Re-Imaging Learning Environments
Proceedings of the European Distance and E-Learning Network 2016 Annual Conference
Budapest, 14-17 June, 2016
ISBN 978-615-5511-10-3
ISSN: 2707-2819
doi: https://doi.org/10.38069/edenconf-2016-ac-0036

CREATING A SOCIALLY SENSITIVE LEARNING ENVIRONMENT FOR SCIENCE EDUCATION: THE SSIBL FRAMEWORK

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Promoting Attainment of Responsible Research and Innovation in Science Education (acronym: PARRISE, an EU project for 2014-2017, http://www.parrise.eu/) has been developing and testing an integrated framework for Socio-Scientific Inquiry-Based Learning (SSIBL) based on the four components: Responsible Research and Innovation (RRI), Socio-scientific Issues (SSI), Citizenship Education (CE) and Inquiry Based Science Education (IBSE), this last being its core element. Adopting this model for science education is important because the relationship of scientific discoveries and innovations and related social issues are rarely indicated in curricula based on knowledge transmission. In an age of intense citizen involvement in government decisions about the preservation of natural environment or regulation of energy consumption, communicating socially sensitive issues through science education is increasingly important – and also motivating for students who thus experience the direct relevance of scientific knowledge for everyday life. Our project team works on creating a science education environment that encourages computer-supported, integrative approaches for a multifaceted, interactive and social issue-based approach. Technology is used to increase the collaborative aspects of learning, prepare science teachers to act as responsible citizens of a social-networked society and educate students who are able and also motivated to enter public debates about the way scientific discoveries are used or abused. This paper introduces the SSIBL model as integrated in secondary school Physics education. A *formal secondary school learning environment* is proposed that includes real life experiments documented and evaluated through computer assisted devices, and *a variety of informal and non-formal environments* (in science centres, visitor centres of scientific research institutions and technological companies) are integrated to offer hands-on experiences through simulations and mock-ups of research and development tools and supported by an *in-service learning environment* for teachers. The development of educational programs to teach about *New Physics* often involves debates to clarify different citizen, researcher and political standpoints. The case study on the use of nuclear energy presented here will indicate how these three technology-rich learning environments interact.

The Socio-Scientific Inquiry-Based Learning (SSIBL) Framework

Science is primarily been taught in Hungarian schools as a knowledge system separate from its relationship with values and social justice, in which deduction is used to apply theoretical knowledge to solve problems. The majority of European public does not feel informed about the developments in science and technology, although at least half of European citizens are interested in these issues. In a 2013 Eurobarometer survey, 59% of respondents told 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 among those countries whose citizens claim not to be adequately informed about developments in science and technology (Special Eurobarometer, 2013). The *Promoting Attainment of Responsible Research and Innovation in Science Education* (PARRISE) Project believes that science is intrinsically social and its products and processes are mediated through power relations (Roth & Calabrese Barton, 2004). 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. This paper describes a pedagogical model and an instructional experiment to address this issue.

Socio-Scientific Inquiry-Based Learning (SSIBL) connects three pedagogical concepts with Responsible Research and Innovation (RRI): Inquiry-based Science Education (IBSE), Socio-scientific Issues (SSI), and Citizenship Education. (Nedelec et al., 2015) The connections between these components are represented on the figure below.

Figure 16. The Socio-Scientific Inquiry-Based Learning (SSIBL)

Responsible Research and Innovation (RRI)

Recognising that technological developments, inspired by research and innovation, both have an impact on, and are influenced by, social values and social change, three underpinning features of RRI are highlighted in this framework (Owen et al., 2012). Science for society focuses on public values and social justice, i.e. normative motivations; science with society dialogue and deliberation between the main actors, i.e. substantive motivations; and the coupling of research and innovation with responsibility as a recognition of the uncertainties and risks associated with the development of any technology and how these might be

ISBN 978-615-5511-10-3

anticipated and managed. Science for Society and Science with Society are therefore critical aspects of Citizenship Education integral to RRI.

Inquiry Based Science Education (IBSE)

"Inquiry is 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 et al., 2004 as cited in Rocard et al., 2007). To support scientific literacy – also in terms of its social applications – the need for responsible involvement of citizens at all stages of the research and development (R&D) process has received greater emphasis. A significant educational impetus has been IBSE, as outlined for example in the Rocard report (2007), which has implications for new teaching approaches and new curricular alignments (Gray, 2012).

