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A. Background to this report

This report is a deliverable of Work Package 6 (WP6) of the European FP7-funded project "European Science and Technology in Action: Building Links with Industry, Schools and Home" (ESTABLISH; 244749, 2010-2013). This deliverable, Deliverable 5.6, presents case studies of science teacher training in Inquiry Based Science Education (IBSE) – selected models adopted by ESTABLISH beneficiaries (Table 1) to for implementing and evaluating science teacher professional development and implementing and evaluating classroom practice.

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The ESTABLISH consortium

Beneficiary short name	Beneficiary name	Country	Abbreviation
DCU	DUBLIN CITY UNIVERSITY	Ireland	IE
AGES	AG EDUCATION SERVICES	Ireland	IE
UmU	UMEA UNIVERSITET	Sweden	SE
JU	UNIWERSYTET JAGIELLONSKI	Poland	PL
CUNI	UNIVERZITA KARLOVA V PRAZE	Czech Republic	CZ
AL	ACROSSLIMITS LIMITED	Malta	MT
UPJS	UNIVERZITA PAVLA JOZEFA ŠAFÁRIKA V KOŠICIACH	Slovakia	SK
UTARTU	TARTU ULIKOOL	Estonia	EE
UNIPA	UNIVERSITA DEGLI STUDI DI PALERMO	Italy	IT
MaH	MALMÖ UNIVERSITY	Sweden	SE
IPN	LEIBNIZ-INSTITUT FUER DIE PAEDAGOGIK DER NATURWISSENSCHAFTEN UND MATHEMATIK AN DER UNIVERSITAT KIEL	Germany	DE
CMA	CENTRE FOR MICROCOMPUTER APPLICATIONS	Netherlands	NL
MLU	MARTIN LUTHER UNIVERSITAET HALLE-WITTENBERG	Germany	DE
FU	FREDERICK UNIVERSITY	Cyprus	CY

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Introduction

The overall objective of ESTABLISH is to facilitate and implement an inquiry-based approach to science education for second level students (age 12-18 years) through teacher education on a widespread scale across Europe by bringing together, the key stakeholders in science education. Other ESTABLISH project deliverables have reported on the effective strategies for dissemination of the ESTABLISH project and outcomes (D8.1) and on the impact of the engagement with stakeholders (D2.3) – which was a unique approach to this FP7 project in involving all stakeholders that make change possible. This engagement of stakeholders has been embedded in all aspects of the project – through the developing of IBSE materials (ESTABLISH Units), teacher training workshops (ESTABLISH Teacher Education Programmes (TEP)) and in overall dissemination and impact of the project.

From the outset teachers themselves were seen as active partners in this project both as developers, researchers and agents for achieving change in classroom practice. Throughout this project both in-service and pre-service teachers have played a pivotal role in developing, piloting and trialling teaching and learning resources for IBSE. A synthesis report of effective models for teacher education in IBSE based on the ESTABLISH framework for TEP has been successfully documented (D4.6). This report focuses on predictive effective models of ESTABLISH TEP based on evidence in the 14 ESTABLISH partners' narratives about how they have implemented the in- and pre-service TEP. In addition, we have developed ESTABLISH evaluation instruments to determine the impact of the ESTABLISH approach on teachers and their students and these have been collated and reported in other deliverables – impact on teachers attitudes to IBSE (D4.5 and D5.5) and impact on students' learning (D6.1).

However, this report (D5.6) presents a selection of case studies of models adopted by ESTABLISH beneficiaries (Table 1) for the implementation and evaluation of science teacher education in IBSE. The use of Case Studies in this report enables the presentation of narratives written by partners to portray their experiences of adopting the ESTABLISH approach in their own countries. The Case studies presented emphasize detailed contextual information on specific approaches, opportunities and challenges different partners encountered in implementing ESTABLISH IBSE teacher education programmes, both pre-service and in-service.

