, Kepler’s laws of planetary motion are a mandatory component of physics curriculum at high school. Nevertheless, most high school physics textbooks lacks of practical activities related to the content of Kepler’s laws. In order to supply this deficiency we propose a didactical activity that focuses on the use of geometrical shapes (circles, triangles, and ellipses) to determinate the shape of the orbit of Mars. This activity is based on Kepler’s method of triangulation and it is designed to be applied to 15-years-old students at the high school. It represents an attempt to include the history of science (in this case, the history of astronomy) in the teaching of physics. The aim of this proposal is to provide an opportunity for the students to experience the “discovery” of the orbit of Mars in the same way experienced by Kepler himself. During a 2-hours lesson, the activity mentioned-above was implemented with a group of 18 in-service-physics-teachers, who are students of a graduate course of science education (lato sensu) at a federal university in Brazil (UNIPAMPA, Campus Uruguaiana). Our major source of observational data was the online Planetary and Lunar Elongation Calendar, available in the following website: http://www.astrohobby.com/crf.htm. A set of positions of the Earth and Mars was obtained by determining the positions of the Sun-Earth-Mars system in a configuration of opposition (i.e., when the Sun and Mars are in opposite sides of the Earth), in the period 2003-2022. The students used this information to plot in a sheet of graph paper a circular orbit of the Earth around the Sun (which is a good approximation since the eccentricity of the Earth’s orbit is $e = 0.017$). By using the same geometrical technique developed by Kepler, the students used the heliocentric longitudes of the Earth and the simultaneous geocentric longitudes of Mars to triangulate its positions. The data gather in this study consist of students’ plots of the orbit of Mars. The theoretical framework used in this study is the socialcultural analysis, as outlined by James V. Wertsch (1998). According to this author, a basic property of mediated action is the claim that “new meditational means transform mediated action” (p. 25). Thus, we are particularly interested in how students reason about the shape of the orbit of Mars with the aid of semiotic (i.e., sign-based) meditational means such as circles, triangles, and other geometrical shapes. The results of this study showed that the students succeeded in plotting an elliptical orbit of Mars, obtaining an average of its numerical parameters with an error less than 14%.

**References**

Diagnostic two-tier testing: does the new physics curriculum lead to improved knowledge about forces?

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The new Flemish (Belgium) physics curriculum for 14- and 15-year old students has been introduced on September 1st, 2012. Unlike all previous new curricula, the topics were shifted over the two years and new goals have been introduced. The key concept for the 3rd year (14 year-old students) is speed (being the link between the topics speed, light, forces and thermal expansion), whereas the key concept for the 4th year (15 year-old students) is energy (being the link between the topics energy, pressure, gas laws and introductory thermodynamics). The topic force has been shifted from the 4th year towards the 3rd year.

The author created a diagnostic two-tier test about forces, based on the goals of the new curriculum for the 3rd year (14 year-old students). The two-tier test does not only focus on forces, but also on the certainty with which the students select their answer. It has been tested at the beginning of the 4th year (15 year-old students) with n = 148 students of different levels (general and technical secondary schools) and the results have been analysed. The analysis reveals that only 1 question has been answered correctly by more than 50 % of the students and all other questions have been answered correctly by 16 till 46 % of the students.

The author presents both the two-tier test, as well as the students' results in this poster. This poster is part of an ongoing project. The testing shall be repeated over the following school years.

Design of a unit of Teaching and Learning for the Kinetic Model of Particles from the Multiple Intelligences of secondary school pupils

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In this part of the proposed research, participate in teacher training, capturing and characterizing the Pedagogical Content Knowledge (PCK) as a basis for reflection on their practice. It is intended to associate the development of PCK and the Teaching Learning Process that characterizes each teacher to assess the results and thus improve its practice through the development of instruments and tools that allow them to:

• Design teaching units in response to the approach of teaching in secondary education, Multiple Intelligences, the programming and its expected difficulties-strengths on what they know (previous ideas), know how to make (reasoning strategies), believe (epistemological conceptions) and believe that they know (metacognition).

The preparation and design of the teaching unit aims to the realization and understanding of the results obtained from the application of the test to detect multiple intelligences in 130 high school students, through the analysis and reflection on teaching philosophy and lines of work, based on theories of teaching and learning, to guide the pedagogical activity permanently and to allow the diversity of plans, in accordance with the characteristics of the students, the context, the teaching role and available resources. According to Gardner, 2001, the intelligence is: "A potential biopsicologico to process information that can be activated in a cultural context to solve problems
or create products that have value for a culture”, formulated his theory of Multiple Intelligences in recognition of the existence of different and independent intelligences, which interact and potentiate one another. From the results of the test proposed experiences and activities that provide learning opportunities to students, according to their interests, abilities and needs. Taking into consideration the contents, levels of difficulty, the variety of learning styles, the active participation of the student, as well as the forms of evaluation consistent with the intentions and the educational experiences designed. The main difficulties of the students on the learning of knowledge relating to the kinetic model of particles resulting from the presence of alternative conceptions, previous ideas or conceptual errors that conform better to their everyday experiences and not the scientific models that attempt to teach.

This proposal and development of teaching unit for the topic of kinetic model of particles is oriented to investigate teaching thought according to the components of the PCK Magnusson, 1999: A= vision and purpose of the teaching of science, B=knowledge and beliefs about the curriculum of science, C= knowledge and beliefs about student understanding about specific topics in science D= knowledge and beliefs about assessment in science, E= knowledge and beliefs about instructional strategies for teaching science. Inquiring about their types of knowledge, this instrument is part of the basis of development to translate the PCK of the professor. The planning and development of teaching units are essential components of teaching practice that it influences the outcomes of learning, as the inadequate organization and improvisation can lead to failure or to a variety of experiences that are not consistent with the purposes set forth. It is important to clarify that the planning of a course does not consist in the distribution of the contents and activities in school periods without further reflection, and is a key part, know the thought and knowledge of the teacher and that the known also for its own research and reflection, because this is one of the weaknesses identified in the teachers.

References

**H₂O: Live motive to a practical teaching of Physic**

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In the last year I taught physic in a professional high school. In these types of school students are more oriented to the practice that the theory of various school subjects. They have the need to "get their hands" on the matter and learn how to handle, investigate and change it.

After discussions with the students at the beginning of the year, I decided to keep the water in its various forms, such as the live motive. Teaching has made use of commonly used tools and of experiments that each student could redo and recheck at home.

The main objective was to introduce students to scientific methods and get them to understand how physics is an integral part of their lives, everyday.

Most of the students, in fact, had declared the first days of school, that the physics is an abstract discipline, without link with their daily experience. Allow them to do "practice" of the tools, units of measure, laws, that the scientist, over the centuries, had determined through observation, reflection, testing, and sharing, has allowed them to break down the barrier between them and physics.
The direct relationship with the material and events has also allowed the students to understand the role of mathematics in physics and in their lives and to mitigate the conflict, constructed and co-constructed in the previous levels of school, between each student and math. The course was conducted through short lectures, practical exercises carried out in small groups, experiments carried out at home by each student. Each exercise and experiment was accompanied by a written report by the students. Reports were consisted of tables to be filled and a reflective part on the method used and the results obtained. The topics were exactly the defaults for the physics course in vocational schools, but each topic has been applied in order to have as a main element in the water and then expand on considerations other materials. The reaction of the students was very good from the point of view of behavior in class, both from the point of view of understanding and learning. The method used has allowed me to make physics more interesting for them, and as a result has led them to study and carry out experiments in an appropriate, reflective and participatory manner. Students after the Christmas holidays have also begun to ask themselves and ask me questions about how some events could be explained: a significant step forward compared to the interest of the students about the world around them that, initially, at least in words, was defined "non-existent.” If physics has at its base the research, then bring forth in students an innovated sense of critical inquiry/curiosity could be a really good starting point.

Intuitive knowledge versus science knowledge when explaining optical phenomena: a study about how to manage knowledge is learned

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Children and students’ knowledge about nature of the light and optical phenomena in the science classroom consists in knowledge constructed from an early age when they interact with their physical and social environment. This knowledge differs substantially from the one proposed by science, which, in turn, is expected to be constructed by formal teaching. Such differences would stem from the ontological (Chi, 2002; 2008), epistemological (Vasniadou, 1994; 2012) and conceptual (Pozo y Gomez Crespo, 1998) principles that underlie knowledge and its representational nature (Karmiloff – Smith, 1992: Pozo, 2001). From this perspective, learning science does not imply the replacement of intuitive ideas by scientific ones. Instead, it implies the coexistence of several representations in the learner’s mind and the development of the cognitive ability to distinguish them in terms of the problem or the context of use. However, how is this type of learning experimented?; which cognitive processes are involved?; which teaching strategies favour them?

This work studies what, how much and how students from secondary level education learn about vision when a didactic proposal is developed in the classroom designed to favour an ontological, epistemological and conceptual change. A quasi-experimental study is implemented with the following design: pretest – intervention – post-test. In order to study what and how much they learned, the way of knowing students used before and after teaching was comparatively analysed from qualitative and quantitative techniques. To study how they learned, the knowledge they used was analysed as it advanced (didactic stages of application and conclusion).

The results reveal that initially students employed an intuitive way of knowing to explain vision, recognizing some of the variables involved (eyes, light) and ignoring the interaction among them. As teaching was implemented, a way of knowing increasingly more coherent with science was
constructed. At first, it led them to assume that to see an object, it was only enough that the light emitted or reflected by it fall on the observer’s eyes. Towards the end of instruction, they managed to recognize the formation of the retina image as a key process to see objects. But the construction of this knowledge proved to be a gradual process during which ideas about science and intuitive ideas seemed to compete in the students’ mind. The situation was such that in the didactic stage of application, and once the phenomena had been theoretically and experimentally analysed, the frequency of use of both intuitive ideas and those of science did not differ. Students managed to consistently apply the models proposed by science with a statistically higher frequency during the conclusion stage, after the teacher had summarized the model of science and students had had moments to analyse the question in depth individually. These results would support the hypothesis that learning implies not only constructing new ways of knowing but also developing the ability to manage them, since both intuitive and science ideas coexist in the students’ mind during and after teaching. They also reveal that it is possible to begin favouring this type of learning in secondary level education.

Teaching electrostatics and dynamics through Project-based learning

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In the classroom programs of classical mechanics, electricity and magnetism at the college level, the electrostatic and mechanics subjects are considered in traditional curriculum. However so frequently, we can see that in the instruction and curriculum the students are focussed only to accumulate and verify concepts. In this work we show a strategy that involves final scientific projects or so-called practical work where the understanding of physical phenomena is developed through experimentation. For this research we rely on authors suggest the possibility of working in classroom activities that bring students to the scientific work. Our instructional strategy based projects is originated in the constructivist approach that emerged through the work of psychologists and educators as Lev Vygotsky, Jerome Bruner, Jean Piaget and John Dewey. Active learning for its part according to Sokoloff states that the teaching of physics can be undertaken using current technologies such as data acquisition systems and sensors by means of Interactive Lectures Demonstration. This research has been focused on developing four projects, namely: basic electrostatic experiments, Torsion Balance Coulomb, Van der Graff generator and rotational dynamics experiments. One part of the project was developed in the first semester of 2014, the second one will be done in the second semester of 2014 with engineering students. We present our Analysis result obtained using psychometric tools such as Bao concentration factor and the Hake gain of learning and interviews applied to students. In addition, the strengths and difficulties of the strategy employed compared to traditional instruction are presented.

Video-analysis based tasks in physics

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Unlike tasks from printed textbooks, video analysis based tasks in physics do not incorporate either all necessary data to solve a problem or a procedure and a way how to find a solution to a task. The role of students in video analysis is to realize necessary physical characteristics, to choose a suitable way to a problem solution and from the relations among physical quantities to find a solution to a task. The tasks can be considered being the problem solving tasks with a well-defined
problem and according to Bloom’s taxonomy of cognitive domain they require higher level solution – mostly application, analysis and synthesis. Many of the video analysis based tasks are suitable also for the Physics lessons at grammar or secondary schools as there is no need to be aware of the integral and differential equations to be successful in solving them. On the other hand, it is also possible to demonstrate secondary school students, by a simple mathematical analysis, the use of integrals and derivatives in physics. The use of video analysis based tasks in physics can significantly affect the differences in the knowledge when students solving traditional tasks from printed textbook.

Comparing methods of measurement of friction with simple equipment and with data-loggers

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The Physics of friction is an important topic in school Physics at school of all types and also of our everyday interest. Students, however, often fail to apply what they learn in real-life situations and that is why experiments should make an integral part of teaching and learning Physics.

The main objective of these experiments is to demonstrate dynamic friction either on horizontal or inclined plane with usual surfaces. All experiments have been designed such that they are not difficult for students and teachers and, at the same time, they use the basic concepts of friction to measure the coefficient of dynamic friction.

The article presents a brand new constructed school tribometer, which is accessorized with Vernier sensors in Physics classroom to demonstrate problems from middle school, high school and university mechanics curriculum. The declinable tribometer enables taking measurements for the following type of problems:

- Finding the coefficient of static and dynamic friction for motion
- Finding the coefficient of rolling friction
- Measuring kinematic quantities of a body moving on a horizontal and inclined plane
- Construction of a tribometer may also be used to demonstrate a fibre friction.

Another significant advantage of this inclinable tribometer is its angle, which lies in the range between – 90° and 90°. This enables measurements of surfaces with very high dynamic friction coefficients.

The methods of finding the dynamic friction coefficient described in the text are:

a) Finding the coefficients of dynamic friction through measuring the pulling force on a horizontal tribometer (inclination 0°)

b) Finding the coefficients of dynamic friction with the aid of changing the inclination of the tribometer.

These methods enable students to verify the following claims through experiments:

- The direction of the frictional force is always opposite to velocity and acts at the point of contact between the moving body and the surface.
- Friction is directly proportional to the component of weight normal to the surface.
- Friction and the coefficient of dynamic friction are independent of the area of contact between the moving body and the surface.
- The coefficient of dynamic friction depends on the material of the moving body and the properties of acting surfaces (how rough they are).
- The coefficient of static friction is greater than the coefficient of dynamic friction
- There is a relationship between the coefficient of dynamic friction and the angle of the inclined plane.
Both methods described above make a use of data-logging sensors by Vernier, which, when connected to a PC, makes tutorials more effective and also enable more exact measurements and data analysis, show graphs and allow to find uncertainties of measurements. Vernier data-loggers enable us to measure several quantities simultaneously and display the relationship between them. Data can be transferred to other programs and can be saved for later data analysis. Using Vernier data-loggers also helps students to be more competent in the use of ICT. Both methods were developed with simple equipment and data-logging software. This article compares the advantages and disadvantages of school experiments with and without data-logging software.

This article presents the results of measuring the coefficient of dynamic friction for common materials used in school Physics. Based on these results, students made their own conclusions about the properties of friction as a force and coefficient of dynamic friction. The results are coherent with common theories. The validity of the relationships between the coefficient of dynamic friction, the frictional force, normal reaction and the angle of inclination was confirmed. They also enhance student understanding that friction can be useful (braking, motion, rubbing and grinding) as well as a nuisance (unwanted deceleration, heating effects in machinery).

Inquiry-based teaching with ICT in photometry

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The physics is a very important field of science necessary to the development of modern civilization. In Czech Republic, the students are not interested in science today. Undoubtedly important part of today's modern education is information and communication technology. The research had done in the Czech secondary schools. The research said that students want to use ICT in learning and also want to do experiment it yourself. Use of information and communication technology in student’s experiments seems to be a good and interesting idea. This is not a simple experiment, but inquiry-based teaching, which contributes to the development of student imagination, and to better understanding and to better remembering the curriculum.

General educational program for secondary school does not contain photometry. But we encounter with the concepts of light, illumination, luminous intensity and luminous flux in our everyday life. All of us are currently trying to conserve energy. Therefore, we should know these terms. And we should be able to choose the appropriate source of light to our homes.

