TEACHING PHYSICS INNOVATIVELY

New Learning Environments and Methods
in Physics Education

e-book

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Teaching Physics Innovatively (TPI-15)
New Learning Environments and Methods in Physics Education
Budapest, 17-19 August, 2015.

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GREETINGS TO THE READERS

Physics is one of the most important branches of natural science and a field of research deeply affecting our daily life through its practical applications. This discipline is also at the core of many scientific achievements of chemistry and biology that are based on physics. Still, learning Physics in public or even in higher education nowadays seems to be less than popular among students. A general aversion of society towards this field is another unfortunate phenomenon of our times.

Among the various possible reasons of this problem, a major one is certainly the fact that learning Physics is difficult indeed. Nature is complicated and exact descriptions of its phenomena and processes are necessarily complicated, too. Many students, however, dislike, and, if possible, avoid difficulties and complications – unless scientific problems are presented in a relevant, authentic and inspiring manner.

Therefore, the conference "Teaching Physics Innovatively" was crucial for the future of science in society, it had an important mission accomplished successfully in August 2015 in Budapest. We were privileged to have hosted the TPI-15 international conference at Eötvös Loránd University, and congratulate the organizers and participants for all of their efforts and results presented in these Proceedings.

August, 2016.

Péter Surján
Dean, Faculty of Science,
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PREFACE

Within the framework of the prestigious conference series entitled "Eötvös Workshops", the conference, **"Teaching Physics Innovatively – New Learning Environments and Methods in Physics Education"** (TPI-15) took place at the Faculty of Science of Eötvös University (ELTE), Budapest, in 17-19 August 2015. The main organizer of the conference was the Graduate School for Physics of ELTE, in particular, its Physics Education program.

The history of this program goes back to 2007, when as a possible measure against the continuous decrease of interest in physics among high school students, the Graduate School for Physics decided to launch the Physics Education doctoral program. Earlier, teachers had the possibility to earn a PhD degree in Physics by carrying out scientific research only, or a PhD degree in Education, a field where Physics plays a minor role. The new program declares that establishing a novel, inspiring way of teaching modern or classical aspects of physics in a class is an achievement equivalent to traditional research results. The program is open for active high school teachers, or for lecturers at BSc study programs who do not possess a PhD degree. The Budapest Program is special since is tailored specifically for the needs of teacher-students. Candidates carry out their research at their own school.

Results of the candidate's research in physics education should be published during or right after their studies. We request at least one publication in a peer-reviewed international journal (for instance, Journal of Physics, Physics Education, European Journal of Physics, Physics Teacher, Physik in der Schule). We urge therefore (and support as much as we can) their participation at international conferences. Three other publications are requested in appropriate Hungarian journals. The participation at local physics teacher conferences is also strongly recommended.

To support the need for intensive exchanges of ideas, we organized a sequence of three conferences in the past years. Interestingly, even these turned out to be international meetings, though with Hungarian as the working language. This is due to a rather special situation we have to face: a physics teacher teaching Physics at a school in Hungarian language might be a citizen of Hungary, or any of the seven neighbouring countries with Hungarian-speaking minorities. TPI-15 was our first international conference in the traditional sense, with English as the working language. We received an overwhelmingly positive reaction to our call, and TPI-15 was attended by about 100 participants, from 18 different countries. Our Physics Education Graduate Program was represented by 29 PhD students, most of whom gave contributed talks.

The event was organized in co-operation with the Hungarian project team of the European project entitled Promoting Attainment of Responsible Research and Innovation in Science Education (PARRISE). ELTE is a member of the Consortium which is led by the Freudenthal Institute for Science and Mathematics Education (FIsme), Utrecht University and consists of 18 teams representing distinguished institutions from 11 countries (for details, see the project's webpage: http://www.parrise.eu/).