This selection offers the teacher, educator and researcher a unique insight into approaches adopted across Europe involving national collaborations with the National Ministry of Education (Cyprus) or international collaboration with ESTABLISH partners (Malta). IBSE teacher education programmes are reported with a specific focus of ICT (Netherlands), Industrial Content Knowledge (Sweden, Estonia) and assessment (Poland). In addition the ESTABLISH approach and activities/units have been incorporated into existing national contests, MINT-Programme (Germany) or Tertiary Healthcare Education (Estonia) or developed as new programmes (Czech Republic, Slovakia) Two case studies have focussed on initial pre-conditions for IBSE amongst teachers (Germany) and teacher pedagogical content knowledge of scientific inquiry (Italy). Results from implementation in schools and the impact on students are reported (Italy, Slovakia, Estonia) as well as feedback from in-service teachers after workshops (Malta, Italy, Cyprus). An evaluation of the impact on pre-service teachers understanding and attitudes to IBSE is also discussed in three of the case studies (Ireland, Germany, and Netherlands). This collection of thirteen case study contributions deepens our understanding of the complex issue of IBSE and extends our experiences and knowledge of IBSE and how it manifests in different educational and cultural environments.

Case Study 1: Italy

Investigation of teacher pedagogical content knowledge of scientific inquiry

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Abstract

In this case study we analyse scientific inquiry in the context of modelling physical systems and point out some related teaching/learning strategies and how these are perceived by secondary school physics teachers. The topic is analysed on the light of the results of a course for in-service physics teacher education held at University of Palermo in the framework of the ESTABLISH Project

Introduction

In designing innovative pedagogical materials it is common to provide supports for teachers' subject matter knowledge and pedagogical content knowledge for students' ideas (e.g., misconceptions). However, rarely supports for the development of pedagogical content knowledge of scientific inquiry are provided.

By inquiry we refer to learning experiences that engage students in various integrated activities of identifying questions, collecting and interpreting evidence, formulating explanations, and communicating their findings, that are consistent with science standards and recent reports (Duschl, Schweingruber,& Shouse, 2007; National Research Council, 1996; Singer, Hilton, & Schweingruber, 2005). Many researchers have shown that Inquiry-Based (IB) approaches to learning are able to increase student motivation, interest, understanding and development (Collins, 1997; Singer et al., 2005). However, despite the consensus found in educational research, teachers may have different ideas about the meaning of inquiry-based instruction and it has been shown that misconceptions abound (National Research Council. 2000). These mistaken notions about inquiry can, perhaps, deter efforts to reform science education.

Theoretical Background

Despite the consensus found in educational research about the efficacy of IB approaches, it has been pointed out that misconceptions about IB instruction abound and serve to deter efforts to reform science education (National Research Council. 2000). The more relevant misconception involves the idea that " *IB instruction is the application of the scientific method*".

Many teachers learned as students that the process of science can be reduced to a series of five or six simple steps. It has been shown that the notion that scientific inquiry can be reduced to a simple step-by-step procedure is misleading and fails to acknowledge the creativity inherent in the scientific process. Research has connected this view with what science's nature is perceived from samples of pupils and teachers (Akerson, et al., 2000; Lederman, 1992). Some studies showing that science teachers persist in holding views about nature of science qualified as empirical or naïvely empirical, identify two peculiar aspects in their thinking, involving: - the role accorded to observation, which is seen as giving experimental data an absolute value; - the role played by theory in conducting experiments and in making observations, along with the value of scientific knowledge as a means of explaining and predicting (Van Driel, et al., 1998; Glasson and Bentley, 2000; Abd-El-Khalick, 2005).

Other studies report that teachers carry positivistic views of their discipline: i.e. they teach only the knowledge aspects of science and emphasize vocabulary rather than balance knowledge claims with knowledge generation and evaluation, and present science as “the method” of understanding the world (Gess-Newsome, 1999). Additional classroom consequences may include a decreased emphasis on inquiry-oriented and problem solving teaching methods that positively impact pupils’ conceptions of science (Gess-Newsome, 1999; Lederman, 1992).

Teaching IB science entails ambitious learning goals for students and thus is complex and difficult for teachers to enact (Marx, et al., 1997; Roehrig & Luft, 2004). Moreover, most of teachers also have not experienced IB instruction as learners and thus need guidance in enacting this type of instruction (Windschitl, 2003). Researches specifically aimed at the implementation of the IB approaches to physics education have shown that teachers aren’t able to make the transition from a purely transmitting didactics to an IB one only through the illustration of the new methods and strategies (Pinto, 2004). Training experiences based on new theoretical models have to be provided. Among these, models that underline the necessity of collaborative construction of understanding and reflection on the enactment of new practices in classrooms and on the consequent adaptation of materials and practices show a relevant efficacy. Such procedures require an accurate designing of the training activities where the roles of the different materials, the disciplinary conceptual knots, the problems related to the introduction of the innovative methods are evident. It has been pointed out that a conceptual change approach is not only relevant to teaching in the content areas, but it is also applicable to the professional development of teachers. For example, as constructivist approaches to teaching gain popularity, the role of the teacher changes. Teachers must learn different instructional strategies as well as also re-conceptualize or change their conception about the meaning of teaching.