The aim of this work is to create a set of inquiry-based learning experiments using ICT. These experiments should development creativity, increase the level of knowledge and skills and teach students to work with ICT. In particular, students should be able to work with a data logging system and then to process and evaluate the measured data using some program such as Excel. Then students have to create a protocol. The protocol has the following parts: name and enter tasks, tools, theory, measurement procedure, measurement data, processing and conclusion.

Students will address some the following issues:

Problem No. 1: In everyday life we encounter the concept of lighting. From parents and teachers we hear that it is important to read and work with adequate lighting. What is the dependence of illumination on the distance from the light source?

Problem No. 2: What kind of light source used to achieve maximum illumination at low cost? How much light makes bulb, energy saving lamp, LED lamp? The illumination is the same in all directions in space?

Problem No. 3: Is the light of bulbs, of energy saving lamps or of LED lamps good for the eye? Compare the spectral properties of these sources with the spectral properties of the sun.

Problem No. 4: What will light after passing through a filter? For example light pass through a coloured foil or sun glasses.
Problem No. 5: What will light after reflection from different materials? For example light reflect from smooth or bumpy and light or dark materials.

First research using these worksheets had done with some students of secondary school and with some students of University of Ostrava. Research has brought surprising results. Very often, students have misconceptions. The most common misconception is connected with the passage of light through the coloured foil.

Inquiry-based teaching should contribute to the overall development of students, both in terms of knowledge and skills to develop creativity, as well as to develop skills for learning, problem solving, social and personal, communication and working.

Inquiry-based teaching should have its place in teaching, because as the old Chinese proverb: "Tell me and I forget, show me and I remember, let me do it and I understand."

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**Digital magazine chapingo sciences; a proposal for supporting scientific culture with digital moodle support in physics area**

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As a teaching-learning approach a digital magazine "Science Chapingo" was implemented in the area of physics from Chapingo Autonomous University in order to develop a collaborative work with our comrades. This paper is a didactic strategy in the teaching of physics via web, for encouraging the scientific culture. The magazine could be a tool used with our colleagues to improve the physics learning process. The growing interest in use didactics media like the educational platforms (Moodle) to teach science, it makes necessary to understand the functioning of alternative systems like personal learning environments. Through this strategy we can achieve two thing: Help other to develop their digital skills, with publishing the works of themselves such as develop practices linked to the physics concepts, using scientific articles, animations, simulation, videos, pictures and digital laboratories. This media allows teaching physics concepts with supports of pictures, web page, videos, texts and computer resources. This approach has been designed in four stages. First stage defines the theoretical framework of the proposal called "Personal Learning Environment in physics (PLEF)". This media was designed to be use in different ways: individual, in a discussion group or in the physics class, considering resources of hardware and software available to be used. Main difficulties were analyzed to get applications in physics on this kind of media and, some elements were proposed in a lineal-hierarchy way. Hence in the class of physics many concepts are studied, with the change of representations, it meaning the constructions of the ideas in different abstraction levels: symbols, graphs and equations. Second stage, describes the didactic model, which consists get data that will help to build or integrate a community that is working to develop digital skill and a scientific culture. Third stage includes the discussion on the data collected and exchange information how the magazine could be a media where teachers and students help each other in physics learning process in the physics area. Finally, the last stage shows how information incorporated on a digital magazine could be useful to study physics concepts using the information showed. The didactic approach here has been tasting in courses of physics like, mechanics, fluids, thermodynamic and electromagnetism with students in order to get a multimedia allows the learning physics and to facilitate the construction of mental models adequate to help the understanding phenomena as well as the experimentation and the formalism with theory equations. This media approach offers real advantages in helping students to construct representations of the same phenomenon, manipulating symbols, graphics, data, text, images, videos, sounds and simulations.
Designing an educational methodology to teaching thermal equilibrium using ICT

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Within the teaching of physics, and in particular within the concepts of thermodynamics it is common find learning problems in college students. This paper is to propose a possible methodology, based on the observation of events and predictions of the students for learning temperature heat concepts also balance heat of a substance, with the assistance of information and communication technologies.

In developing methodology, Professor used as auxiliary devices a Wiimto, a wireless board and flash animations in addition to several programs or educational software such as heat balance simulators for various substances.

Basically we have the following scheme of work with students. First activation of the previous concepts is carried out, after the students are divided into groups performed to predicting phenomena related to thermal equilibrium with the two substances. As a third step, students conduct an observation of the experimental phenomena, but using ICT. As a fourth step, groups of students perform a discussion on the results observed in the previous step, and finally takes a analysis and synthesis of the activities of each session. This cycle has been reported in the literature as PODS cycle, which consists of the aforementioned steps: Prediction, Observation, result Discussion and Synthesis. The methodology is based on the constructivist principle concerns the fact that the students construct their own knowledge, from their experiences with physical phenomena and using the observation, discussion and synthesis of results. The part that interest in teaching methods, is that they can use simulation instead of direct physical phenomena, when they make the step from the observations. Here, we have faith that the computer programs that run the simulation, are sufficiently reliable to trust in the computer simulated results that are close to the actual results.

The topics that are intended to see in the classroom are:

- Theme 1. Heat and temperature. This topic is intended to students distinguish between the concepts of heat and temperature.
- Theme 2. Heat capacity and specific heat. This theme is intended that students understand these physical concepts.
- Theme 3. Thermal equilibrium of two substances. It teaches the concept heat transfer, between two substances.
- Theme 4. Calculation of the thermal balance of two substances. It intended that students do mathematical calculations related to the heat balance of the substances.

Originally this methodology was planned to be performed for students of the College of St. Elizabeth of Hungary in Bogotá, Colombia; the teams of students were established of 4 participants maximum; and the methodology was applied by the author's graduate student Diego Fernando Becerra Rodríguez. The ICT resources employed, as the wireless board, and software didactic are used together, making that the software can be activated by the use of the board. This is proposed as well, because the institution where the methodology is applied does not have any calorimeters, this causes that an interactive demonstration class, may be replaced by software such as whether students were using actual physical material. At this point, is where the advantage is observed to assist the teaching of physics with educational software. So we hope, that the presentation of this alternative learning methodology is useful for teaching of the basic concepts of thermodynamics, in schools of low budget to acquire real resources laboratory.
The Evidence Analysis of Internet Learning in Environment Education

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Facing the challenge of sustainable development, the environmental education is considered as the key issue in establishing and practicing various sustainable environmental strategies as well as to systematically change the attitudes and behaviors of the public. To realize the efficiency of E-Learning resources for student to capture the basic concepts and fundamental knowledge in sustainable development, this study adopts the technology acceptance Model (TAM) to quantify the students’ attitude and effectiveness toward E-learning, in which various environmental websites are screened and embedded into teaching activities. To build the TAM, three exogenous latent variables, including basic characteristics of E-Learning resources, interactive in learning, and the background of students, and are defined. To determine the causalities among exogenous latent variables, perceived usefulness and perceived ease of use, six hundred elementary school students are selected to capture the environmental knowledge from environmental websites by changing learning habits or/and expanding the depth and breadth of student learning. Finally, questionnaires and quizzes methods to conduct the variance analysis of learning performance before and after teaching. The results shown can be used to understand the role and importance of environmental education in elementary school.

Remote and Virtual Laboratories as Part of Online Courses

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Nowadays penetration index of mobile devices (MID) is much higher than a similar index for personal computers. More than that, there is a tendency to replace traditional PCs with mobile devices. In addition, the power, multimedia and communications capabilities of mobile devices are constantly increasing, which allows to use them for access and effective representation of multimedia content in education. In the last two years another important trend has become obvious – MOOCs (Massive Open Online Courses) have a great potential for the education process. They can be available for hundreds of people living in different countries.

In every natural science, experimental and laboratory work should always be a part of the education process. Remote laboratories are real laboratories with real experiments; however, anyone can access these laboratories, whenever and from wherever they wish via an internet connection using freely available browsers. Virtual simulations create a virtual reflection of the real word objects and their characterization, going to the least details as are mistakes and errors and noise influence.

Using remote and virtual laboratories, students can on their own explore the development and behavior of each experiment and measure and record data, transfer them to their personal digital devices via the internet and finally assess the data, draw them into graphs and create appropriate tables, verify various curves etc. So, remote physical experiment is the natural choice for using these courses on the internet. Using Java script for creating delivery systems of remote experiments
allows the use of remote experiment on all platforms: PCs, Androids, iOS or Winsows Mobil. This makes it possible to implement the learning process regardless of the software embedded on a personal digital device.

In our opinion, schools cannot make a transition to using mobile technologies on their own. This is due to the fact that modern information technologies require professional support at all stages: from creating remote and virtual laboratories to using them in the learning process. Therefore, an important goal is to provide schools with methodological support including remote and virtual experiments as the most challenging part associated with the transition.

Remote and virtual laboratories in addition to mathematical treatment of data obtained during experiments also contain teaching materials and evaluation of learning outcomes in the form of testing. For this purpose, it is advisable to use Learning Management System (LMS) Moodle hosted on university sites. This education environment allows to integrate in one place all the necessary content (educational texts, samples of laboratory work and test cases) with the necessary hyperlinks to external internet resources.

Creation of intellectually saturated learning instruments and educational technologies requires joint work of a number of specialized teams of programmers, designers, professors etc., which is impossible to achieve within the framework of one University. That is why remote and virtual laboratories are currently created by several teams from several countries.

Experiments in Thermal Physics

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The aim of this article is to publish the thermal physics experiments. The experiments will be a part of a new methodology for the teachers of elementary and secondary schools. The methodology will be based on the results of the research that was carried out at the beginning of winter 2013. The research was surveying the misconceptions of 75 university students in the area of thermodynamics. Students were the first-year students of the Faculty of Science.

The findings that can be considered serious are that some students think that the temperature of a human body is the same everywhere; students have incorrect misconceptions in the area of the thermal conduction and radiation. The research confirmed the results of the international research. On the basis of these results and after a didactic analysis of physics textbooks, of the Framework Education Programme for Elementary Education in the Czech Republic and of the Framework Educational Programme for Secondary General Education (Grammar Schools) in the Czech Republic, a list of thermal physics experiments was created. These experiments will be a part of the new methodology. The methodology will suggest the experiments to teachers and students, for example using the modern measuring systems - a thermo camera.

The thermo camera is one of the modern measuring systems in which it can be expected that it will soon be one of the tools in primary and secondary schools. The device's name indicates that it can be used in thermal physics. Another benefit of thermo cameras is the opportunity to strengthen the inter-subject relationships between biology and physics among students. Only by thermo cameras it is possible to capture thermal radiation, thus they enable us to conduct many experiments that are impossible for other measuring systems to conduct.
Assisted Software in Physics Education: Free Open Source Software (FOSS)

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Teaching methods continues to be discussed on today. Instead of traditional teaching methods, the new models that led to research and to be integrated with the technology, are discussed. The students who study on science will be intertwined with the technology in future. These students need to based on mathematical modeling in problem solving in project assignments and laboratory studies, so they should be directed to software-based studies. Due to the high cost of licensed and paid software for educators and students, free or open source software (FOSS) is more appropriate than paid ones. In our study, the some of free open source software will be introduced. There are the software which the engineering students in basic physics classes can be used. These software are simple and very useful in the fundamental physics lessons and in the next academic year programs. The mathematical analysis software such as Maxima, Interactive Differential Equations and the physics software such as Simlab2011, Physics Virtual Laboratory, Physics Cheat Sheet Demo, Physion, Projectile Calculator 1.0, Solve will be introduced. However, the opinions received from the students will be presented. Our aim is to also create awareness regarding FOSS.

PONTo - promotion and support for MST teachers (non-profit organization)

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PONTo is a Dutch abbreviation for (translated into English) promotion and support for MST teachers. PONTo organizes as a non-profit organization in-service training for primary and secondary school MST teachers. All participants experience our contextual approach and perform all experiments with day-to-day materials. Since its first in-service training in 2008, it has organized in-service trainings for the following physics topics: optics, sound, health, general integrated science for 12 year-old students in the new Flemish curriculum, electromagnetism and pressure. Also chemistry in-service trainings were organized: introductory chemistry for 14 year-old students and a chromatography workshop. Each participant gave evaluative feedback by means of a questionnaire, in order to improve our approach.

This poster presents the PONTo vzw approach and the reception of the initiatives by the MST teachers who participated in our initiatives.

How do pre-service physics teachers explain force interactions in different systems?

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Knowledge transfer is important among the physics contexts. However, change of the contexts bring different variables to be taken into consideration. So, the transferred piece of knowledge
might be missing and inappropriate for some contexts in spite of similarity at the first glance. This study qualitatively examines how pre-service physics teachers explain “force” in different systems from micro to macro. Five teacher candidates participated in the study. Data were collected by semi-structured interviews. The analysis indicate how pre-service physics teachers consider new and context specific variables while transferring knowledge among the contexts.

**Representation System of Pedagogical Content Knowledge : The Case of Electric Field**

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From studies of Shulman (1986) have been developed different investigations so fruitful, they relate the nature, characteristics and implications of Pedagogical Content Knowledge (PCK) in the professional knowledge of teachers. Several investigations (Etkina, 2010; Michelini et al, 2013) have shown that although the academic knowledge: psychopedagogical knowledge, knowledge of the subject matter, science knowledge and teaching and learning knowledge, are essential in training and professional development but, they are not sufficient, teachers require scenarios where they recognize and develop their PCK on specific topics of their teaching.

In the last 20 years, the PCK has been the livelihood and the heuristics, of a lot of research on training and professional development of science teachers. However, we believe that a tool unexplored inside processes of reflection and characterization of PCK are holistic representations of this knowledge, independent PCK’s models.

In this regard, Henze and Van Driel (2008) request their participating teachers design their own models of PCK. Participating teachers are who represent the relations between the different components of the PCK and they define the general characterization of each component. Park and Chen (2012) represent the connection between the components. They count the frequency of segments of analyzed information. They defined as a segment of information to consider only those containing at least two components of the PCK.

We present a way of representing this knowledge as result of a longitudinal study on the development of the PCK for the case of the electric field with two high school physics teachers in Colombia. The coding scheme was based on Magnuson et al.’s model and on the common components reported in research on physics PCK: (i) orientations to science teaching; (ii) knowledge of the curriculum; (iii) knowledge of pupils’ understanding of science; (iv) knowledge of representations and instructional strategies; (iv) knowledge of evaluation; for the description of each component, we took into account the evidence provided by the information analysed and by science teaching models (Jimenez Alexandrei, 2000; Martín del Pozo and Rivero, 2001; Porlán et al. 2011). The representation symbolizes the frequencies of the segments analyzed information about each component, we do distinctions between what the teacher says, designs and does in classroom. The results suggested that the traditional tendency was predominant in all three levels. However, in the level declarative there is not a definite trend when we analyze for content (charge, electric force and force line and intensity of the electric field).

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Mathematics in Physics – Influence of University Education in high school classes

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This work, based on the development of practicing teachers and undergraduates in physics, aims to verify which aspects of the teaching process throughout high school could be prioritized. We analyzed the differences lesson plans developed by teachers already in the field and undergraduates in training, during the disciplines of Physics Teaching Methodology. The results would show the differences in perspective of each group in the classroom setting. We hypothesize that when college graduates go to high school as teachers, they have difficulties giving meaning to concepts in physics without using mathematical equations. To complicate even further, according to results obtained in previous research, undergraduate students dichotomize the process of learning for their profession and learning for success in exams and tests that they will be submitted to (Diniz&Pierson, 2010), making the relationship between teaching and learning in a university context even more difficult. So we are trying to verify the influences that the usage of mathematics, in the way that it’s been taught during early phases of undergraduate studies and teachers in Continuing Education, both more oriented to the development of the future researcher rather than the physics teacher, could have in the way that Physics is taught in high school.