Socio-scientific Issues (SSI)

Ryder's (2001) review of the role of socio-scientific issues and its relations to curricular science suggests that school science often has to be recontextualised and transformed to make it amenable to acting on SSIs (Layton et al., 1993). A common objection is that socio-scientific problems are too complex for school study, where the problems are often discussed in a simplified manner or the science used is one that is beyond the remit of the school (Dawson, 2000). Although socio-scientific reasoning skills (SSRs) have been proposed for arriving at rational solutions to SSIs, there is little evidence that such skills can be generalised (Sadler et al, 2011).

Citizenship Education (CE): Science for Society and Science with Society are therefore aspects of critical Citizenship Education which are integral to RRI

Science with society is participative, acknowledging that those affected by the technology, as well as scientists, are involved both at the upstream stage (that is when the scientific ideas are initiated and possible consequences anticipated) as well as downstream at the point of production, application and distribution. This assumes a knowledge and understanding of the underlying science, as well as a critical appreciation of the process of the research. Participative R&D is therefore a multi-agency approach to research and innovation because knowledge is differentiated and distributed in form (i.e. from academic knowledge including different disciplines, professional knowledge, and knowledge-for-living). Hence these foreshadow interactions between formal (curricular) and informal (non-curricular) knowledges.

ISBN 978-615-5511-10-3

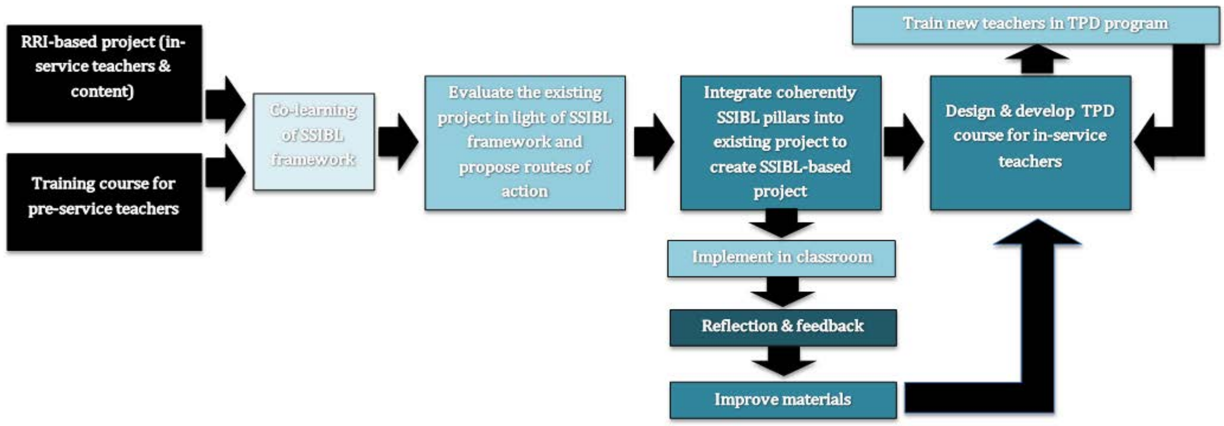

Figure 17. Model for the Hungarian in-service teacher training program based on the SSIBL Framework

The four pillars of the framework are employed in a Hungarian teacher training course for secondary school teachers on innovative methods for teaching Physics. The course also provides a scientific background on current research results as well as social issues related to their application.

Learning Environment Design

Hungarian designers of a new learning environment to support the integration of social issues in science education must take into consideration that science teachers in this country are *reluctant to employ ICTs tools as they consider real-life experiments a core constituent for authentic teaching and learning of their discipline*. The tension between human and machine approaches to learning has, however, been reduced in recent years. According to the OECD study on educational innovation, more direct observation of scientific processes and description of phenomena by students in secondary school science lessons is detected, and these hands-on activities are often supported by ICTs. The use of computers resources for primary and secondary science education instruction significantly increased in Hungary. "Between 2003 and 2011, Hungary saw a difference of 18% points in the proportion of 4th grade students using computers to practice skills and procedures in their science classes; the change in this metric for 8th grade science students was 24% points over the same period" (OECD, 2012; p.4).

School computerisation has also taken new momentum with massive government purchases of notebooks and laptops in the first decade of the 21st century, and the slow but steady increase in the use of mobile devices in the second decade. Bring your own device (BYOD) initiatives and large storage space through cloud computing offered free of charge for schools and teachers have been supporting the proliferation of ICTs in education and create a more favourable context for technology-rich environment design in Hungary (European Schoolnet, 2013). Social inclusion and the creation of a learning environment that supports students with special needs is another important design issue to consider. "Broadening the horizon of science teaching and learning in Hungary aims to focus on creating an inclusive learning environment, hence increasing accessibility, parity and equity in science education, going

ISBN 978-615-5511-10-3

beyond self-evident excellence in Hungary" is the aim of a socially focused research project, the results of which we also considered (AMGEN, 2015).