Founding on research related to the Inquiry Based (IB) methodology and to models of the teachers training, our research takes as theoretical framework the following key points:

a) to analyse conceptions, reasoning schemes and teachers’ knowledge in the light of the specific operative processes of an IB approach and to study how these can enhance or thwart the introduction of innovative strategies and contents;

b) to develop and test a Training Action (TA) that proposes subjects and strategies focused on the specific operative processes of an IB approach.

Method

The TAs developed by our local project propose subjects and strategies focused on the specific operative processes of an IB approach, as well as on analysed ways to integrate them in a pedagogy aimed at pointing out relevant elements of an adequate Pedagogical Content Knowledge (Shulman, 1986) for SI. Some pilot teacher workshops (W) have been designed aimed at finding operative answers to defined research questions. Here, we report about some preliminary results of a 4 hours W where teachers were put in a real problematic situation that made them face with a real problem, whose solution required the activation of the typical operative processes (theoretical and experimental) of scientific investigation. Our research questions are the following ;

1) Which kinds of approaches to a complex problem are preferred by teachers ? Which cognitive resources are involved?

2) Which relevant procedures of scientific investigation are put in action and how are these intended by the teachers?

15 in- service secondary school teachers participated to the pilot workshop. They had different backgrounds of graduation, pre-service training and kind of teaching experience in different grade levels (junior or high school level). The W has been developed into two phases: a) analysis of a real problematic situation and development of a solution; b) reflection about the proposed solution and definition of the characteristics of the procedures put in action for the searching of the solution. During the first phase a real problematic situation involving the phenomenon of heat conduction through different materials was proposed to teachers (see Fig. 1).

In particular, teachers were requested, through a questionnaire, to look at seven different flat plates, different in material or mass, area and thickness and to predict what happens if seven identical ice cubes are placed upon them, i.e. to predict the time sequence of ice cubes melting. As a second question, they were requested to put into evidence the parameters they considered relevant in influencing the melting process, and to design a set of experiments devoted at checking the relevance of such parameters. Then, the experience was really performed and they were required to compare their predictions with the experimental results, writing down their comments.

The questionnaire sheets were photocopied and then returned to teachers for further processing. As a second phase teachers were divided into 3 groups (5 teachers in each group) to discuss their solutions with the guide of a researcher. The 3 researchers had previously developed common discussion guide-lines and questions in order to make explicit teachers conceptions about the meanings of investigation procedures as to make a hypothesis, to construct a descriptive model, to find an explanation or to compare different kinds of explanations. All the discussions have been audio taped and the detailed analysis is in progress.