One of the activities analyzed was about “Electric Circuits”. It was observed that both the presented goals and the activities to be performed during class show a dichotomized view of physical science. In no moment was the relationship of the activities with technological production and the society we live in considered. The use of experimentation and simulation in class relate with the goals and are limited exclusively to explanations of formulas of physics, overvaluing mathematics as a language of explanation and training of these students.

Despite the appreciation for an up-to-date curriculum and the demand for a teaching process that aims to prepare informed citizens, the analyzed research shows that the subjects opted for lectures...
that were based on a more formal development of concepts of physics, instead of opting for a more phenomenological and conceptual discussion. Even though the subject’s acknowledge the inadequacy of proposed methods, at first they found difficult a structured approach that is not based on mathematics. Although we were able to overcome some of this resistance and noticed an improvement of students toward new approaches of teaching physics in high school, the subjects of this research remain finding the mathematical approach the most appropriate way to teach physics - in spite of the different direction defended by official documents (curriculum proposals and parameters), teacher trainers and a considerable part of the textbook market.

The question remains of how much the practicing and future professors are aware of the effectiveness of the choices they make during this stage of schooling. A possible anachronism on the production of Science Education teachers and its decontextualized practices are not due to a rejection or prejudice to the area (even though they still exist) or the lack of research in the institution in which a particular teacher works (Delizoicov, 2005). The anachronism and its decontextualized practices are due to a difficulty in understanding the transition from the physics learned at the university to the physics taught in schools.

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The philosophical conceptions on environmental education of future physics teachers

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This research is about the understanding of the concepts of philosophical environmental education of physics students and future teachers at the Instituto Federal Sul-rio-grandense – IFSul, in the city of Pelotas, in southern Brazil. The literature on environmental education shows us that there are different concepts that are associated with different epistemological basis. Thus we consider studying three different philosophical epistemologies.

Epistemology of Environmental Education that relate to their practical applications directed to a utility value of thought, called Pragmatic Environmental Education. The idea of "conservation" of the environment considers its qualitative and quantitative aspects. It involves aspects of environmental education and its informational role or lead to information on the subjects related to environmental issues as well as possible in resolving them. Although this concept include social aspects not considered in economic relations. The rational use of environmental resources must be understood in the sense of enabling the use for future generations.

The second epistemology is the one related to thinking that contemplating inductivism, objectivity, experimentation and search for a scientific veracity in dealing with environmental issues, called the Environmental Education Positivist. Environmental education in these conceptions is associated with acquire knowledge of the natural sciences with the environment being an object of knowledge that would enable a particular solution or action. In this perspective of knowledge about environmental education and / or solutions to environmental problems could be solved by science and / or its method.
The third epistemology of Environmental Education is one related to thought based on critical theory in environmental education that is addressed in the context of political economy that involves relationships of interest from different social classes, called Critical Environmental Education. This concept is characterized by the dialectical method in which humans and their social relationships are nature and must have a balanced relationship with the environment. In this context, while the human being is a biological being, is also a social being which has its historicity. Thus, the social relations should be understood as belonging to the context of the environment.

Questionnaires were applied to 12 students in 1st, 3rd and 5th semesters representing 44% of the total. The results show a strong trend of 80% of respondents to a positivist epistemology that environmental education is seen as a form of awareness and utilization of science and technology to solve environmental problems. 20% have a more pragmatic view that Environmental Education is looking for more immediate solutions to environmental problems. The critical and emancipatory epistemology of environmental education not verified satisfactorily some noises these conceptions being observed in some students. Thus, pragmatic and positivist conceptions can be interpreted not only with its negative aspects. The positivist thought it possible to build the knowledge and perspectives related to pragmatic thought possible solution to specific problems, and can be interpreted with the complementary contributions of critical and emancipatory, that allow an interpretation of a relationship with nature in order to form balanced social and forming part of the environment. Environmental education should contemplate a practice that involves culture and science dialogue towards the understanding of environmental issues in their entirety. The analyzes of this research points to the contribution of possible reformulations in pedagogical project of the course and better knowledge about environmental education and about how we relate to the environment.

**How experimental resources in physics teaching facilitate conceptual learning?**

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In the physics teaching frequently we use the discourse of the teacher and the solution of exercises as the main didactics resources. In most students, this does not seem to promote the construction of knowledge about the science and its nature. Following the proposal of the critical meaningful learning of Moreira, the application of theory of conceptual fields of Vergnaud and the epistemological approaches derived from a non standard view about science, we asked, The intentional integration of traditional resources with the experimental resources, in one sequence of situations-problem of physics that put the student in action (do and think about the doing) will promote the conceptual learning? To achieve this, we have organized a sequence of didactic situations centered in problems, which refer to the situations regarding of the conceptual field that we have constructed from the physics, and that set out a complex conceptual hierarchy. In this sequence, we incorporated to the traditional resources, three experimental resources in a complementary manner and intentional, these are: i) demonstrations of phenomena that highlight relations between variables or consequences of their changes; ii) virtual simulations that allow interaction with the elements of the physical model through virtual phenomena built; and iii) experimental data obtained from induced events that highlight with some degree of approximation the implicit relationships in the physical models considered. We apply this proposal (action research) with a group of student-teachers in training during a course of Fundamentals of Physics, for learning concepts about kinematics; which lasted six weeks, with two classes of three hours each per week, at a regular period of 16 weeks. The students in cogniscitive and practice action worked in-group while the teacher mediated the learning process guided by the MLPLaW (model
learning of the physics laboratory work). The information about the student's the learning outcomes in the situations were collected through: initial and final tests, observation of teacher researcher and working guide delivered to them. Among the most relevant results, we have found that students in the final test were able to recognize many of the situations we presented them, identify goals and make anticipations and be able to account for new or modified cognitive elements (compared to the initial test) which we assume were developed during teaching, this was inferred of productions presented; also, the students was willing to participate and monitor their learning process. Also, they was qualified some positive the incorporation of experimental resources in the process of their active construction of meanings, and became aware of the theory-experiment-model relationship. As future teachers they was rated as good the didactic strategy. This work confirms that the establishment of the field conceptual in terms of situations, concepts and representations is a suitable tool for the organization of teaching and assessing the progressivity of meaningful learning of concepts; as well as the integration of theory and experiment in physics teaching would promotes learning and the understanding of the nature of science.

**Teacher Education: science education under the light of the phenomena of physics**

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The research was based on the assertion that language is the primary tool used by teachers, because they are continually communicating with the individuals learners. Many education professionals have the textbooks as the only or the main teaching tool. However, we observe through the praxis of thinking and acting in the classroom, the speech used in the preparation of textbooks, most often, is not attractive to students. Another considered question in this study was that the contents related to quantities of measures are not sufficiently internalized-appropriate by the learners. Thus, the narrated stories develop the concepts of mass, weight, volume, density, among others, creating meaning, rhythm and movement to the apprehended phenomena. Throughout there have been proposed some problems in order to inspire in the individuals learners an investigative approach to resolving that problems in the way of development of hypotheses, testing procedures and use measurement instruments such as precision balance, ruler, Becker, among others. Thus, through some strategies for solving problems arising in the context of narratives, students were encouraged to use the inductive / deductive reasoning; to formulate hypotheses to explain certain phenomena; to think of procedures able to confirm or disprove their hypotheses; to perform the prediction of experimental results; and use the argumentative discourse. Such procedures are necessary to the academic training process so that individuals can act in socio-political and economic developments of contemporary society. This study was based on the Socio-Historical Theory of Lev Semenovitch Vygotsky. The psychologist contended that children learn best when faced with tasks involving a not very discrepant cognitive challenge. Thus, for Vygotsky, the language consisted of mediating instrument used by people in social relations. The more the individuals of the knowledge develop language, they better elaborate the processes of cognition and higher mental functions. In this way they resignify and understand the processes so that they can actively act on themselves. Then use mediation as a way of learning that reconfigures facts, situations and phenomena passed unnoticed. For such possibilities the concept of mediation was working as specific knowledge to science teaching. The individual student is constituted as the receiver of the process in a movement of appropriation of activities through factors such as memory, attention and perception, although initially not mediated, was with the use of signs, which qualitatively changed the learning process by setting the upper and / or cultural features. This study began with the assumption that the use of innovative features - paradigmatic book - coupled with some didactic strategies for solving
problems has the potential to facilitate communication of the concepts that we intend to teach; to make the students closer to the subject of study; to promote the development of inductive / deductive reasoning, because through the solutions presented by students, teachers come to know the actual level of development of the students and act in the zone of proximal development, increasing the development of the individuals learners. The purpose of the research, from the assumption outlined here, therefore, was to evaluate under the light of Vygotsky's theory of the learning development of the individuals of this research mediated by tools and signs arising from the natural science.

**An Inquiry-based approach to the Franck-Hertz experiment**

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Nanophysics and nanotechnology are rapidly advancing, together with their significant applications and implications for everyday life. The practice of scientists and engineers is today exerted within interdisciplinary contexts, placed at the intersections of different research fields, including nanoscale science. Thus, the education of science/engineering undergraduates is fundamental to contribute to the scientific and technological progress. Several challenges are related to a full understanding of scientific concepts at nanoscale. The development of the required competences is based on an effective science and engineering instruction, which would be able to drive the students towards a deeper understanding of quantum mechanics fundamental concepts and, at the same time, strengthen their reasoning skills and transversal abilities. On the other hand, a careless simplification of the sophisticated concept of nanoscience could generate misconceptions, lead to superficiality and risk of misrepresenting.

In this study we present the results of an inquiry-driven learning path experienced by a sample of 15 selected engineering undergraduates engaged to perform the Franck-Hertz experiment. Before being involved in this experimental activity, the students received a traditional lecture-based instruction on the fundamental concepts of quantum mechanics. Despite the instructor’s introduction to specific technological/engineering-based contents during the course, the students’ answers to an open-ended questionnaire, administered at the end of the lectures, demonstrated that the acquired knowledge was characterized by a strictly theoretical vision of quantum science, basically in terms of an artificial mathematical framework having very poor connections with the real world. This could be ascribed to the many difficulties that students demonstrated to have in order to deal with concepts at scales in which they cannot have a direct experience in their everyday life, especially at microscopic and sub-microscopic scales. Moreover, students prefer to conceptualize matter as being continuous rather than discrete.

In order to fulfil these lacks, the students were invited to actively participate to an experimental activity within an inquiry-based learning environment at the Laboratory of Condensed Matter Physics at the Department of Physics and Chemistry of the University of Palermo. The Franck-Hertz experiment was introduced to the students by starting from the problem of finding an experimental confirmation of the Bohr’s postulates asserting that atoms can absorb energy only in quantum portions. By following the lines of a scientific inquiry, the students, working in group, performed a questioning activity that naturally guided them throughout the steps of the Franck-Hertz experiment. The whole activity has been videotaped and this allowed us to deeply analyse the student perception’s change about the main concepts of quantum mechanics. At the end of their inquiry-based learning path the students were also asked to answer to a structured interview with questions similar to those proposed by the initial questionnaire.

First of all, video analysis clearly demonstrated a great participation and motivation to learn, both in terms of useful discussions and scientifically relevant questions. Moreover, we have found that the reasoning effort asked to the students to successfully perform this learning experience
successfully reinforced their understanding of the quantum mechanics fundamental concepts. This experience definitely favoured the building of cognitive links among student theoretical perceptions of quantum mechanics and their vision of quantum phenomena, within an everyday context of knowledge. In conclusion, our findings confirm the benefits of integrating traditional lecture-based instruction on quantum mechanics with learning experiences driven by inquiry-based teaching strategies.

A fresh hands-on approach to improve students' understanding of introductory thermodynamics (continued)

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The test and exam results from 4th year secondary school students (generally 15 years old) proved year after year a poor understanding of introductory thermodynamics topics that were taught. The results were remarkably lower than other physics topics that were covered in the same years. This poster presents a fresh hands-on approach to improve students' understanding, using an small scale research project and a visit to the local DIY (do-it-yourself) store, combined with an alternative evaluation and assessment method. This resulted in better results. A comparison and a SWOT (strength, weakness, opportunities and threats) analysis of the project will be presented. Also, the results over the different years of the project shall be presented.

Mathematical Model of Didactic Structure of Physics Knowledge embodied in Physics Textbooks

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Transforming from scholarly knowledge of physics to "physics knowledge to be taught" is a fundamental process to design physics curricula. "Physics knowledge to be taught" has a carefully versioned form of knowledge, adapted to be appropriate for teaching physics in particular context. "Physics knowledge to be taught" is transformed further into teaching materials. Teaching materials are actually learnt by students in their classrooms. "Physics knowledge to be taught" has the key role of connecting scholarly knowledge of physics and teaching materials. The author has proposed a mathematical model to describe the didactic structure of "physics knowledge to be taught" [1, 2]. The mathematical model was developed on the basis of on the basis of the channel construct described by Barwise–Seligman’s channel theory [3]. The basic components of "physics knowledge to be taught" form are represented via the notion of classification. The classifications are mathematical sets of "physics knowledge to be taught" related to the events and activities which students experience in their science classroom. Those classifications are connected to each other with the functions called infomorphisms. The infomorphisms show information flow between classifications. The relational structure of the “physics knowledge to be taught” form comprises linked classifications and is modeled as a distributed system. A diagrammatic representation of the didactic structure of "physics knowledge to be taught" was obtained from a series of learning activities. The learning activities, such as experiments, observations, and problem-solving exercises, were classified, and the relational structures between them were considered as distributed systems. Classifications called cores play a key role in information flow in the distributed system.
In this presentation, the mathematical model described above is applied to analyse the content of physics textbooks. Physics textbooks are one of the important teaching materials. "Physics knowledge to be taught" should be embodied in physics textbooks for students' effective learning. Each textbook was written on the basis of its own educational and editorial policy. Therefore a physics law or proposition is related to different learning activities depending on the textbook. Such a relation is represented by the structure of a classification in our mathematical model. The relational structure of the content of physics textbooks comprises linked classifications and is modelled as a distributed system. Classifications involving key learning activities are considered to be cores in a distributed system. Hierarchical structure of the content of physics textbooks is also discussed.


Applicaiton of a didactic strategy for the comprehension treatment of the physics concepts at secondary school

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Traditionally the subject of Physics is one of the most complex issues. In this research surveys about physics concepts on Vectors, mechanics, heat and fluids, Electricity and Magnetism were applied to students and teachers of third grade Level (Secondary). Data corroborate the complexity of the topic because despite the physics themes has been studied in class, survey results reflect a low or a lack of concept understanding. Due to this problematic situation, and to attenuate it, a didactic strategy was applied where in a sole activity the student can: observe, model, interact, interpret, describe and argue about the physical phenomenon. In an integral activity students will interact and verify the physical phenomena. The first phase of implementation of the strategy was aimed at teachers of physics, so that once dominated the proceedings it can be generalized to students.

It was necessary to use a number of devices and software on physics, designed by the authors for this purpose. Concerning to the Physics Software it was designed for use it in different modes: in class demonstration, as a problem solver class tool, as a tool for test problem design, or as learning activities that are designed as open problems with a large number of answers that allow them to argue and express conclusions. Regarding Physical devices those were designed and built for simple experiments in the area of mechanics, fluids and Heat, Electricity and Magnetism and Optics so that could be performed in classroom. These two resources, software and hardware, are used to achieve the link between theory and practice as the essence of the strategy for the conceptual understanding. This strategy takes into account the potential offered by different educational components for a better concept learning. In this paper we show how it can be applied the strategy, and the results obtained.

For the first application phase of the didactic strategy, it was necessary to train teachers though a twenty hours course, in this case twenty teachers of secondary education level. In a classroom twenty computers were equipped with the physics software one computer for each teacher for an individual interaction with the virtual laboratory. And the experiment were installed in the same classroom in order to allow the teachers develop the experimental activity.
The way to tackle the physical phenomena described above allowed the study of physical phenomena in a full way ie, the same teaching activity can fulfill three essential moments raised: observation, to understand how the phenomenon manifests, penetration their regularities by phenomena modeling, and verification by the experimental activity. The dynamic nature of these different moments associated with the use of different resources, allowed to work the observation and interpretation in the same activity, which enable teachers to gradually develop an interpretive logic as they were able to explain in their own words what they had observed.