PARRISE has developed a framework for Socio-Scientific Inquiry-Based Learning (SSIBL), a novel pedagogical approach based on four interacting concepts and approaches: Responsible

Research and Innovation (RRI), Socio-Scientific Issues (SSI), Citizenship Education (CE) and Inquiry-Based Science Education (IBSE). A detailed summary of the approach is given in the introductory presentation written by Andrea Kárpáti, on the next pages. The consortium regularly reports about important related events: the 2015 December issue of the PARRISE Newsletter included a one-page summary of our conference, which we reprint as a page attached to this preface. The choice of some of the main topics of the conference (as can be seen at its webpage: http://parrise.elte.hu/tpi-15/) were developed as a cooperative efforts of the two partners.

The same spirit is reflected in the choice of the sectioning of this proceedings. All the keynote speakers kindly provided us with a written version of their talk. They appear here along with almost all the contributed presentations. The effort and positive reaction of our participants expresses the fact that there is an increasing international interest in novel approaches. The benefit of the meeting for the teaching community in Hungary is shown by the fact that new directions, never existing before, seem to have been established, such as the inclusion of novel socially sensitive issues in physics teaching and experience based Science Centre physics. Parallel to this, we may also witness the strengthening of the inquiry-based learning approach, and an increasing interest in environmental aspects, as reflected also by the contributions included in this volume.

We would like to thank all our contributors for providing insightful and well-written articles, and our referees who increased the professional quality of this volume. (All contributed papers were seen by one referee at least.) The members of the Scientific and the Local Organizing Committees (cf. http://parrise.elte.hu/tpi-15/) helped us not only in the preparation and running of the meeting, but also in organizational problems arising during the editing process.

Special thanks are due to the Paks Nuclear Power Plant for organising a guided tour with detailed scientific explanation and discussion of related social issues to all accessible parts at their Maintenance Centre, at a rather late time, after the closing of the conference. Another partially related event at the meeting was the Expert Roundtable on socially sensitive issues. We are thankful to László Egyed, science communicator and founding Director of the Palace of Miracles, the first Hungarian science centre, for organizing and moderating this important discussion. The report about the visit to the power plant, and a written version of the roundtable are special highlights of this proceedings.

The technical help in organizational issues provided by the Hungarian Physical Society is acknowledged, as well as financial support received from the Hungarian Academy of Sciences, the program of International Year of Light 2015, the Pázmány-Eötvös Foundation, and ELTE University.

We hope to provide you with an insightful and enjoyable conference proceedings,

the editors,

Andrea Király
Coordinator of the Hungarian PARRISE project team

Tamás Tél
Head of the PhD program for Physics Education

Teaching physics innovately

by Márta Jávor & Andrea Kárpáti
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An international conference was organized at the end of the summer in Budapest about how to teach physics innovatively in secondary education. Nowadays physics is not the most popular subject in high school –a fact that makes discussions about how to best teach physics more important. At the conference, teachers from several countries shared their ideas about the modernization of physics education.

The highlight of this conference was the presentation of environmental and socially sensitive issues, and innovative teaching methods using the most recent IT technology in formal and informal learning environment, such as science centres, museums and research sites. Contributions were organized around themes with direct relevance to socially sensitive issues in science education and recent findings from physics education research. The SSIBL Framework was introduced in a plenary presentation and discussed in paper sessions. A roundtable discussion on socially sensitive issues, e.g. on nuclear energy, and a visit to the Paks Nuclear Power Plant was also used to highlight the importance of a SSIBL approach to science education.

The exchange of ideas during the conference by 101 participants from 18 countries was inspired by invited speakers, who included well-known researchers. *Marisa Michelini*, President of *GIREP* (*International Research Group on Physics Teaching*) was the first speaker about how to develop modern physics' thinking in secondary schools. *Hannu Salmi*, from the University of Helsinki, a member of the PARRISE External Advisory Board, presented relationships between formal education and informal learning via science centres. *Ulrike Feudel*, professor of theoretical physics of the Institute for Chemistry and Biology of the Marine Environment in Oldenburg gave insights into introducing students to complex systems in nature and their socio environmental consequences.