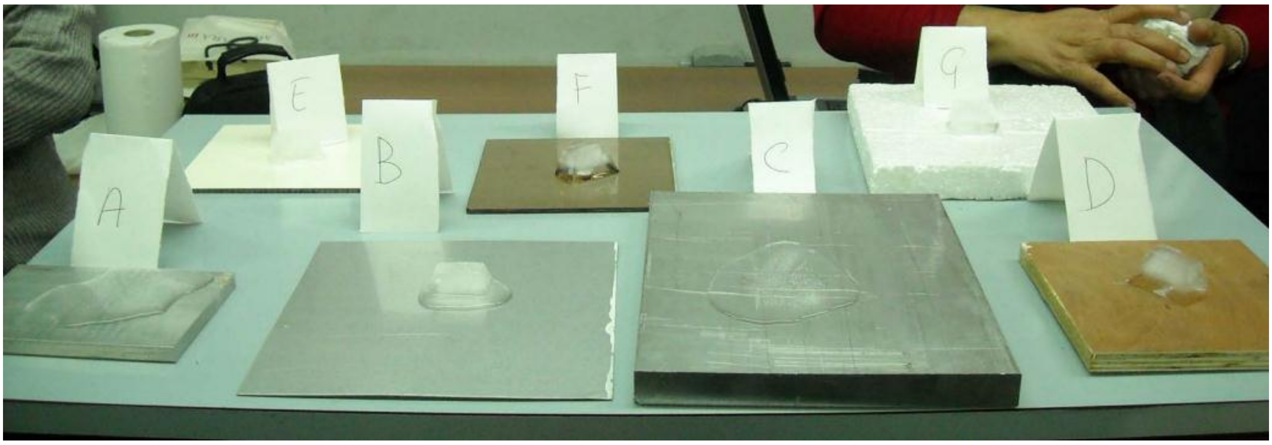

Figure 1. *The experimental situation, first only theoretically proposed, then practically analysed by the teacher group. Some ice cubes are placed on plates of different material, mass, area and thickness, identified by letters A, B, C, D, E, F, G, H.*

Results

A detailed analysis of teacher incorrect predictions with the related explanations is in progress. We note here that all teachers correctly predicted that the ice cubes melt sooner when placed on aluminium plates, but only 3 teachers performed the correct prediction by appropriately ranking plates with different masses and thickness. By considering at a finer grain detail the predicted melting time sequence for the three aluminium plates (of different geometrical characteristics), as well as the teachers' explanations about the parameters that have to be taken into account for the correct description and explanation of the phenomenon, some considerations can be drawn about the procedures they followed in formulating their hypotheses.

The correct analysis of the proposed situation must take into account several parameters, i.e. the plates' geometrical characteristics (surface area and thickness), thermal capacity, thermal conductivity and the temperature difference between the two plate faces. All these parameters have to be considered together to correctly explain the phenomenon. An approach based on the typical theoretical knowledge about thermology, resulting from classical university education can easily guide the teacher to search for an explanation to the phenomenon based on thermal conduction, i.e. on the idea of heath flux between two surfaces at different temperatures. From the Fourier law, we know that this flux is proportional to the surface area and inversely proportional to the plate thickness, so thinner plates should make ice cubes melt quicker, as they allow a bigger heath flow. Indeed, for a clear understanding of the phenomenon other factors involved in the analysis of thermal interaction between two bodies (the ice cube and the plate that exchange thermal energy until equilibrium is reached) must be taken into account. This second kind of approach actually produces opposite predictions with respect to the previous ones, i.e. a greater melting speed of ice cubes placed on the thicker (and so heavier) plate. Our data show that 6 teachers appear to describe the phenomenon only on the basis of the Fourier law by considering as more relevant factor the plate thickness and 5 teachers that seem to consider thermal capacity as relevant for the explanation of the phenomenon, but not plate thickness or thermal conductivity coefficient. It is worthy to note that the 4 teachers performing the correct ranking (2 graduated in Biology, 1 in Physics and 1 in Natural Science) analysed the experimental situation by trying to point out the different characteristics of the various bodies and evaluating the relevance of each of them and not by searching, in their knowledge, for laws to apply to the experimental situation.

In comparing their predictions with experimental results, the majority of teachers that predicted the melting of the ice cubes on the basis of a partial acknowledgement of relevant variables expressed, in different ways, a sort of "surprise" with respect to the results. They did not try to search for an explanation of the differences by showing that their predictions were mainly driven by memory of subjects studied during past courses. Only a few made reference to the necessary comparison between what they remembered from textbooks and real-life experience. The great majority of teachers at last commented that the approach to the proposed situation posed them some difficulties, as it is one that is not part of their theoretical knowledge about thermology.

As previously mentioned, the group discussion during the second phase of the W was devoted to deepen the teacher conception of the different procedures involving in a scientific investigation stimulated by the real situation analysed. A preliminary analysis of the audio taped discussion shows the relevant factors described in the following.

During the discussion, all teachers mentioned (at least one time) the need to apply "the" Scientific Method (SM) in order to solve the different problems involved in the analysis of an experimental situation. When requested to clarify what this means, most teachers recited from memory the steps of this process (with only minor variations): observe, develop a hypothesis, conduct an experiment, analyse data, state conclusions framed in some theory and generate new questions. In their idea, these unproblematic rules give them the guarantee to always find a solution to the problems posed. In order to understand this full confidence in the SM it must be taken into account that the first chapter of all the high school physics textbook has the title " The Scientific Method".