After the training experience, surveys were applied to determine the degree of understanding of physical phenomena and result data evidence that teachers show a tendency to develop skills, their chances of criticism and self-reflection are better. Teachers, reflect, value and use the acquired knowledge, linking it to activities and practices to everyday life situations and their context.
Students of the 21st century learning science: the use of drama to teach and to discuss sciences

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This work tries to defend an interdisciplinary and transdisciplinary approach in Science Education to high school students. It has as its main goal to stimulate the reflection on possible contributions of events that articulate the theatrical language with the scientific practice in the processes of science learning. Through researches, interviews and a focus group we can realize that there is a new and efficient way to learn science. It presents a methodology that seeks a useful learning of science to life and to work in which information, knowledge, skills, abilities and values are real instruments of perception, interpreting, judging, acting, learning, satisfaction and personal development. It is proposed that theater presentations based on science and philosophy, managing scientific problems and concepts, should be a useful, enjoyable and effective way to learn. Interpreting science and technology to a large and diversified audience is the main mission for our group of researchers. The changes that take place in society demand new approaches in the relationship with high school students. We analyze how High School can reinvent the way through which science shapes its relationship with the community and with its identity as a knowledge center in the 21st century.

Drama, being an instrument of communication and reflection par excellence, may have an important role to play in shaping students' conceptions about the nature of science. As a human activity, the process of construction of scientific knowledge has a varied list of topics that could be represented in the arts and drama. History and philosophy of science can serve as generators of these thematic elements, integrating the contents of the sciences to the context of its production. Thus, the union between drama and History and Philosophy of Science may permit a differentiated approach that is traditionally offered in school.

A contextual approach to the epistemology of the natural sciences involves multiple issues such as politics, ethics, gender and others, and can allow students to reach the perception that scientific knowledge is not born ready, finished or that it arises from the mind of a few geniuses. On the contrary, it is built in a multifaceted process. Based on this belief, from 2010 to 2013, an experience using theater with professional guidance has been developed. This experience, which lasts eight months per year, intends to discuss the nature of science.

The group has developed three parts: an adaptation of Galileo's Life of Bertolt Brecht in 2007 & 2009, an adaptation of Oxygen of Carl Djerassi and Roald Hoffman in 2008, an adaptation of Frankenstein of Mary P. Shelley in 2010 and 2011 by researchers authors, and two own texts "The Invisible Enemy" about the Hungarian physician Ignaz Semmelweis, 2012 and "The Monkey Trial" an update on the trial of Prof. John T. Scopes, 2013. The pieces were staged in the month of November each year, in the Interschool Drama Festival reaching over two thousand spectators. Our study will demonstrate a high possibility of interactive teaching; exchange of experiences and knowledge, dynamism characteristic of the contemporary world. With respect to interdisciplinarity, the goal was complete by modifying the classical structure adopted by the faculty, thereby restructuring the usual model of science teaching.
Chinese Old-Style Poetry in Physics Courses

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How to merge organically the cultures of science and humanities in university courses is one of important problems in cultivating talents with comprehensive qualification. Traditional Chinese culture has the profound cultural foundation and a very long history. Poesy is an important part of Chinese traditional culture. "Poetry expressing ideals"(Yao, 2377 BC—2259BC), it can describe things and express one's emotion, and also can state principles. The Chinese ancients have frequently used poems to explain or state technological essentials. For example, 《Recipes in Rhymes》 (Qing∙Wang Ang, 1694 AD) and 《Jade Dragon Verse》 (Yuan∙Wang Guorei, 1329 AD) etc systematically and completely state respectively the medications and acupuncture knacks of Chinese medicine and is to be passed from generation to generation. Using poems to epitomize scientific and technological concepts and laws in university courses could improve students' learning interest and make the scientific contents easy to be understood and remembered.

We have written some Chinese old-style poems about Thermo-Physics and used them in Physics classes. The used poems fall into several categories [1]:
(i) As an opener of the courses;
(ii) To describe physics concepts and laws;
(iii) To explain learning and remembering methods;
(iv) To summary the teaching contents of classes.

Applications of poems in physics teaching draw near the distance between the art and science and stimulate students’ zest for learning. Physical poems concentrate the physical essentials of the course by tersely phrased statements, help students sum up and remember the learned knowledge breezily. Our teaching practices indicate that using the Chinese old-style poetry in Physics courses is helpful to improve student interest in Physics and conceptual understanding, and enhance the general quality of students.


The study of optical instruments through the construction of a complex network

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Textbooks in Brazil have maintained a very systematic approach regarding the study of optical instruments. In general, the textbooks show the very basic functioning principals and the types of mirrors and lenses used in these kinds of instruments. This method, which is merely expository and lacking in meaning, has led the students to develop a distorted vision of the nature of science (MCCOMAS, 2009). Because of this, many authors (MATTEWS, 1994; ALLCHIN, 2011; GALILI, 2011) have presented arguments for an education in which the History of Science will come to have a main roll, promoting a reflexive approach regarding the development of science and a contextual vision of the construction of scientific knowledge. In these terms, a teaching module was developed for optical instruments, using the scientific and cultural history of Holland in the
17th century as background. The IKN (Interactions of Knowledge Network) is used as a starting point in this module, with Constantijn Huygens (1596-1687) at the center. In this network we can name leading figures such Christiaan Huygens (1629-1695), expert in microscopy Anton van Leeuwenhoek (1632-1723), the philosophers Baruch Spinoza (1632-1677) and René Descartes (1596-1650) and the painters Rembrandt (1606-1669) and Johannes Vermeer (1632-1675). All these worked or experimented with issues related to optics in their respective fields. In this paper we demonstrate how this IKN can be constructed in the class room through some activities suggested by the teacher which enable the students to independently assemble the above-mentioned network and understand in a contextualized manner the development of various optical instruments that were built during that time period. Subsequently, the students studied some of the optical instruments used in modern times. During the preparatory phase, the corpuscular theory (Newton) and wave theory (Huygens) were presented, along with a discussion about the nature of light. After the debate, the teacher intervened and demonstrated, through historical evolution, how these theories where developed until the emergence of the modern concept of wave-particle duality. Following this, a very formal study of the optical phenomenon of reflection and refraction, including plane and spherical mirrors as well as the behavior of optical lenses was performed. At this moment the teacher separated the students into groups and proposed an activity of research and presentation. Each group of students elaborated a small presentation about one of the figures in the network; the other three groups presented the following themes: religion, commercial structure, cultural and artistic panorama. All the themes were based on Holland in the 17th century. The students are then evaluated through an evaluative activity with questions referring to associations between the leading figures, the historical period and regarding the nature of science (NOS) based on Clough’s research (2008). The intention was to verify if the students were able to establish relations between the leading figures and the apparently divergent themes. The study ended with students displaying a very different comprehension of the NOS than they had in initial discussions. Moreover, the students demonstrated motivation, presenting high performance in tests of optic knowledge. The Module closes with the teachers presentation showing a section of the network through a complex view (Morin, 1999; Demo, 2008), indicating that a IKN must always be developed in a global way, where the sum of the parts must be different from the whole, and understood as an event which was the result of creativity and multiple factors that converged toward a given happening, resulting in teaching that has reflection and contextualization as its main goal.

**Teachers' views about the implementation of an integrated science curriculum**

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The implementation of Integrated Science Education curricula in school practice has been extensively debated since the last three decades of the last century (Adeniyi, 1987; Arcà & Vicentini, 1981; Hurd, 1986). Integrated science curricula focus on contents and methodologies common to science disciplines (Biology, Chemistry, Physics and Earth Science) and aim at fostering students’ capabilities in interpreting natural phenomena from different viewpoints (Frey, 1989). Moreover, an effective integration of science disciplines may improve students’ scientific literacy (de Boer, 2000). However, as for other curriculum innovation in science as, for instance, the Science – Technology - Society movement (Aikenhead, 2003), research results are often controversial (Harrell, 2010; Wei, 2009). Some of these studies point out that teachers’ disciplinary background and attitudes toward teaching may significantly affect the implementation of integrated
practices (Venville, Wallace, Rennie & Malone, 2002). However, few studies have investigated teachers’ ideas about the introduction of an integrated approach in their teaching practice. In Italy, this issue has become very crucial with the recent introduction in the secondary school of new national guidelines that explicitly suggest an integrated approach in science teaching, even though the sciences subjects are still taught by different teachers. As a consequence of this separation heritage, teachers found difficult to identify suitable topics and objectives so to cope with the new curriculum demands. This work aims to address these issues by investigating teachers’ idea about integrated science curricula through the following Research Questions: 1) what science topics do teachers think can be taught more effectively in an integrated science curriculum? 2) What learning objectives do teachers think can be most effectively achieved through an integrated curriculum? In order to answer the research questions, a case study approach was used. In particular, one chemistry, one physics and two biology teachers were interviewed using a protocol consisting of 11 questions. The interviews, each of about 45 minutes, were transcribed and analyzed according to categories emerging from the data and refined by the authors. The scientific topics (RQ1) identified by teachers were first listed singularly and then grouped according to main areas of content. Similarly, all the mentioned learning objectives (RQ2) were first individually identified and then grouped into macro-areas. The preliminary results can be summarized as follows. RQ1: the main content areas identified were Scientific method, Energy, Gases, Energy and matter flow in systems. RQ2: the general objectives identified were: a) familiarize students with the scientific knowledge as a whole, b) provide students with tools and methodologies to understand real-world problems and act in a responsible and conscious way, c) experience the scientific method and train students to learn “by discover”, d) increase the effectiveness of the instruction. These preliminary results suggest the need of specific teachers training courses dealing with the problem of the reconstruction of scientific contents for an integrated approach. To this concern, the four interviewed teachers will be involved in a training course aimed to develop and implement suitable integrated science teaching-learning sequences in their practice.

The use of Scientific Museums in Physics and Astronomy Education courses for pre-service Primary School Teachers

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We report on a learning experience in scientific museums carried out within the course in Physics and Astronomy Education for pre-service primary school teachers. The project has been developed in collaboration with the Museum of History of Physics of Padua University and the Museum of Astronomy of Padua Astronomical Observatory. Both Museums keep important collections of historical physics and astronomical instruments which show the fruitful scientific activity carried out in Padua throughout the centuries. The main goals of the didactical project were: (a) stimulate in pre-service teachers a reflection on how scientific museums could be used for proposing effective and motivating scientific experiences within primary school curriculum, (b) make them to experience and recognize the advantages of an historical and narrative approach in the learning of a new subject. The presentations in the Museums were focused on the relation between the construction of new instruments and the evolution of scientific knowledge. Cosmological models from the ancient times up to eighteenth century were presented using instruments, paintings and significant narratives of important astronomers and physicists of the past. The effectiveness of the experience has been evaluated through a written essay that students have been ask to do at the end of both visits.
A superficial textbook presentation of the Geneva Lake experiment for measuring sound speed in water: Students’ considerations of coherence between textual and visual information

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**Aim:** The implementations and role of the history of science in science teaching has been in focus by many science researchers to highlight different variations in its use from the epistemological, pedagogical and sociocultural levels (Matthews, 1994; Monk & Osborne, 1997; Seroglou & Koumaras, 2001; Besson, 2012). Many studies have been conducted to analyze textbooks with historical contents, and to explore how the history of science provides a didactical support for both students and science teachers (Galili & Hazan 2000; Rodriguez & Niaz, 2004; Kokkotas et al., 2009). Being so, it is surprising to find out that there is almost no research exploration on how or what students learn from history-related parts of their physics textbooks. The main aim in this study was to evaluate students’ understanding of a textual-visual textbook presentation of the Geneva Lake Experiment (GLE) for measuring sound speed in water (Slisko & Hadzibegovic, 2014) and their development of critical and creative thinking during an active learning session in the classroom settings.

**Method:** The study participants were a group of 121 students from eighth grade (14-15 years old) in a Bosnia and Herzegovina primary school. We created a worksheet as a research tool to be used during a classroom physics session. The session was carried out by the first author and lasted 45 minutes. The basic worksheet content is an incoherent physics textbook description of the GLE. The incoherence is related to fact that the artistic drawing does not contain various elements superficially mentioned in the textual description of the experiment. These elements, whose detailed description is important for proper understanding of the experiment, are missing in the drawing. Related questions were designed in such a way to make possible to explore whether this historical experiment presentation was structured in cognitively adequate way which would give students an opportunity to learn about the nature of physics and to show students’ potential for critical and creative thinking.

**Results:** The findings give an insight that students involved in the research were able to think critically related to a superficial textbook presentation of the GLE. Students also showed their creative thinking skills by suggesting devices that might play role of the missing elements in the experimental design presented in the physics textbook. There were 94% of students who have suggested the keywords for the missing elements in the attached worksheet-textbook drawing and they identified incoherence between the textual and visual GLE information. 76% of students have presented their illustrations of different devices for sending a light signal, and 55% of them presented the drawings of a classic chronometer, but 18% of students had applications of different digital chronometers.

**Conclusions and implications for physics teaching:** Research in which students were faced with different tasks related to a superficial textbook presentation of an historical experiment has provided evidence that most of the students are able to think critically, even more than textbook authors who proposed such a superficial textbook information. In the same time, the physics teachers need to be prepared to know how they can use some history of science information to create a useful didactical tool to develop students’ abilities of critical thinking and creativity.

**References**


Motions of a metal ball in three imaginary tunnels through the Earth: A pilot study in Bosnia and Herzegovina on coherence of students’ gravitation and inertia conceptions
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The role of thought experiments in development of scientific knowledge was popular theme in the philosophy of science (Brown, 1991; Sorensen, 1992). Consequently, many physics and science educators were analyzing conceptual meaning and educational potentials of thought experiments, stressing their importance for introducing the nature of science into physics curricula and students’ learning of school physics (Helm, Gilbert & Watts, 1985; Reiner, 1998; Gilbert & Reiner, 2000; Reiner & Gilbert, 2000; Reiner & Gilbert, 2004; Reiner, 2006; Galli, 2009).

“The hole in the Earth”, one of the most creative “destructive thought-experiment” (Brown, 1991), was invented to reveal fundamental weakness of Aristotelian theory of motion. As it is well known, this theory considers that there are two fundamentally different types of motions. The “natural motions” towards bodies’ “natural places” do not need any force for their executions. The “violent motions”, in which bodies move away of their “natural places”, do need an external force to happen. In an imaginary hole, bored through the Earth from Pole to Pole, a heavy body would execute a “natural motion” towards the Earth’s center where the motion would change abruptly to the “violent motion” away of its “natural place”, without action of an external force, a change that clearly contradicts Aristotelian views on motion. Although the authorship of this thought experiment is sometimes attributed to Tartaglia and Galileo (Clement, 2009), historical evidence shows the experiment was proposed earlier by Nicole Oresme (Hall, 1978). Recently, “the hole in the Earth” situation was used for exploring the gravity conceptions held by children (Blown & Bryce, 2013) and college students (Asghar & Libarkin, 2010).

The aim of this study was to find out how many students are able to activate the concept of inertia when predicting the motion of a metal ball in three imaginary tunnels bored through the Earth (“horizontal” West – East tunnel, “vertical” North – South tunnel and “inclined” North East – South West tunnel). With two initial positions on opposite ends of each tunnel, the students’ had to predict and justify six motions, a number sufficient for revealing a coherent or incoherent conception. This aspect of students’ conceptions was not studied systematically in previous investigations.
The sample involved 37 junior high-school and 57 high-school students (mean ages: 14 and 17.5 years) in two schools in Sarajevo (Bosnia and Herzegovina). 24 students at the junior high-school level and 32 students at high-school level provided justifications that made possible to judge their conception of gravitation and activation of the concept of inertia. Only one junior high-school student and four high-school students predicted correctly that, due to its inertia, the ball can’t stop at the Earth’s center and it would perform oscillatory motion in all six cases. All other students didn’t apply the concept of inertia while predicting the motions in the tunnels.