Witty experiments by *Miha Kos*, the founder director of House of Experiments in Ljubljana, Slovenia showed how "*doubtology*" helps you avoid misconceptions when illusions trick you common sense. *David Featonby* from the UK, physics teacher and ambassador of "Science on Stage Europe", presented the *Science on Stage* international network of innovative and socially targeted science education and its biennial festival, which will next take place in Debrecen, Hungary in 2017. *Zoltán Néda*, a Hungarian professor of the University of Cluj-Napoca, and external member of the Hungarian Academy of Sciences, demonstrated how light and kinematics experiments lead students to a deeper understanding of the basics of the theory of relativity, as part of the celebrations of the "*International Year of Light*" in 2015.

Participants enjoyed an exciting lecture by *György Szabó*, researcher of the Wigner Research Centre for Physics in Budapest, about game theory and its applications to the understanding of social and scientific phenomena. *Miklós Vincze*, a member of the von Karman Laboratory of Environmental Flows at Eötvös University, demonstrated that fluid dynamical experiments can faithfully model phenomena, even phenomena related to climate change. The researchers of the Institute for Nuclear Research at Debrecen developed an entertaining adventure game which can help students to understand nuclear systems and processes. *Zsolt Fülöp*, the director of the Institute, showed participating teachers how to use this game for developing a firm knowledge base as well as sensitizing students about social issues around the use of nuclear energy. In connection with this crucially important issue for the Hungarian society, *Attila Aszódi*, professor at the University of Technology and Economics in Budapest, discussed the scientific, economic and social issues of the enlargement of the Nuclear Power Plant in the town of Paks, also explaining the problems regarding its public acceptance.

In the conference sessions, speakers presented their favourite educational project in nine areas. There were several content areas that have not yet been included in the actual curriculum of physics, however their social and scientific relevance would make an inclusion justifiable. We had 60 contributing speakers, and most of them were high school teachers of physics. Many of the Hungarians among them have learnt about the SSIBL Framework during a course offered by the doctoral programme on Physics Education at Eötvös University.

The conference reached its pinnacle at the *round-table discussion about nuclear energy use*, a socially sensitive issue in Hungary that has to be reflected in science education (see Figure 15). An excursion to the town of Paks, where participants visited the *Training Centre of the Nuclear Power Plant*, completed this debate and showed how teaching Physics is relevant for shaping public opinion through providing authentic scientific information.

Figure 15. Round-table discussion, participants (from left to right): Hannu Salmi (University of Helsinki, Finland), Zsolt Fülöp (Institute for Nuclear Research, Debrecen, Hungary), Attila Aszódi (University of Technology and Economics, Budapest), David Featonby (Science on Stage Europe, United Kingdom), László Egyed (moderator of the discussion)

SOCIALLY RESPONSIBLE SCIENCE EDUCATION – A CONTEMPORARY PEDAGOGICAL CHALLENGE

INTRODUCTORY PRESENTATION

The majority of European public is *actively interested in, but does not feel informed* about the developments in science and technology, although at least half of all Europeans are interested in these issues, according to Eurobarometer. In this survey, 59% of respondents claimed that they had read articles and 47% talked to friends about recent results of scientific research in printed press or on the internet. Civic activities related to issues of social relevance were, however, rather limited: only 13% signed petitions or joined street demonstration, 10% attended public debates about scientific issues of social relevance. Hungary is also among those countries whose citizens claim not to be adequately informed about developments in science and technology. This fact emphasizes the importance of science education in our country. Science teachers are perhaps the most important shapers of the minds of young citizens, and, through them, their families. They do not only distribute knowledge, – they also share values and attitudes about the role of science in solving problems that define the ways we live and shape our future.