In order to combine scalability with personalisation, and provide a learning environment for the social contextualisation of science education, the Hungarian PARRISE team adopted educational directions for design. We agreed that experiments had to be demonstrated first and foremost in a real-life context in science laboratories of schools. ICTs were supposed to be used as a supplement for documentation and measurement. Simulation and modelling of processes were only utilised for experiments that are impossible or too expensive/time consuming to demonstrate. Social computing was constantly employed for sharing ideas and observations as well as catalysing discussions.

When developing a new learning environment – merging formal, non-formal and informal spaces – we had to consider the present situation that influences the attitudes of teachers about innovation. Teachers need to be informed about current results of science in an authentic manner, preferably from the researchers themselves. When innovating, teachers are more inclined to assume the role model of Physics researchers than educational researchers. The teacher professional development (TPD) programs should demonstrate a pedagogy that facilitates the translation of current science issues into educational content. Student performance in science surveys keeps declining while best students still excel at Olympics. Apparently, education targets high performers and transmits basic knowledge necessary to embark on a science career.

The PARRISE team collects good practice examples and builds transnational, multidisciplinary communities of science teachers, teacher trainers, science communicators, curriculum developers and citizenship education experts to implement the SSIBL Framework. In-service training events provide a methodological repertoire for the realisation of inquiry based and social issue focused science education. Teachers are empowered to act in one or several of the following roles: learner, teacher, developer, and researcher. In Hungary, teachers' professional development is regulated by a government act that requires the renewal of teaching skills and abilities every seven years through participating in training courses with a total of 120 credit points. The offerings for science teachers focus mainly on methodological innovation: the *modernisation of teaching*. However, the other aspect of pedagogical practice: *education of critical and responsible citizens* seems to be ignored or tackled as an *inferior* "add-on".

As members of the PARRISE community, we intend to create a networked system of learners who developed active, collaborative agency around shared knowledge objects (Hakkarainen et al., 2004), who worked and learnt together towards common goals such as investigating a socially sensitive scientific domain. Community driven inquiry learning based on progressive inquiry and collaboration was especially suitable for involving students in disputed, social issues related to science (Venturini, 2012). We have selected the following *pedagogical and learning characteristics* to develop during our course:

ISBN 978-615-5511-10-3

- An ability to distinguish between scientific, social and ethical propositions;
- Understanding the basics of Responsible Research and Innovation (RRI): to internalise how scientific principles can be transformed and operationalized in social and ethical contexts;
- Introduction of dialogue, reasoned discussion and argumentation in science education;
- A recognition of the social and political context in which decisions arising from Socio-scientific Issues (SSI) are made;
- Development of an educational repertoire for negotiating SSIs in relation to the evidence available, the personal, political and social consequences of decisions based on research results, and the extent to which any issue divides sectors in society.

Being a teacher of responsible citizens of the future who would be able to dispute political action related to scientific discoveries and their applications requires a twofold set of competences. First, teachers need to possess the social sensitivity and strategies of action they are required to educate for. Second, they need a profound knowledge of results of current research related to focal points of school curricula in order to identify socially sensitive issues and develop teaching strategies to introduce them at school. To identify these issues, the theoretical framework of *Responsible Research and Innovation* (RRI) is being used. In Hungary, the attitude change from *research for society* to *research with society* is especially important as it emphasizes a more and more intense public demand of democratisation of education.

The current course is structured to enhance both capacities. Through presentations and experience-based workshops, teachers will be made aware of current research in Physics in areas closely related to the teaching material they are supposed to cover. This component develops a knowledge base required for authentic teaching as well as the identification of topics discussed in the media with more or less scientific grounding. Through the second component of the course, the model of *Socio-scientific Issues* (SSI) will be introduced. Physics teachers will be empowered to raise these issues in formal and informal education and develop critical citizenship skills of their students with a firm grounding in responsible research and innovation. Good practice examples of international SSIBL teams and Hungarian projects that qualify as SSIBL practice will be showcased during this phase, and Hungarian adaptation options considered.

An international conference was organized in August of 2015 on "Teaching Physics Innovatively (TPI-15) – New Learning Environments and Methods in Physics Education" (http://parrise.elte.hu) with the following purposes: to supplement the TPD with a workshop, a panel discussion and an informal learning event; to collect ideas about the further improvement of the TPD from international and Hungarian experts; and to develop international connections on teaching physics through ICT supported formal and informal teaching methods. More than half of the participants of the conference were Hungarian in-service physics teachers or teacher trainers. The major objective of the conference was to

ISBN 978-615-5511-10-3

collect good practice methods on IBSE in physics education, and the keynote speakers were encouraged to focus on socio-scientific issues in physics.