Aristotelian-like view that the ball should stop at the Earth’s center was clearly revealed by 3 junior high-school students and 22 high-school students. It should be added that they didn’t speak about ball’s “natural place” but saw the Earth’s center as the point where all bodies are gravitationally attracted to or where the gravitation is the strongest. Seven junior high-school students have shown coherently the conception of gravitational force acting only downwards for “vertical” and “inclined” tunnels. For two cases of “horizontal” tunnel they thought that motion of the metal ball would be affected by the magnetic attraction of the Earth. Such an incoherent approach to conceptualize similar physical situations was detected by other researchers, too (Libarkin & Stokes, 2011). 12 junior high-school and 6 high-school students provided very fragmented views on the ball motion, depending critically on particular tunnel orientations and initial positions.

**Study of Impact of micro physics’ workshops in preschool level in Mexico**

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In their program of studies for preschool level Secretary of Public Education of Mexico try promote it develop of 4 skills for science: Scientific knowledge, applications of scientific knowledge and technology, skills associated to science and attitudes associated to science. However, these level teachers have a lack in these skills so hardly they try to developing it in classroom. On the other hand, in the National Polytechnic Institute (IPN), was studied the positive impact of join to professionals of physics with preschool teachers for their capacitation in science themes, in particular physics themes. In this work we shows how were built with formal physicists, educational physicists and preschool teachers "Mini Workshops of physics" and to applied it directly in classroom for measured the develop of 4 skills mentioned before. We built with the teachers, didactic material's classroom and teacher's manual for 5 fundamental themes: electric circuits, heat and temperature, magnetism, optics and knowledge of the world, furthermore to create the evaluations that allow measure the conceptual gain and the develop of skills in the students. We have interchange of experience with the Cimarron Project of University of Baja California, University of Nuevo Leon and with the Republic University of Uruguay, moreover implement research results reported in several events like AAPT and WCPE. Finally, we pretend create a model of develop scientific skills based in the results of educative research made in IPN (like has been made in an other institutions, ITESM for example), that will be proof directly en classroom and evaluated by researchers of IPN and external.
Methodologies based on non-formal-learning and emotion-based learning for teaching physics in primary and lower secondary schools.

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Teaching Physics in primary and lower secondary schools involves the choice of particular strategies and methodologies, as often the students of this school band lack the mathematical tools to formalize the concepts. But apart from that, in many cases they lack the basic knowledge of many phenomena, the interest in direct observation and experimentation, the participation in laboratory activity. Often then an intuitive and misleading interpretation of some concepts is given, and it causes errors in understanding difficult to get rid of [Besson, 2004]. A relevant example of this is the concept of the density/specific weight of bodies, which it is regularly confused with the weight (gravity). Starting from these problems we decided to set up an interactive laboratory on this topic, consisting in a series of experiments during which the ‘surprise effect’ of a counter-intuitive and unexpected event would play the role of stimulating the kids to go deeply into the understanding of the phenomenon. It was to be a kind of ‘scientific investigation’, so as to make them better understand where the initial error was, and what the interpretative mistake was due to. At the core of this work has been in fact the belief that the attitude of a scientist's research is driven by curiosity, by a desire to explain the phenomena, to understand how they work and why they occur, and that these ways of feeling and questioning are similar to those that children have spontaneously when they are not influenced by environmental factors, e.g. having to provide performance subject to evaluation. Hence the choice of a workshop, of a non-formal didactic approach developed in a learning environment which, starting from the logistic connotations, looked like a user-friendly and involving interface. This give us the opportunity to create a link between everyday knowledge and scholastic knowledge [Guile, 2004].

In our design we have always kept in mind the results of recent research on informal/non-formal-learning and emotion-based learning, which highlight how the emotional involvement of the learner is able to remove mental blocks and activate deep structures that generate a stable knowledge [Michelini, 2006; Bachara et. al., 2000; Damasio et. al., 1994]. In the case under consideration (the school-laboratory project ‘From Archimedes to submarines: the concept of density’) the concept of specific weight of a body is not presented as an a priori definition, but as the culmination of a journey rich in discoveries and surprises: a series of experiments, which to the eyes of young learners often look like spells, with an alternation of surprises, emotions and moments of reflection. The experiences worked out as ‘outputs’ of the learning course have been interesting indeed: they consisted in the development and realization of theater sketches in which students of some of the classes involved were transformed, for the occasion, into scientists and teachers, performing to an audience of parents, teachers, and in some cases authorities invited for the occasion. This last step of the project, which consisted in a concise rendering of the learning progress, has been important in terms of real understanding /appropriation of the concepts studied, as well as of an increase in interest in the subject and a significant increase in self-esteem, essential prelude to a positive perception of what studied.

Bibliography

Non-formal learning: learning embedded in planned activities not explicitly designated as learning (in terms of learning objectives, learning time or learning support), but which contain an important learning element. Non-formal learning is intentional from the learner's point of view. It normally does not lead to certification.

Respiratory system - at the crossroads of physics and biology

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In many educational systems the science disciplines, like physics, chemistry and biology, are taught as one interdisciplinary subject, called science, integrated science or world orientation. The main purposes of such approach are to show the relationships between different science disciplines, and to promote the idea of science integrity and complementarity.

The main objective of this work was to demonstrate the possibility of taking advantage of the interdisciplinary character of biophysics for teaching science at various levels of education. To this end, we have designed a learning unit, based on some experiments, which enables modeling of the selected vital functions and learning of some concepts, associated with the respiratory system. The underlying themes and the difficulty levels of the tasks were adjusted so as to suit a variety of age groups, ranging from preschool to higher education.

The proposed learning unit is divided into three main sections to be utilized in a sequence. In the first section students are familiarized with the expansion and contraction of lungs and the role of midriff. They are asked to prepare their own model of lungs and to play with it in order to be able to fill in the tasks in worksheet. This part can be implemented at each educational stage. The second section focuses on the lung volume and experimental determination of the maximum vital capacity of the lungs [1]. In the course of the activities students are asked to find out the capacity of their own lungs. Due to the necessity of mathematical calculations, this part can be useful for teaching science or physics in older grades. Last section is linked to the maximum expiratory pressure and to its calculation done by utilizing the Clapeyron equation [2].

All experiments can be conducted with common, everyday objects, so the learners do not need any special equipment. The theoretical and mathematical background is provided in the worksheets, which contain also instructions for performing the experiments. During the poster session all parts of the proposed learning unit, including a real model of the respiratory system, will be presented to the audience.

Bibliography:
Workbook in teaching of physics at secondary vocational schools

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Knowledge of physics is necessary for pupils of secondary vocational schools and especially because of its interconnection with the most of vocational subjects. In the period before introduction of the Workbook in the teaching of physics the reality was that pupils didn’t enjoy physics too, pupils did not want to work in hours and their writing of schoolwork often didn’t correspond to its length or content interpretation and writing of teacher. Based on the study of problems in teaching physics associated both with lack of motivation of pupils and with lacking technical equipment of classrooms for teaching physics at secondary vocational schools, both qualitatively and quantitatively, was designed, prepared and in the school year 2010/2011 in the framework of pedagogical research then introduced the Workbook Mechanics for 1st year of Secondary Vocational Schools to the teaching of physics. The workbook was compiled and created so that pupils were able to acquired knowledge and skills further develop and to use in technical subjects: e.g. pupils of field Mechanics - Electrician in the subjects Basics of Electrical Engineering, Technical Documentation, Materials and Technologies; pupils of field Transport Operations and Economy in subjects Road Vehicles, Cars, Traffic and Transport and Logistics; pupils of Gastronomy in the subjects Technology, Restaurant and Hotel Operations, Food and Nutrition. The structure of the Workbook is based on the structure of physics textbooks. The Workbook is divided into identical thematic sections, chapters and sub-chapters. In the Workbook there are contained tasks to writing the words, polynomial tasks with multiple choice answers "one right answer", assignment tasks, tasks to do sketching pictures and physical problems, including graphic sketches. From the questionnaire survey, which was part of the pedagogical research, showed that parts of the Workbook devoted to proposals and realizations of laboratory works, notes from viewed videos and documents, quizzes, competitions, attractions and links related to the subject matter, not only from the world of science and technology, but also in everyday life, were evaluated by pupils as the best. Verification of using of the Workbook in practice was carried out by the form of pedagogical research, which was attended three vocational schools and one high school. It was examined whether the introduction of the Workbook in the teaching of physics will increase both qualitative and quantitative levels of knowledge and skills and whether also will improve their attitudes to the subject physics. Based on the results of the Entrance test, test Mechanics a questionnaire survey, which was for the pupils of experimental classes focused not only on find out pupils' attitudes to physics, but also their opinions on the introduction and the contents of the workbook, it’s possible to state the following conclusions, which applies to files of pupils which were included into the pedagogical research. The Workbook as an incentive in physics education positively influenced the attitudes of pupil towards the subject physics and was recorded and increase knowledge and skills of pupils of experimental classes of technical fields using the Workbook with respect to pupils of control class of technical fields, who had only classic workbook. The introduction of the Workbook into the teaching was positively evaluated both pupils and teachers in the experimental classes, but also pupils’ parents and other teachers of the participating secondary vocational schools. In view of the fact that the workbook can be continuously innovated, it is possible to think not only about how to modify the existing Workbook aimed to closer specialization right to the fields electrical, transport, gastronomic, but also about the preparation workbook for pupils of higher years. The Workbook will be gradually translated into English.
How does teaching in an out-of-school learning lab act on academic self-concept of pre-service physics teachers?

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Content knowledge (CK), pedagogical content knowledge (PCK) and pedagogical knowledge (PK) are said to form teachers’ professional action competence (Baumert, 2006). Although highly skilled in theoretical issues, applying their knowledge in practice is often difficult for future physics teachers. Enhancing school-like interactions with students in a special course of study already at university might provide appropriate learning opportunities to gain pre-service teachers’ academic self-concept and efficacy beliefs both acting on professional action competence.

In the „Lehr-Lern-Labor-Seminar“ at the University of Wuerzburg pre-service physics teachers work out experiment setups and learning materials on a certain topic (e.g. optics). As a second step they repeatedly instruct students in conducting these experiments in a out-of-school lab at university. The pre-service teachers receive feedback from both their peer group as well as from their lecturers in physics education. A pilot study (Trefzger, 2012) suggested positive implications of that course on pre-service teachers’ self-rating.

In this study the impact of school-like interactions with students within the framework of „Lehr-Lern-Labor-Seminar“ on pre-service teachers’ self-concept, academic self-concept and self-efficacy is assessed with a paper and pencil test in pre-post design. The self-concept scale (Schwanzer, 2005) is adopted from Marsh and O’Neill (Marsh,1984), the academic self-concept scale (Dickhäuser, 2002) is slightly adapted to cover the threepart structure of science teacher education according to the model of professional action competence (CK, PCK, PK). Self-efficacy is assessed on a general level (Schwarzer, 1999) and also on the specific level of science teaching (Bleicher, 2004).

We will overview the theoretical background as well as the study design. The focus will be set on the academic self-concept. The construct is assessed using items in four different classes of reference: Pre-service teachers have to rate their academic skills in general before they are asked to rate them related to their peer-group, related to the requirements their course of study makes on them and finally they have to rate the perceived evolution of their skills. Reliability measures and descriptive statistics will be reported as well as first ANOVA results.

Literature
A singing wine glass as an instrument for teaching acoustics

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Vibration and waves are classical topics in all physics curricula. One of the more usual lecture demonstration is to make a wineglass sing by rubbing its rim with a wet finger. Young people are very familiar with the phenomena and many street musicians can even be found giving concerts with wineglasses containing water, but most of the students only observe and they never analyze and quantify.

A wine glass can be simple and complex at the same time: to produce sound is easy but to understand the phenomena and quantify it is different matter. As a topic for physics courses can be not only an amusing event but an very useful instrument of learning and can become an excellent way towards experimentation.

This work describes the tests performed to identify variables, and their measurement, that where used in the experimental analysis of a singing wine glass.

First, for different shapes of wine glasses, with a microphone and a laptop, the natural vibration frequency of each one were determined; it was concluded that the frequency depends on the shape.

Second, the wine glasses were filled with different amounts of water to obtain a relation between the volume and the frequency, again with a microphone and a laptop. Frequency decreases with volume.

Third, the wine glasses were filled with different amounts of liquids, classified by their density, viscosity and surface tension. Again, with a microphone and a laptop, the vibration frequency was measured for different volumes of liquid. Frequency depends on the amount and of the class of liquid. For all liquids, frequency decreases with volume.

Last, knowing the resonance frequency of the wine glasses, with the help of a signal generator, a speaker and an amplifier, the wineglasses were excited at their resonance frequency until they were broken. The time they took to be broken was measured when the excitation power of the speaker was changed. The energy needed to break the wineglasses as well as the oscillation amplitude were obtained. A mathematical relation between the input electric power, the output sound pressure level of the speaker and the time of rupture was found.

A high definition and a high speed cameras were used to record the standing waves formed in the rim of the wineglasses. The resulting photographs and videos were analyzed with a software and It was possible to obtain quantitative results. Although this is a simple experiment, considering it for teaching sound waves can be a very illustrative experience.

Polish edition of the Chain Experiment

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The Chain Experiment is a Polish National competition that combines physics teaching and learning, scientific thinking and do-it-yourself (DIY) skills. The idea was taken from Slovenia, where the Chain Experiment was established in 2005. In Poland the competition is organized by the Institute of Physics, Jagiellonian University. The main purpose of this event is to build a device that will enable to move a small metal ball from one side to the other by employing as many interesting physical phenomena as possible. The main idea of the Chain Experiment is to promote the science (especially physics) among students at different stages of education.
The Chain Experiment consists of several stages. At the first stage, which usually takes several months, participants submit their applications and design their devices. Groups participating in the competition consist of 5 people supervised by a mentor. All guidelines for the construction are specified in the rules of the competition. At the same time the organizers visit schools and present a so-called "mini-chain" demo version to the students. The goal of such events is not only to demonstrate and explain how the exemplary device works, but also to share experiences with the construction of facilities for the chain. The most important part of the competition is the Grand Finale, when all devices are connected to each other to form one long chain.

In 2013, the Chain Experiment involved more than one hundred teams from all across the Poland. Participants were divided into four different age categories: primary school - grades 1-3, primary school - grades 4-6, lower secondary school (grades 7-9), upper secondary school (grades 10-12) and students. There was also a separate category for competing families. A five-person jury awarded the main prizes in each age category. Three prizes were also awarded by the public. A demo version of the chain experiment was presented in about 50 schools and also at various events organized by the Jagiellonian University. During the poster session we will present a video showing the final of the First Polish Edition of the Chain Experiment.

This year the second edition of the competition is organized. As in the last year, most applications are sent by students from lower secondary school – the stage of education at which in Poland physics is introduced as a separate subject for the first time. Thus the organizers hope that the Chain Experiment will help to increase interest in physics in the further course of their education.

**Informal teaching of physics at a Hungarian Science Center**

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Almost the best places of informal teaching the world wide popular science centers. One of them is the Mobilis in Hungary which is the only transportation themed science center in Europe. This Center is one of the most advanced places in Hungary for informal education. The Center’s aim was to put the phrase „teaching by playing” with the help of informal education methods like dissemination of knowledge, putting various educational task into practice.

The poster describes three different fields of activity.

- One of the most important goals has been to show people the value of natural sciences paired with some approach shaping and to build up a positive attitude towards these fields. This should begin in the early childhood. The parent’s way of thinking, their attitudes give the basics of their children’s career choice. That is the reason why the programs represented here involve multiple fields of interest and good practices for various ages.

- The link between the informal learning, and between the school education. Methodological assistance and additional opportunities are given to the teachers and to the schools. The teacher’s fears have to be dispelled: Their task and their talented students are not removed; in fact multiple possibilities of motivation, valuable information and ideas are given to these teachers. Searching and mentoring of talented students are also one of the most important objectives.