Another relevant factor is connected with teachers idea of scientific explanation; very few teachers are aware that explanations are representations of scientific phenomena that link observable features of that phenomenon with hypothesized events, properties, or structures that are not directly observable because of their inaccessibility (as for example the molecular movement) or conceptual nature (as for example forces, energy,….). They did not show a clear distinction between explanation and description, by often using observations or empirical laws as explicative or conjectural models. Finally the fully confidence in the mathematical laws as explicative framework was a common characteristic; our whole teacher sample was completely confident in the explicative value of the Fourier's law and no one was fully convinced that the Fourier's law is an empirical law based on observation. These results obtained in the second phase of our work, integrated with the answers to the problem posed in the first phase account for the need of an epistemological clarification about what the term 'scientific investigation' means and how this can be related to the construction of scientific knowledge.

Discussion and conclusions

The analysis of data previously reported allows us to draw some conclusions with respect to our research questions.

The majority of teachers showed an approach mainly involving the activation of cognitive resources as memory of past learning experience in order to make sense of reality. It seems that the way the proposed situation is first considered, or "read-out", plays a crucial role in achieving an accurate description and activating the correct strategies to select the relevant variables. In some cases, these strategies seem to activate "textbook-like" cognitive resources like memory and formulas, acting as conceptual obstacles to the IB approach. This, in some ways works like a sort of "short-circuit of knowledge", avoiding a phenomenological approach to the problem and a complete formulation of hypotheses. This last conclusion seems to be enforced by the consideration that 3 out of the 4 teachers that correctly explained the ice melting process are not graduated in Physics and probably have superficially analysed thermal conduction in their University courses. So, it seems that previous knowledge (particularly that coming from university) built in environments not linked with real life experience, is not really significant for the learner and acts as an obstacle for the inquiry competences that we want to develop in teachers. Practices as formulating hypotheses or design appropriate experiments are strongly influenced by the searching for appropriate physical laws.

The second phase of our W showed that our teacher sample had an uninformed view that the scientific method is a fixed step-by-step process; many teachers explicitly declared that "science is a systematic process and that only by following these steps in an orderly way, valid scientific knowledge can be constructed." Teachers may have these uninformed views about scientific inquiry as a result of the traditional portrayal of recipe-like experiments in science textbooks, as textbooks often play a vital role in understanding the process of science (Abd-El-Khalick, et al., 2008). It may therefore be reasonable to argue that science textbooks should be revised in line with the contemporary conception that there is no single scientific method to be used in developing scientific knowledge (Abd-El-Khalick & Lederman, 2000; Abd-El-Khalick, et al., 2008; Lederman, 2004; McComas, et al., 1998).

Guide lines for future TAs suggested by the approaches followed by our teachers can be synthesizes as follows. During the training time, characteristics of IB practices must be explicitly addressed from an epistemological point of view, as well as problem based activities that are not too much focused on specific disciplinary knowledge. Preliminary results about teacher TAs involving environments based on problems and situations not belonging to the field where teachers are expert show a greater involvement of teachers that pay a greater attention to inquiry procedures rather than to the correct application of disciplinary knowledge. In this way the previously cited "short-circuit of knowledge" seems to be avoided and teachers can activate the reasoning resources necessary for a profitable development of their Pedagogical Content Knowledge about SI. Moreover teachers need to gain a more epistemically congruent representation of how contemporary science is done by developing activities across different domains of inquiry and many types of investigations.

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Case Study 2: Italy

Results from a guided inquiry-based teaching-learning path in secondary schools

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Abstract

The Italian partners of ESTALISH prepared a Guided Inquiry-based teaching-learning unit on thermal science. In fact, by following the project's guidelines, the University of Palermo Physics Education Research Group (UoP-PERG) developed a teaching/learning unit about the actual problem of applying energy saving strategies on the construction of low energy houses. The preparation and experimentation of this inquiry-based teaching-learning path by partners from UoP-PERG in collaboration with Sicilian secondary school teachers is presented.

Introduction

The unit (available at http://www.uop-perg.unipa.it/establish/classroom_materials.htm) is aimed at engaging high school students in designing and building an energy-efficient scale model house through the understanding of the relevant concepts in the content area of energy flow in thermal systems. The learning project intends to introduce pupils to the basic knowledge of thermal science and infrared imaging thermography. The unit is developed into four subunits, each one focused on a specific problem to address and, in particular, on the analysis of the different effects produced by the three mechanisms of thermal energy transfer (conduction, convection and radiation).