Teaching Methodology

We developed a knowledge community of teachers supported by resources shared through digital technology (the Moodle e-learning environment and Web 2.0. resources like science blogs and interactive science portals. The introduction of digital resources in the training program was justified by research on changes of science media consumption. The technological paradigm shift accompanied by changing user preferences resulted in rising digital news consumption and decline in print media subscriptions, even among adults aged 40 and more (Jenkins, 2004). Students as well as teachers like to collaborate with their peers and they prefer using online learning environments, like blogs, that can motivate them to take active part of discussions (Salovaara-Moring, 2012). Mentoring in closed online learning environments where teachers socialise and learn using integrated social web applications to share and discuss their learning experiences provides an excellent mentoring space for transmitting innovative educational practices (Kárpáti & Dorner, 2012).

Our TPD method takes place into four steps: presentation of the theoretical elements and the logic of the SSIBL framework; offering ICTs supported tools and methods to teachers; mentoring teachers while co-constructing an SSIBL scenario (implementation); debriefing and reflections. These four steps include several roles for the students. At first, they are learners understanding the theoretical framework of SSIBL and its relevance for the Hungarian educational and social context. In the second and the third roles, they are developers implementing the SSIBL process. In the last role, act as researchers trying in a collaborative process to add to the framework what the practice has revealed.

The course has a modular structure. Compulsory and elective modules cover current issues in Physics and their pedagogical "translation". The method of delivery is interactive, all presentations are followed by interactions: discussion and series of experiments. Home assignments include reports on educational practice, self-designed experiments and teaching aids (mostly digital). Performance evaluation at the end of the course involves tests and oral examinations as well as the assessment of the home assignment. Socio-scientific issues in the Physics TPD that are used to implement the SSIBL framework: philosophical aspects of "Big Bang"; creation *theories* in contemporary Hungarian society and their educational implications; The *Butterfly Effect*: naïve beliefs and scientific explanations of cause-and-effect processes; chaotic dynamics in science and society; history of popular assumptions about the structure of the Solar System; nuclear energy: pros and cons in scientific context.

The last theme will be used here as an example for the use of the SSIBL Framework in a complex, technology-rich environment for Physics education: *educational communication of the use of nuclear energy* – the most controversial socio-scientific issue in contemporary Hungary, one that divides the Hungarian public as well as the research community. The media seems to favour renewable energy contained through solar plants or bioenergy

ISBN 978-615-5511-10-3

providers – solutions that many researchers consider less effective and more expensive than power plants. According to the SSIBL Framework, this issue was presented through a series of formal and informal learning experiences during a TPD course.

1. *Socio-epistemological inquiry and cartography of controversies* to identify different types of uncertainties linked responsible research and innovation: collection of resources and sharing them through the virtual learning environment and social media applications;
2. *Presentation of current research* on the use of nuclear energy in power plants – lectures and special presentations during the conference *Teaching Physics Innovatively* (TPI-15), organised at ELTE University, Faculty of Science in August 2015, an informal learning component of the TPD course;
3. *Debate method* used to elicit professional and epistemological risks felt by teachers with these new practices, positions of the teachers about these risks: roundtable session at the TPI-15 Conference;
4. *Demonstration of educational methods* integrating the use of real objects, models and simulations in the Visitor Centre of the Paks Nuclear Power Plant, another informal learning component of the TPD course. Modalities of interactions and goals of them within the classroom, argumentation, socio-scientific reasoning and action were presented and discussed with explainers of the informal learning environment of an integrated space including elements of a technology museum and science centre;
5. *Designing classroom activities* by teachers based on their experiences during their training process involving inquiry, presentation and demonstration.

The participants of the in-service training course demonstrated different viewpoints about nuclear energy that may or may not have been changed during their activities in this complex, technology-rich and innovative learning environment. In any case, they acquired a methodology to present controversial socio-scientific issues in education through a methodology that is research-based and interactively designed to catalyse different opinions and channel them towards a sophisticated, scientific argumentation. Participants were expected to deliver a pedagogical essay and suggest e-learning materials and applications on strategies of teaching about the four main subject area of the course: modern physics, microphysics, astronomy, and chaotic dynamics. These essays utilised the SSIBL framework and reflected on social implications of science. Some teachers embarked on learning tool design and created ICTs-supported solutions to enhance the interactive nature of their teaching. All participants learned that developing socially responsible citizens is a major responsibility of science education.

ISBN 978-615-5511-10-3

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Acknowledgement

The project presented in this paper has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 612438.

ISBN 978-615-5511-10-3