- One of the biggest problems in Hungary is that the youngsters have lost their interest in technical professions and disciplines. In Győr the vehicle industry (Audi and its partners) offer great career possibilities for young people that is why these programs are aimed to guide the children into these ways since a lot of training is needed to be successful in this field of commitment. On one hand elementary school children are being oriented towards higher educational forms in order choose one of the many trainings Győr offers for them in its technical secondary schools, on the other hand high school leavers are oriented towards technical and science Universities. Mobilis is localized near one of the biggest technical university in Hungary called Széchenyi István University.
Joining to the list of tasks mentioned above the poster briefly presents a few concrete practical and theoretical improvements:

- Constructing and teaching the methods of how to use experimental tools in experiments which include both children and adults such as: fire tornado, multiple rockets, operating superconducting material, homopolar electric engine etc.
- Project days with special activities (revolving stage in co-operation of 80-120 students, with competitive tasks, external speakers, making of many different operating principle vehicles)
- Various talent study groups’ theme and results are shown to 7th and 8th graders, high school students (study groups based on tablet PC-s, electric go-carts, and trainings to help studying for elevated graduation, “Young Physicist” groups)
- Possibilities of special events (European Mobility Week, Mini Science Picnic, projects in co-operation with the Széchenyi University)

The activities in Mobilis are motivating and helping teachers, students and parents as well. Throughout the quite narrow window of transportation, people can get closer to various applications, and can get a better understanding of basic theories, science and technical fields. Meanwhile the actors of the industry, education and high education one by one became part of an integrating process which activates them, make them think more creative and makes them to cooperate with each other.

**A new physics curriculum for a vocational school**

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Physics is considered a prerequisite for many professional subjects in vocational education. In Italian professional curricula, physics courses are planned in early years and focused on activities in laboratory. Regrettably, current practice is very different from one school to another. Sometimes laboratory is not properly equipped and usually physics and vocational teachers do not coordinate their educational action. Despite selected physics topics are essential for understanding many professional subjects and practices, their relevance in everyday situation, in which students will ultimately work, often remains hidden. Thus, physics is usually perceived as a boring set of laws very far from professional experience.

Recently, a pilot learning path was realized in an Agricultural Technical Institute within the Italian National Plan for Science Degree and succeeded in involving students and teachers in a more effective and motivated learning process. Starting from this positive experience, we proposed to school's management of redesigning the physics curriculum and a solid support was obtained. This was made possible by the recent reform of the secondary school that changed the schedule for many subjects, decreased technical support in the laboratory, leaving the responsibility of the contents of the learning process in the context of the autonomy of each school. The physics course for this vocational school requires for two years 3 hours per week, including one in laboratory with the co-presence of technical staff not specially trained in physics.

We present the initial proposal discussed with physics teachers, the methodological choices and some meaningful example of lab activities. Attempts of involving teachers of vocational matters, suggestions for innovative labs, students’ and teachers’ difficulties have been discussed, elaborated and overcome during periodic meetings with teachers. Successful teaching methodologies from physics education research, such as active learning, have been proposed and adapted to boundary conditions (available materials, teachers’ experience, topics related to professional practices or devices). We report how the initial proposal was adapted following teachers suggestions, in particular at the end of the first year when some choices in relevant topics (like mechanics and electricity) have been discussed again and reconsidered in order to obtain a learning process more suitable for students' capabilities and teachers more confident in their teaching action.
Since 2012, all first classes in the school followed the new curriculum (about one hundred students, age 15-16 y) and all physics teachers (5 participants) contributed to designing and testing the curriculum in class, while other 6 participants (3 teachers of vocational subjects and 3 technical staff) were occasionally involved in meetings. Assessment was discussed and inserted in the regular assessment of science skills to which all students in the school are annually submitted. It was more difficult to obtain an independent assessment dedicated to physics curriculum in which to test the overall effectiveness of the proposal by using tools developed in physics education research. Thus, we present some preliminary results at the end of the second year of physics curriculum.

Physics based magic tricks in the teacher training

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Demonstrations have lots of roles in physics teaching. Physics demonstrations help students to understand the phenomenon, make physics more interesting, give deeper conceptual and quantitative understanding, connect theories with the everyday life situations etc. Physics based magic tricks can also be used as a demonstration method. By magic tricks it is possible to achieve both entertaining and teaching perspective. People want to understand magic tricks. Applying the magic tricks during the physics lessons the students get a sight to the secrets of magic and they feel the lessons more interesting. On the other hand, the magic tricks are just entertainment and in that case the role of the tricks is to bring some fun to the lessons – for the students as well as for the teacher. The physics demonstrations (Lenz law, inertia, reflection, refracting, polarization etc.) can be presented as a traditional way but because several phenomena of physics are the basis of the magic tricks, these same physical phenomena can be demonstrated as a magical way.

This study was carried out to find out
1. the teachers’ opinions about the magic tricks in physics teaching,
2. if teachers already use magic tricks in physics teaching and reasons for that and
3. how the teachers understand the physics based magic tricks and the phenomena behind them.

As a part of physics demonstration trainings organized for the teachers were tested physics based magic tricks. The participating teachers were teaching at primary school and upper secondary school levels. The main idea of the training was to give motivational physics demonstrations to the teachers so that they could utilize them in their own teaching. The magic tricks were presented as demonstrations as well. The teachers had to write down the phenomenon of the trick after every trick. The demonstrations were mostly conceptual. After the presentations teachers answered an inquiry.

The inquiry consisted of three different parts. In the first part were studied the teachers’ opinions about how physics based magic tricks can be used in physics teaching and as a demonstration method. The second part of the study concentrated on the question about? why teachers use the magic tricks on their lessons and what would be a suitable age of students to whom show these kinds of tricks. And finally it was studied how the teachers understand the physics based magic tricks.

The result was that by using the magic tricks in physics teaching can be aroused the students’ interest on the physics lessons and help students to find the phenomenon of physics from everyday life. The magic tricks can enrich the teaching and offer new ideas. The theories explaining the magic tricks are sometimes very difficult to understand. So if the target is to teach phenomena, it is better to use the tricks at higher school levels. But if the aim is to attract students’ attention, the magic tricks suit students of all levels from the lower level primary school to the university level. In both cases, the magic tricks increase the interest in physics. Magic tricks are also a new and cheap way to present old demonstrations in a different style which motivates teachers to use
demonstrations. It appeared that physics behind the magic tricks is very difficult to explain. Only reflection, pressure and induction were well-known. The teachers recognized the basis of the magic tricks but explaining the theory was too difficult even for the teachers. Analysis of the results and the tricks will be presented in detail at the conference.

Physical modelling: a different approach to teach non-physics majors

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This work describes how to build a simple qualitative physical model of the electric conduction in the heart, which may help students, interested on health sciences, to understand relationships among physical phenomena and physiological processes. Additionally, it shows the importance of learning physical concepts and analogies, such as electrical resistance, heat conduction, which leads to the introduction of the Seebeck, Peltier and Joule effects, as well as to the Ohm and Fourier laws. Modelling in a Physics course provides stronger conceptual connections between different subjects and it becomes a nice experience, disappearing the traditional disconnection that exists from physics to health sciences. Modelling in different subjects can help to emphasize the interplay of concepts in science.

The heart is an organ with complex structure. Cardiac muscle is composed of low-resistance connected individual cells, but it is impossible to model the tissue by modeling each individual cell since it contains a large number of them. The electrical signal that controls the mechanical activity of the heart starts at the sinus node, travels down a specialized conduction system and then propagates through the ventricles, the main pumping chambers of the heart. At the cellular level, the electrical signal is due to a variation of the cellular membrane potential, called the action potential. This electrical activity manifests on the surface of the body in the form of the electrocardiogram (ECG).

Most cardiac impulse conduction models consider an action potential wave-front, and assume a continuously uniform intracellular resistivity in the direction of propagation. Modelling the wave-front can help students to understand this phenomena and to relate different physical concepts. In order to simulate the electric conduction in the heart, it is assumed that the propagation of an electric stimulation is similar to heat conduction, so that students can visualize it by color changes produced by temperature changes in a Reversible Liquid Crystal Mylar Sheet. With a fast response time, these temperature-indicating sheets provide a quick visual readout in laboratory, testing and evaluation applications.

Placing the sheet near a gentle heat source, or warming it, causes the liquid crystal to change color, indicating areas of different temperature. Using Type K (CHROMEGA®-ALOMEGA®), thermocouples and an AC/DC adapter, different heat sources may be obtained, and the concepts of the Seebeck, Peltier and Joule effects may be introduced. If each thermocouple is connected to a trimpot, different temperature change rates may be achieved and, thus different cells of the cardiac electric conduction system are simulated, visualized as bidimensional heat conduction similar to the complex models which simulate the electric propagation in a cardiac tissue.

Various conditions of cardiac cells may be modelled by changes in the resistances, the temperature variation rate, and different cells are modelled through changes in the time of heating, the excitation frequencies variations. Here, Ohm and Fourier laws can be introduced. This experiment introduce students to the art of modelling and by the way they have enjoyable learning experience.
“Elixir for Schools” – a new initiative supporting Czech physics teachers

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A poster will describe a new initiative that in the last school year lead to the creation of 18 regional centres where physics teachers can meet. Their meetings take place once a month and are open to all physics teachers free of charge. The teachers can learn new ideas there, share their experience and borrow some teaching aids. The Elixir for Schools project is an example of how a private company can support useful educational activities as part of its social responsibility. This project was prepared as the pilot project of The Depositum Bonum Foundation which was founded by the Czech bank Česká spořitelna. The Elixir for Schools’s activities are based on the experience of a long-term informal educational initiative Heureka (already described at GIREP and some other conferences). Elixir for Schools enabled us to scale up considerably our previous work with teachers and to expand it to a higher level. It is important that the regional centres are led by physics teachers, former active members of the Heureka Project. They can use their previous experience and positively influence physics teachers in their regions. The total number of teachers touched by the Elixir for Schools project is now almost four hundred. Also, the centres foster the creation of stable groups of participants. We aim to make their participation really active, with the individual participants bringing and presenting their own ideas and experiences and not just passively visiting the meetings. Though this is a long-time goal, we have already seen some positive shifts in this direction. The Elixir for Schools project is aimed at teachers from junior secondary schools (age group 12 – 15). However, teachers from higher secondary schools can participate at the regional meetings too. The whole activity of the project is, from the methodical point of view, supported by teacher trainers from Charles University in Prague. It is also supervised by a group of experts from 8 universities in the Czech Republic where pre- and in-service physics teacher training is organized. In the poster, we will present the experience gained in the first year of the project, its scope, type of activities in the regional centres, feedback from both teachers who lead the centre and from the participants. We will mention also some other aspects of the project and its perspectives. We hope that our experience can be useful for teacher trainers in other countries who build and organize similar teacher support networks and activities.

Responsible Research and Innovation in Science Education: The IRRESISTIBLE Project

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The partners in the EU funded IRRESISTIBLE-project (Project Coordinator: Jan Apotheker, University of Groningen, Netherlands) develop activities designed to foster the involvement of high school and elementary students and the public in Responsible Research and Innovation (RRI). The latter is defined as a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to ethical acceptability, sustainability and societal desirability of the innovation process and its marketable products to allow a proper embedding of scientific and technological advances in our society.

In this project, awareness about RRI is raised in two ways: increasing content knowledge about research by bringing topics of cutting edge research into the program; fostering a discussion among the students on RRI issues about the topics that are introduced.

Responsible Research and Innovation focuses on six key issues:

1. Engagement, joint participation of researchers, industry and civil society in the research and innovation process
2. Gender equality, unlocking the full potential of society
3. Science education, creative education to foster the future needs of society
4. Ethics, including societal relevance and acceptability of research and innovation outcomes
5. Open access, free, on line access to the results of publicly funded research
6. Governance, the responsibility of policy makers to develop harmonious models for RRI

One of the features of the project is to combine formal (at school) and informal (at an exhibition, science centre or festival) teaching to familiarize schoolchildren with science. Sixteen partners in ten countries are involved in this European project coordinated by Science LinX. Each participants will establish a community of learners (CoL). These communities will included school teachers together with university experts in the field of science communication and science centre staff. In the project, ten CoL will develop materials that the teachers will use at their own schools. Students will develop an exhibit for a science centre in their own country. The exhibit should engage the audience in the relationship between research and society. Once they have completed their teaching module, the teachers will each train five colleagues, in using the developed modules from the first year. Ultimately, this project will train almost ten thousand pupils to consider the social impact of scientific research.

The partners in Italy (Università di Bologna andUniversità di Palermo) will develop a module that, starting from the applications of nanotechnology aims to enhance students’ awareness of the importance of science in everyday life and to promote chemistry and physics knowledge needed to understand uses and implications of nanoscience and nanotechnology. Ethical problems connected to the development of nanotechnology will be part of the module, as well as the historical background of the atomic and molecular theories that enables students to better understand the nanoworld.
Simple experiments supporting conceptual understanding of body colour

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We perceive our environment mainly through visual stimuli. Seeing colours is one eminent part of visual perception. Understanding the phenomenon of coloured bodies based on adequate physical concepts poses a big challenge for students in initial optic courses (Martinez-Borreguero et al., 2013). A number of students' alternative conceptions about body colour, which hinder the understanding of colour phenomena, are known from physics education research. One prerequisite for understanding (geometrical) optics on a basic level is the idea that light emitted from or reflected by an object needs to enter the eye of the observer in order to produce a visible sensation (deHosson et al., 2007; Guesne, 1985). Feher and Meyer (Feher et al., 1992) summarize the following ideas as the most frequent categories of students’ conceptions on the colour of illuminated objects: (1) the coloured light mixes with the colour of the object, (2) coloured light is dark and makes objects appear darker, (3) coloured light gives its colour to the object, (4) coloured light has no effect on the appearance of objects.

What makes the situation of instruction even more difficult in initial physics instruction in Austria is that the physics curriculum of year 8 contains colour phenomena as part of geometrical optics. The wave nature of light is, however, not part of year 8, but is first brought up in year 10. Consequently, the teaching of colour phenomena is restricted to reconstructions of body colours not including the wave aspect of light. Usually, Austrian students learn about two phenomena relevant for colour phenomena, namely additive and subtractive colour mixing. What students mostly retain and use in any situation if appropriate or not – are the mixing rules they know from their water colour boxes.

In order to support learning process we base the teaching about body colour on real phenomena and reconstruct the explanation with the processes of selective absorption and emission of light. Several easy experiments, which are supposed to help students to relate body colour to processes of selective absorption and emission, were developed. In the course of these easy experiments, students are instructed to observe and determine the paths of light from a light source via the body to the observer. This poster presents a number of easy experiments (see pictures below**) which support students in acquiring the following key ideas:

• We can only perceive an object if we receive light from it.
• We perceive an object in a certain colour, because we receive a certain kind (quality)* of light.
• The kind (quality)* of light we perceive from an object depends on two main conditions:
  a) the kind (quality)* of light we illuminate the object with
  b) the kind (quality)* of light the body sends off (emits) again.

We tried these experiments in some year 8 classes and got very positive feedback.

*) Kind (quality) of light is used in this context to describe the „colour of light“, so to say the wavelength(s) of the light in question.

**) It was not possible to upload any photos.

References


Towards a programme for the development of cognitive meaningful learning strategies of physics

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This is to establish a cognitive profile, a predictor of academic success and an intervention program to develop cognitive strategies for meaningful learning (PRODECAS) from physics, in terms of learning strategies, critical thinking and academic performance model that new students to enter careers in Civil Engineering from the University of Bio-Bio, Concepción, Chile. It seeks to improve the processing of information, and the quality of learning. The results show the need to include in the program PRODECAS: a) images and heuristics to develop the ability to organize and sequence content, b) methodological renewal in Problem Based Learning (PBL) and Problem Solving (RP), to promote transfer files and meaningful learning.