The results of science education, therefore, are far more than attainment on knowledge tests. Scientific knowledge may support political decisions and challenges of private life – or else, its lack may result in public and private crises, even catastrophes. At this conference, speakers have taken up this challenge and shown us ways to reconceptualise and retool science education. *Reconceptualization* means being current: integrate new results in school curricula and modify those that have become outdated. *Retooling* enables us to use cutting-edge technology to experiment, explain and test knowledge and educate for discussions that further scientific inquiry. Most educational models presented in this volume are interactive and encourage participation in knowledge construction and also in discussions about the use of research and innovation. Experimentation has always been at the core of Hungarian Physics education, but the social issue-based approach presented here may be new and relevant in turbulent times like the first decades of the 21th century.

Science has primarily been taught in Hungarian schools as a knowledge system separate from values and social justice, in which deduction is used to apply theoretical knowledge to solve problems. We joined the

Promoting Attainment of Responsible Research and Innovation in Science Education (PARRISE)

project, a Seventh Framework Program (Grant Agreement No. 612438, duration: 2014-2017) in order to expand our perspectives and enrich our repertoire of socially responsive teaching and education. The PARRISE team has developed and is now piloting a framework for *Socio-Scientific Inquiry-Based Learning (SSIBL)* based on four components: Responsible Research and Innovation (RRI), Socio-scientific Issues (SSI), Citizenship Education (CE) and IBSE (Inquiry Based Science Education), − this last being its core element. The PARRISE Project believes that science is intrinsically social and its products and processes are mediated through power relations. Science education needs to address issues of social relevance and encourage students to become responsible adults, able and willing to influence political decisions influenced by scientific research. For Hungary, communicating socially sensitive issues

through science education – a group of disciplines highly successful till the 1990s and fighting problems of student disinterest and scarce funding for inquiry based approaches today – is especially relevant. This conference was also a training opportunity where presentation, a round-table discussion and an informal learning event (visit to the Paks Nuclear Power Plant) has provided new insights about educational methods of presenting perhaps the most disputed social issue related to science in Hungary: the expansion of the Paks Nuclear Power Plant. The SSIBL Framework and other models introduced by our speakers have one idea in common: in order to educate responsible citizens, we must make them aware not only of the potentials, but also the challenges and risks of scientific discoveries and show how they were solved. A deeper understanding may lead to changing mind sets and embracing solutions that had been considered unacceptable before.

This conference was dedicated to the encounter of teachers and scientists – mediators and promoters of Physics. Science teachers seem to have an inclination to identify themselves with scientists as role models – however, their mission reaches far beyond the interpretation of results. Teachers have to possess *affective skills and social competences that make them more than science communicators and assume the role of science educators.* Mapping controversies in social debates about the utilisation of research and innovation (like the use of nuclear energy) and providing authentic standpoints (impartial representation of scientifically valid viewpoints) are basic requirements for responsible science education. Promoting reflection and collaboration in resolving disputes and developing arguments based on facts and laws taught are educational targets that are crucial for developing democratic citizens. Criticality and willingness to listen, respecting the viewpoints of others with openness and honesty, engaging in discussions of controversy without injecting own biases, and the ability to reflect present alternative viewpoints where necessary are attitudes much needed for responsible citizenship – and often lacking in our contemporary society.

When manifesting the responsible researcher as role model, teachers of Physics often have to face challenges that educators of liberal arts are likely to be spared of. Developing an understanding of science-as-practise and show how scientists co-operate with each other and with lay stakeholders for a common goal in research and development often involves identifying controversies in how science is produced and applied, and sophisticated presentation of the risks of never fully predictable technological and social outcomes. Students should appreciate science as a human endeavour and construct with its limitations, constraints and opportunities. Vivid discussions that characterised the conference sessions where teachers faced researchers whose findings they were supposed to interpret at school, showed concern on both sides to promote evidence based policy making through educating the young to understand and appreciate scientific endeavours. The *inquiry-based model of Physics education that* has been the dominant Hungarian educational paradigm for decades, kept reoccurring during the conference. Detecting problems, developing hypotheses and predictions, collecting and interpreting data and communicating results: this model is based on experience of scientific procedures and ethics and is therefore a solid foundation for s*ocially responsible science education*.

Andrea Kárpáti
on behalf of the Hungarian PARRISE
project team