In this context sought; Implement PRODECAS intervention program for teaching and learning content, processes, attitudes, laws and principles of physics I, leading to an overall development of students, in terms of information processing, critical thinking and academic behavior; Set the cognitive profile of new students to the career of Civil Engineering, based on characteristics necessary to achieve meaningful learning, develop a predictor of academic success or failure model for the subject of Physics I, depending profile of cognitive and academic performance at the end of the course and finally design and develop a program of action to address the content PRODECAS Physics I.

The proposed methodological renewal included in the PRODECAS program considers ABP and RP, where the traditional process is reversed, ie, the problem occurs, the previous ideas, learning needs are identified, the contents to investigate, then seek information needed to finally return to the problem before solving a sequence of smaller problems that lead to the solution of the great problem. This process facilitates the transfer of files to new situations, necessary to achieve meaningful learning and develop cognitive strategies, Fondecyt, 1071050 and 1090618 (Sanchez et al, 2009 and 2011) projects condition.

It is now established cognitive profile of students of Civil Engineering, University of Bio - Bio, based on cognitive variables: processing strategies and elaborative deep, shallow and repetitive, concrete and formal information, information obtained at the beginning of academic year 2012 and 2013. To set the predictive performance model performance obtained in the course of Physics and all variables were analyzed using Multiple Correspondence Analysis (MCA), these results lead to design and develop the PRODECAS is incorporated. The results in terms of learning strategies show that engineering students at the University of Bio -Bio, possess one hand, learning strategies shallow and repetitive processing, ie, take time to study and repeat on the other hand, there is a group of students who enter engineering with characteristics of meaningful learning, ie having high elaborative processing and deep at the same time, ie is capable of organizing and transferring information in different contexts).

The results show the relationship between methodological renewal, development of critical thinking and learning strategies, is an emerging research issue. In this sense, this empirical study is a breakthrough for future research to try to gather evidence in this line of work. Although the results reported sufficient evidence to affirm the existence of a positive relationship between the intervention in a subject of Physics, with methodological renewal and development of critical thinking, in one semester, it is not possible to establish categorical judgments due to large number of variables involved. Certainly the development of cognitive skills related to critical thinking required to have this time of intervention that greatly contributes to this positive relationship and a multidisciplinary approach methodological renewal in a larger number of subjects to occur
simultaneously in this context, it is inferred any program to develop critical thinking in higher education, you should consider methodological renewal and intervention time. This work is part of an investigation, which is made possible by funding through the Research Project FONDECYT 1120767.

Multiple bounces of different material balls in free fall

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In this work, we present a proposal for a more dynamical experimental physics course for physics and engineering students of the Universidad Autónoma Metropolitana. Unidad Iztapalapa (UAM-I) in Mexico City. Term in the UAM-I lasts only three months so time students spend in the laboratory must be use wisely to get the best learning and with the experience we present here we attempt part of this objective.

In UAM-I, physics experimental courses are independent from theoretical courses, so students usually do not relate problems they solve in theoretical courses with the work in the laboratory. The aim of this proposal is to teach students how to experimentally analyse problems that they solve in their theoretical courses. The idea is to integrate Mechanics I, Waves and Rotations and Differential Equations courses with topics that must learn in their experimental courses, such as error propagation, least mean square, the use of spreadsheets, video analysis, etc.

This proposal is not resolved in textbooks and students enjoyed the experience. Students observed and described the behaviour of three different material balls falling freely until they arrive to the floor. They repeated the experiment but over their desk and finally they replaced the balls by their notebooks which also fell freely from the same height. Students used their cellular phones to record the experiment and analysed the videos obtained with the help of Tracker program.

Students has to determinate the force that made the balls go up after each bounce and then with their results try to explain their experience with the notebook.

With their observations, students has to write a proposal for studying experimentally the problem, the proposal had to contain the questions arised from observations, their hypothesis, and an experimental procedure for made a quantitative analysis.

With this experiment, students was also introduced to model the phenomena. Measuring the distance reached after each bounce, and the time to get it, the loss of energy could be quantify. The experimental results was compared with theoretical results considering the phenomena similar to the behaviour of a damped oscillator.

This problem might look simple but led to a more extensive research work with different explanations to the ball behaviour at collision with the ground and a very interesting debate of ideas between their own work team and other work teams. A very nice learning environment was created by the collaboration between students, helping each other how to use Tracker program and other programming languages. Some students even analyzed the chemical structure of the balls to understand the elastic properties of different materials.

So we consider that learning strategy would be very useful for our experimental courses.
The use of texts as an aid for learning the ontology of scientific concepts

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This work presents several research results that have been obtained through the application of Chi's Conceptual Change Theory (2008, 2012) combined with the use of texts as an aid for learning. A fundamental idea of this framework is that entities in the world belong to different ontological categories or, in other words, they have different nature. The distinction among ontologies can be represented by means of ontological trees that have different ontological attributes associated with each of them. A concept's belonging to a certain ontological category can be tested through its predication with the ontological attributes of a category: if, as a result of such a predication, a sensible proposition is obtained, the concept belongs to that ontological category. To state, for example that "the electric field is stopped by a metal" shows an understanding of the electric field as a material thing that can be "stopped". This proposition does not make sense since the field is a property of each point of the space and as such does is not capable of "being stopped".

When a person learns a scientific concept he assigns to it (many times in an unconscious way) a certain ontology that may or may not be the same as that of the ontology accepted by the scientific community. In doing this, the learner assigns to the concept certain attributes with which he generates explanations and descriptions about different Physical situations. According to Chi's model, the learning of a concept will not be achieved unless the ontology of students' ideas matches the concept's ontology. In the last revisions to Chi's theory, she identifies three types of conceptual change, being that of "change of category" the hardest to achieve.

Textbooks, papers, notes, among others, are one of the most common didactic aids that university students use when learning. In the special case of physics texts, Alexander and Kulicowich (1994) identified two systems within them: symbolic and linguistic. While the symbolic system includes equations, drawings, and graphics, the linguistic system is used to explain in words those situations referred to by symbols. In other words, the linguistic system simplifies the information processing that the reader must do to understand what he is reading; the more explained the symbolic system is, the less difficult it will be for the reader to understand. These kind of linguistic explanations are specially important in the case of acclimatation readers (Alexander y Jetton, 2000) that are those who are learning to read in order to understand and learn new concepts. The ontology of a concept is mostly described by sentences (words) thus, texts rich in the linguistic description of the nature of the concepts were the focus of our investigations.

In this work, we will show some of the results that have been gathered through research that has studied the effects of texts whose common denominator is that of being rich in the ontological description of the presented concept. Cases such as the learning of the electric field, lines of force, and displacement current are presented. It is concluded that, as these ontology-rich texts favour comprehension, there are other characteristics of the texts that inhibit it.

REFERENCES
University professors' receptivity to Physics Education Research: the case of classical mechanics

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Numerous research in physics education have been conducted in order to better understand student's ways of reasoning when facing physics’ concepts and laws. A lot of them have led to develop pedagogical materials and teaching instructions with the aim of improving students’ understanding in physics. Nevertheless, although a great deal of effort has been done into research, results of PER are only marginally incorporated in teaching practices, particularly in higher education.

Overview of the research and research question

This exploratory survey aims to document physics' teachers (first university years) commitments with results coming from physics education research. We wonder to what extent physics' teachers in higher education are responsive regarding PER materials. In mid-terms, this relates to supplying in-service university teachers’ training sessions plan in the context of professional development in physics' higher education [1].

Methodology of collecting and analysing data

The survey has been carried out through the analysis of nine audio-recorded interviews conducted with physics academics coming from two French universities. The PER material for interviews was based on multiple-choice tests (MCT) developed by researchers with the aim to measure and analyse students' conceptual understanding. Here, the FMCE test [2] was reinvested by including two clusters of questions mainly defined by different contexts [3]. Two different models of reasoning were thus investigated: “the force exert by an object is proportional to its velocity” [3] and “the more active / energetic (or bigger / heavier) object exerts more force” [3]. Emergent categories were inferred from the transcription of the audio-recorded interviews using the first steps of a semi-inductive method, i.e. an adaptation-transformation [4] of the Grounded Theory approach. These categories structured an analysis grid.

First findings

Analyses completed lead to the following results: first, the professional routines of the surveyed teachers may influence both reading and appropriating of MCT based on PER. As an example, all teachers focused on the linear momentum concept MCT’s collision problems while PER researchers questioned the force concept connected with movement and the third law of Newton. However, routines do not appear to be an important barrier to using such MCT in teaching practices as long as it is used as a self-diagnostic tool for students. A possible reason for this positive sign of integration is that MCT allows detecting students’ reasoning in a more relevant way than common tasks and exercises which usually lack in testing students’ understanding of physical concepts and laws.

Conclusion and perspectives

Among the research perspectives, it seems important to confirm these findings by testing others type of PER materials for others misconceptions in physics and using the analysis grid developed along this research. We also suggest to investigate the effective teaching practices using MCT (which constraints, resistance, impact on student learning?) or the use of MCT as an auto-diagnostic tool for students’ homework as suggested by some interviewed teachers. Furthermore,
Coaching teaching assistants in tutorial classes and the physics labs

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Most lecturers agree that the tutorials and labs are very important for students. That is the place where students get to master the subject since they have to demonstrate by doing exercises or by relating theory to practice they understand what has been taught. It is therefore amazing that tutorials and labs in most cases are conducted by graduate and undergraduate students with no formal training in teaching whatsoever.

A general observation is that in a majority of cases lecturers and teaching assistants work very hard to explain theory and demonstrate how to solve problems and students tend to lean back and observe. For many lecturers and teaching assistants it is hard to find ways to activate students during lectures and even during tutorials, especially when large groups of students are involved in these courses.

Furthermore, the majority of courses are still taught in a very traditional way: in lectures where students are passively exposed to large amounts of complex information perfectly explained by experts. When confronted with this usually the reasons given to justify this behavior are: (1) large groups of students do not allow for interaction, (2) there is insufficient time to deal with examples and anyhow, that is why homework is given and tutorials are held, and (3) this is the only way to cover everything that is in the book.

The last two years a program has been developed to support lecturers and teaching assistants how to make their teaching more effective by doing less, and making students do more. Lecturers have been provided with tools to activate students during lectures and ways of formative assessment during the course to ensure learning by students has been effective, and also as a tool to evaluate their own teaching.

To make tutorials more successful the teaching assistants need to undergo a short training. The following constraints have been considered: (1) graduate and undergraduate students have limited time available to undergo training, (2) the training should address immediate needs only specifically for the tutorials offered, and (3) as lecturers are responsible for their courses they are the ones deciding on what is to be covered as exercises during the tutorials. Coaching has been offered along the period of the tutorials or labs are offered. Typically 1.5 hours weekly meeting were scheduled to address immediate needs for tutorials or labs. The coaching programs will be presented along with the successes obtained for a number of tutorials and lab courses.

References
Implementation of a proposal to teach quantum mechanics concepts from
the Multiple Paths of Feynman applied to the light

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In this work we analyze the results of a didactic sequence (Arlego, Fanaro y Otero, 2012) for
Teaching different aspects of light in a unified framework and non traditional way. It was carried
out in two different secondary schools, during 2012 and 2013. The data analysis is based on all the
students’ productions and it was realised using the Theory of the Conceptual Fields (TCF)

The proposal is especially careful using terms like "photon" and avoiding phrases like “particles of
light” or “wave-particle duality”, that might be confuse for the students in a first stage. The goal is
to propose the quantum theory of light as a unified and universal framework to describe different
phenomena observed.

The didactic sequence was carried out starting from the experiences of reflection, refraction and the
double slit experiment. These experiences were realized in classroom with mirrors and a graduated
circle specially designed to analyze the reflection and refraction, a container and different liquids
for the refraction, and a metallised sheet designed with two thin slits. In all of them a common laser
light was used. The students made the three experiences and they were able to describe the
experimental results.

Then the results of the double slit experience showing individual detections were presented, coming
up with a sequence of real images of the double slit experiment, with very low intensity light. This
shows individual detection events, and the light hitting the screen in a granular form. At the
beginning, the individual events seem to be distributed randomly over the screen, but as time goes
on, a pattern of maxima and minima is formed on the screen. In this case the light exhibits a
different behaviour from previous experiences: some particle-like aspects such as detection of
individual events on the screen, but something like in the experience realized in classroom, as the
concentration fringes formed on the screen. The concept of discrete detection was highlighted in
this part.

A model to explain all these experiences was proposed: the laws of quantum mechanics for light
using the path integrals technique of Feynman, adapted to the mathematical level of students.

Graphic representations and basic operations with vectors, which capture the essential aspects of
the theory, were used. A simulation made with the software GeoGebra(R) helped students to
visualize the results of the “sum of all the alternative paths” technique to a simple case of emission
and detection light. The concepts of probability and minimum time were highlighted in this part.
Then, these results were applied to the double slit experience to explain the results noted in the
previous situation relative to the granular detection and successive fringes of concentration.

Finally, the technique to consider alternative paths was applied to the reflection and refraction of
light, using simulations made with GeoGebra(R). The students noted that the results were
approximated of those observed in the previous experiences. Thus, they conclude that the laws of
quantum mechanics describe the observed phenomena.

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Didactical proposal for teaching physics: a challenge to teachers

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In this paper a didactic proposal, which involves teachers and students, using several technical devices which could arise cultural and scientist aspects. The development of different topics in a physics course should be structured by motive activities. Several means may guide an effective integration in the teaching-learning process. The methodology applied in class recover aspects which implies a knowledge focused in investigation, using devices involved in educational technology. This proposal is concreted with students attending courses of physics for engineering careers at Universidad Tecnológica Nacional –Facultad Regional Santa Fe.

Students’ understanding of first law of thermodynamics

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The present study discusses undergraduate students’ understanding of the first law of thermodynamics using predict-observe-explain strategy. Their understanding is tested through a questionnaire followed by activities related to the first law of thermodynamics. Thirty undergraduate students (who have completed basic course in thermodynamics till the end of their first year of undergraduate program) were participants of this research study.

The questions were based on the application of first law of thermodynamics in isothermal process and adiabatic process. The initial part of the presentation will discuss the analysis of students’ responses to these questions.

Students were then introduced to the activities based on the questions that they encountered. The activities aimed at building their understanding regarding: i.) isothermal process, ii.) adiabatic process, iii.) calculating work done using a $PV$-diagram and iv.) Calculation of work done and change in internal energy in first law of thermodynamics.

Students were asked to perform the activities instead of just observing it and hence we called it predict-perform-observe-explain approach instead of predict-observe-explain approach.

In case of isothermal process (activity 1), a cylinder made of copper walls was used. The temperature of air inside the cylinder was measured using a chromel-alumel thermocouple. Students were asked to carry out the process slowly in which they could observe that the temperature of the air inside the cylinder remains constant. They also calculated the work done during the process by two methods:

i. using the formula $W=nRT\ln(V_2/V_1)$

ii. using their observations to plot $PV$-diagram.

In adiabatic process (activity 2) a similar exercise was carried out. A plastic syringe was used as an adiabatic cylinder. The work done was calculated again by two methods:

i. using the formula, $W=\frac{nRT(V_1^{1-\gamma}-V_2^{1-\gamma})}{(1-\gamma)}$

and

ii. using their observations to plot $PV$-diagram.

In the third activity, each term in the first law of thermodynamics, was calculated. In this activity a hollow copper cylinder (connected to a pressure sensor and a volume indicator) was immersed in a hot water bath. The change in the temperature of air inside the cylinder was measured using a chromel-alumel thermocouple. Work done was calculated by noting the Pressure and Volume
observations. By recording the changes in air temperature, the change in the internal energy was calculated. With these values of the work done and the change in the internal energy specific heat capacity of air was calculated which agrees well with the accepted value of specific heat capacity of air.

During all the activities, students were asked to comment on their observations at every step. The questions asked in the activity sheets were framed with an objective to make them think and explain about the steps they follow to perform the particular activity.

Finally, they were asked again to answer the same questionnaire based on their observations in the activities and provide explanations for their responses. This presentation discusses these activities and students’ responses at various stages of this research study.

University students’ conceptual difficulties about rotational and rolling motion concepts

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Physics is basic and fundamental science to understanding the world around us, but many students have problem in learning physics. Physics education researchers try to clarify students’ difficulties in learning physics. So, they have developed Concept inventories which are valuable and necessary diagnostic instruments to investigate student understanding of the basic concept in physics.

Rotational and rolling motions are one of the important topic in mechanics that students have many common difficulties in understanding concepts related to this topic. Although, there have been many studies on linear motion, only few focused on rotational and rolling motion.

In this research, introductory physics students’ difficulties in learning rotational and rolling motion concepts were investigated. For this purpose, a multiple choice test was used. The test was developed by Rimaldini and Singh (2005). The test doesn’t cover all topics involved with rolling and rotational motion but it focuses on important concepts, which are moment of inertia, rotational kinetic energy, angular velocity and acceleration, torque, rolling (relative motion), rolling (role of friction and other parameters), sliding/tumbling cube on an inclined plane. The test was translated into Turkish language and administered to introductory physics course students.

The multiple-choice test consisted of 30 questions was administered to 268 students. The students were given 50 minutes to take the test. The reliability index a was found as 0.71, and the point biserial discrimination coefficients were calculated between 0.2 and 0.5. These statistical results are in consistent with statistical values of the original version of the test.

The findings of the research showed that; students were not familiar with either the rotational and rolling motion concepts or with the physical laws and relations. Many students didn’t know that moment of inertia (I) is a function of the mass distribution about an axis, and that the rotational kinetic energy depends on I and not just on the total mass. Most of the students couldn’t establish a connection between the net torque and angular acceleration. For example; Question (28), which was the most difficult question on the test for the students. This question is related to torque. Only 28 students answered this question correctly and 66 students gave no answer. The wrong choice (a) was chosen by 131 students instead of the correct choice (e). Student responses to question (28) showed that net torque on the disk+clay system about a point on the axle, many students, by choosing (a), felt that the mass of the disk should also contribute to the net torque. Students had also difficulty distinguishing between the speeds of different points on a rigid wheel with respect to the center of the wheel or ground. Some students did not recognize that the bottom point of a rolling wheel was at rest with respect to the ground. They were also unaware of the role of friction in rolling motion. Many students had difficulties in determining the role of friction in rolling without slipping of a rigid wheel on a rigid horizontal surface in the absence of air resistance.
Teaching Of The Physics Through Of The Construction Of Prototypes

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In this work we show a strategy for the programs of classical mechanics, electricity and magnetism at the college level. It is a strategy based on the design and construction of prototypes that allows the use of the scientific method on the development of projects. Besides the students can also activate other level skills of graphic expression, oral and written. This research also takes some aspects of constructivism and more particularly uses the project-based learning and active learning. The project-based learning proposes interdisciplinary teaching activities in long or medium term and focused on the student, instead of short educational processes and isolated. The construction Of Prototypes and project-based learning is used as an educational strategy which constitutes an authentic instructional model in which students plan, develop and evaluate projects with application beyond the classroom. The instructional strategies based on projects are rooted in the constructivist approach that evolved from the work of psychologists and educators such as Lev Vygotsky, Jerome Bruner, Jean Piaget and John Dewey. This work has been focused on three topics: Parabolic Movement, electrostatic machines, oscillations and vibrations. One part of the project was developed in the first and second semester of 2013; the second one will be done in the first semester of 2014 with engineering students. We present Analysis and results obtained using psychometric tools such as Bao concentration factor and the Hake gain of learning and interviews applied to students. In addition, the strengths and difficulties of the strategy employed compared to traditional instruction are presented.

Impact of a discussion method on high school students’ understanding of kinematical concepts

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Despite of its importance for future physics learning, Kinematics is a field where students’ misunderstanding is the most pronounced. One possible explanation concerns the alternative schemas the students already have on the properties of motion, which they develop by interacting with daily phenomena and that may interfere with learning, especially if they are not taken into account. In this regard, the use of the discussion method allows students to compare their ideas with those of others, and thus to assess their consistency and effectiveness to predict and explain physical phenomena (Knight, 2004). However, the link between the discussion and understanding of concepts has not been established through research in a clear way. Indeed, the discussion as a teaching method is poorly defined and often associated with exchanges between students, so that it does not contain specific information on what teachers and students should do (Viennot & Chauvet, 1997). Therefore, our first research objective aims at conceiving and identifying the conditions of implementation of a discussion method of the properties of kinematical phenomena which takes into account alternative schemas of the students and allow them to prove their hypotheses in the laboratory. Our second research objective consists in assessing the effect of such a strategy on the high school students’ understanding of kinematical concepts.
Our study consisted of four classrooms of a total of 122 French-speaking students of a 12th grade physics course given in three different high schools in Canada. The discussion method was implemented during four successive periods of one hour and quarter for three groups and three consecutive periods for one group. In each of these periods, the students had to answer a question taken haphazardly in a bank of problem of a test of understanding during five minutes of the period. This disposition allowed us to follow the evolution of the understanding of every student throughout the implementation of the discussion method (Lin et Lawrenz, 1999). To determine if the discussion had an effect on the understanding of the pupils, a repeated measures analysis of the variance was performed to determine if the increase of understanding according to the number of periods of the discussion method is linear (Howell, 2008). To study the implementation of the discussion method, the main researcher held a research diary where he recorded his observations on the sequence of events, the critical details regarding the introduction of the discussion method by each teacher, and comments of the teacher in meetings with the researcher (Altrichter & Hollly, 2005).

A positive and significant linear trend in students’ understanding was present in two groups out of four where the discussion method had been implemented. In the two groups where there were no significant results, it appears from notes in the diary that the discussion method had not been implemented as planned, one of the teacher was unprepared to lead the discussion, while in the other class, a quick coverage by the other teacher of the cases of motion studied did not encourage discussion among students. Our research results seem to lead to a question mark. On the one hand, our discussion method seems promising, as it allows students to expose and compare their ideas, develop arguments to defend them and verify their reasoning by proposing experimental tests. On the other hand, the complexity of the classroom environments reveal the multiplicity of influences that can change, sometimes positively and sometimes negatively, the course of discussion in physics. Our research therefore concludes with recommendations for future research to go further.

**The use of sporting issues in the teaching of Mechanics: What force required for initial boost an athlete in 100 m?**

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The suggestion for this work comes from reading the article published in Science Olympic blog, where the subject was treated in the sport of athletics 100 m. An information in there called me much attention. In establishing the new world record in 2009, Usain Bolt would have a force equivalent to its own weight? This made me think that it should be next acceleration gravity. I found surprising since heard that high performance cars do 0-100 km / h in 10 s approximate. What would an acceleration of the order of 3 m / s². That sounded intriguing worthy of investigation. So I thought of a way to check if this fact was even possible to happen?

I remembered a video in super slow motion I had seen a while back, also the record holder Asafa Powell. The video showed the start athlete that served to gather data on the location and time. But do these measures was not easy because the video did not display a stopwatch and even information about the frame rate of the video, nor any reference to size. It was necessary to think about how to get this data? And convert them to SI.

The strategy used was to take 7 printed frames with equal time interval, find a point in the body of the athlete that does not modify vertically along the translation. Choose a benchmark and measure the position of this point in relation to this framework, it has been used for a graduated ruler in centimeters. However to use SI units you need to convert the values measured in meters, and was not a mere change of cm to m, it was necessary to know the full scale of the film. Was used as the conversion factor Asafa Powell's foot. By the data on its height made an estimate of the size of your
foot, and it was used as a conversion factor from centimeters to meters. For the time was estimated
to give the first last 0.4 s, extracted from another video of real racing.
With position data collected and moments, became graphical analysis and from the distribution of
points was fitted quadratic curve, position versus time s (t).
\[ S(t) = 6.6t^2 - 0.24t + 0.01 \]
The acceleration found in this model is of the order \((13 \pm 2) \text{ m/s}^2\), in agreement with MARTINHO
(2012) which is in agreement with what was written in the blog post Olympic Sciences. Ie, it is
reasonable to say that the force that drives the athlete to start is the order of its own weight.
However, the athlete can not keep it and it decreases as the speed increases. This has to do with the
power produced by the muscle to put the body in motion.
This issue exemplifies the teaching of physics can be attractive and interesting for students to
present conceptually rich situations as opposed to repetitive and irrelevant questions presented in
textbooks (SILVEIRA, 2011). This approach can be easily introduced into the classroom,
prompting the student through a real problem. This is a great opportunity to make you skilled at
some very important tools for physics, such as data analysis and graphics.

An IBL Approach to the Surface Area to Volume Ratio and its Implications
to the Nanomaterial Properties

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Nanotechnology is a science, engineering, and technology conducted at the nanoscale, which is
about 1 to 100 nanometres. It is an important area as the same material may exhibit very different
properties at the nanoscale from the properties of the bulk material. Nanotechnology is a
dynamically developing scientific field of this century. Many nanomaterials and nanoproducts are
currently used in our daily life in various ways. Thus, it is important to educate people and students
about them, but also about their benefits, risks, as well as about social and ethical aspects of
nanotechnology. Nanoscience and nanotechnology offer teachers the opportunity to bring the latest
scientific knowledge and new technologies to the classroom. There are many “hands-on” activities
and experiments which can demonstrate fundamental effects at the nanoscale and properties of
nanomaterials in our macro-world. Therefore, teaching nanoscience and nanotechnology at the
secondary school level offers opportunities for an inductive method as an inquiry-based learning.
Nanotechnology is a multidisciplinary field where science disciplines such as physics, chemistry,
biology, engineering and material science are included and inseparable. Through nanotechnology
teachers get an unique opportunity for the interdisciplinary collaboration.
This teaching module introduces one of the main ideas of nanoscience and nanotechnology – the
size-dependent properties as a surface-dominate properties. If the bulk material is divided into
smaller and smaller objects and the total volume remains the same, the general surface area is
dramatically increased. Some properties that occur at the surface will become magnified at the
nanoscale, for example the melting point, rate of reaction, capillarity action, and adhesion. The
teaching module consists of several parts. The first part is dedicated to the motivation of students.
The teacher prepares an experiment which shows the effect of increased reactivity with enlarged
surface area. Then the student’s activities start. The student’s task is to find the shape with the
largest surface area and then the most effective shape while keeping the greatest possible surface.
These activities lead to the microporous materials with a really large surface area. Students are
asked to find the example of this microporous material and test their hypothesis. Will this microporous material react in the same way as the material from our motivational experiment in the beginning of the module? The next part of the module offers a tour to the laboratory (real or virtual). The students learn about the measurement device to measure the surface area of solids and to determine their porosity using the method of gas sorption. Finally students will discover the use of microporous materials. At the end, the teacher summarizes the fundamental knowledge obtained throughout the module. This lesson has been tested on the group of students.

**Implementation of Peer Instruction Method to the Czech Schools**

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Peer Instruction was originally created for engaging students in more interactive learning during physics courses at Harvard University in Boston. The creator of this teaching method, professor Eric Mazur, converted his lectures during 1990s after using the Force Concept Inventory test. He realized that even though his students liked his lectures and even they did well in the course, they still had problems with basic concepts.

Peer Instruction moves content delivery out of the classroom, instead assigning pre-class reading. In class, students engage in small group (at most 5 members) discussions about fundamental concepts. These conversations successfully improve students’ conceptual understanding. Each ConcepTest, a question given to students to promote discussion, involves a basic concept of physics. It usually consists of one correct answer and other answers which are common misconceptions. Before discussion in small groups students have time to think about the question. There are different ways for students to commit to their answers before discussion: they can simply write the answer, or use some type of polling system or flashcards. After first polling students discuss their answers and try to find the correct answer together with other team members. During discussion students teach each other. After a good discussion more students choose the correct answer than during the first polling. During the years Peer Instruction has been used in different subjects and different levels of learning.

Cooperating with teachers from different education levels, we are preparing a Case Study called “Interactive Instructional Methods of the Peer Instruction Type and the Exploration of Their Implementation in Physics Education”.

Our goal is to help teachers with implement Peer Instruction into their classes, describe the problems with using this method at Czech schools and highlight the advantages connected with teaching this way. These “stories” from real Czech teachers will help others.

There is an online free database of ConcepTests in the Czech language prepared for physics teachers involved in this Case Study. Some questions are ConcepTests translated from Eric Mazur’s book Peer Instruction A User’s Manual [1] and the other part is based on the basic concepts research book Žákovské prekoncepce ve výuce fyziky [2].

We try to support teachers in many ways. There are many interesting videos with Eric Mazur’s talks about Peer Instruction and assessment and videos from classes describing how to implement this method, but all these videos are in English (or another foreign language). Most Czech teachers are not able to listen and understand English. We are translating these videos and creating Czech subtitles.

One of the most important things is preparing teachers for their classes with Peer Instruction. Mazur Group at Harvard University in Boston is creating the tutorial for teachers all over the world who want to learn about this method. Teachers who have questions about Peer Instruction can find answers there. This tutorial will be online and free, so teachers only need an internet connection and a laptop. Knowing that for some teachers it is not possible to study in the English language, there is an opportunity to create different language translations, including Czech.
Questions as an indicator of significant learning in physics and its impact on learning strategies, and the level of scientific reasoning.

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Universidad del Bio Bio, Chile

The present work shows the way of using the different types of questions that can realize to the pupils to teach and to learn, which go from the exploration of ideas before the transfer of contents; also they are considered to be guides by questions of Really and Falsely by justification that they go from the interpretation to the transfer of contents. The proposal applies in order to; Achieving change the dynamics of closed questioning, learning how to ask better questions: stimulants, reflective or hypothetical questions b) Develop a sequence of questions for tutorial work on the contents of the subject c) Establish address the impact of the physical content through guides to acquire meaningful learning and assessment in new situations.

The following proposal how to build inclusive environments of learning content based questions comprising the factual, understanding and creative than what is considered major and significant, organized guides with conceptual questions, they consider that described is principal and significant, and aspects of relevance, appropriateness and openness. These in turn are divided into categories, interpretation, application, analysis, synthesis and evaluation of creative responses that motivate students to acquire strategies of deep and elaborative learning and development level of scientific reasoning, the work in this way part of a methodological renewal proposal which claims a part master class with no m {as 20 minutes and resolution guide with questions for understanding the rest of the class working in teams in an active and participatory.

This research is performed through a quasi-experimental design (Cohen and Manion, 1990), which defines two groups (experimental and control), which will apply pre and post-test in each of the study variables: levels of Learning Strategies, level of scientific reasoning and academic performance. It is noteworthy that the groups involved in the subject Physics I, the contents of Kinematics and Dynamics, and Collisions and Roto-translation (II). To measure of Learning Strategies and level of scientific reasoning, the instrument will be applied before the start of the course (pre-test), and two months after the end the intervention (post-test). The determination of academic performance will occur after the intervention.

On the other hand it is tried to show like the different types of questions are employed at the classroom and at evaluations, as indicator of significant learning

From results obtained in courses in 2012 and 2013, about the impact of methodological questions renewal under the type of acquired learning, academic performance, learning strategies and level of scientific reasoning, statistically significant differences in these variables are set for group intervened. In this scenario one can say that the way work is adequate and is motivated learners and reviewers favorably of her.

Use of these questions in the University area, allows students to learn to learn, encourages discussion of the contents, has a good interaction and participation during class, leading to acquire meaningful learning. This form of class work (with questions to work in groups) gives the opportunity for all members of a working group to develop their skills. Moreover, questions encourage the development of attitudes to work in groups such as participation in dialogues and
discussions, curiosity for learning, respect for the opinions of others, objectivity in analysis, partnership.
This research is made possible through funding obtained from the research project FONDECYT N° 1120767 entitled “Towards a program to develop cognitive strategies from physics.”
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