The unit is presented with four subunits as outlined:

- Subunit 1 guides students in the construction of a model house and in making explicit the different factors that contribute in heat dispersion and energy consumption to maintain warm the house. The effects produced by each mechanism of energy transfer are deeply analysed in the other three subunits, which are developed around a particular problem that guides the inquiry.
- Subunit 2 analyses the role of different materials in heat dispersion by developing the relevant concepts connected with energy transfer through conduction.
- Subunit 3 analyses energy transfer in fluid material and the main concepts connected with the convection process.
- Subunit 4 introduces the concept of energy transfer by thermal radiation, analysing the different effects of solar radiation spectrum.

The global content area of the unit concerns the topics of energy and power in thermal systems. The subunits are mainly devoted to 14-16 year old students. However, a specific deepening, involving more mathematisation of data analysis and theoretical formalization, is designed for 16-18 year old students. The estimated duration of the whole unit is 30 hours. However, it could be used partially and/or at different deepening levels. The unit uses hands-on activities, scientific simulations and probe-ware measurements as tools to promote an Inquiry based approach.

The unit was first experienced by a selected group of in-service teachers, in terms of a pilot validation, and then administrated to a wide sample of secondary school students. In particular, a sample of 22 teachers, distributed among science teachers at lower secondary schools and physics teachers at upper secondary schools, was selected to be actively involved in the project. The aim of their engagement was first to discuss and validate the unit and then personally guide the experimentation of the teaching-learning unit "A Low Energy House" within the curricular activities of their classrooms. The list of involved schools included five lower secondary (LS) and four upper secondary (US) schools in Sicily, for a total of 216 students (107 and 109, respectively) aged between 15 and 19, with no previous experience in inquiry based learning.

In Figure 1 we show just two pictures of the activities carried out by the students within the ESTABLISH inquiry-based learning path. Much more information on all the specific activities can be found in short video available at the web page: http://www.uop-perg.unipa.it/establish/tools.htm (Video ICS Guglielmo II)

Figure 1 *Pictures from learning paths experienced within the ESTABLISH Project.*

The results of the unit experimentation at secondary school are provided and discussed in the next section. In it, explicit attention is given to the students' outcomes, exploring their perceptions of science as a subject to study at school, their ideas about the usefulness of scientific knowledge in everyday life. The efficacy of a GI-based teaching approach is tested both in terms of motivation to learn and development of nature of science views.

Students' experience of scientific inquiry

The unit was proposed to all the students involved in ESTABLISH. Some teachers had the opportunity to guide the students through the exploration and scientific investigation of all the problems addressed in the four subsections, while some others focused on specific aspects within one or two subunits, depending on the amount of curricular time the teachers had the possibility to dedicate to the project. However, the results reported in this section refer to those 216 students who were effectively involved in inquiry activities, having the opportunity to deeply experience the spirit of inquiry-based learning, independently of the time spent to explore a given subunit. On average, the students spent about 25 hours to experience the unit.

The ESTABLISH project developed two specific questionnaires to collect the students' feedback before and after a series of several learning subunits for upper (Questionnaire 2A) and lower (Questionnaire 2B) secondary school, respectively. The two questionnaires are structurally very similar, with the questionnaire 2A containing few questions more and a specific part dedicated to ask opinions about learning and understanding science and some aspects of the nature of science. The results presented below were obtained from the analysis the students' outcomes to these questionnaires.

Initially, we have extracted all the common issues addressed in the two ESTABLISH questionnaires, in order to draw a direct comparison between the responses provided by the students attending the lower or upper secondary school. After that, we focused our analysis to those specific aspects addressed only in upper secondary school students.

The first part, entitled "My science classes", is devoted to collect information about the students' general ideas on science as a subject and usefulness of science and technology in everyday life. The issues addressed in this part are specifically the following:

- School science is a difficult subject.
- School science is interesting.
- School science is rather easy for me to learn.
- I like school science better than most other subjects.
- I think everybody should learn science at school.
- The things that I learn in science at school will be helpful in my everyday life.
- School science has increased my curiosity about things we cannot yet explain.
- School science has increased my appreciation of nature.
- School science has shown me the importance of science for our way of living.
- School science has taught me how to take better care of my health.
- I would like to become a scientist.
- I would like to have as much science as possible at school.
- I would like to get a job in technology.

For each of the above items, the students were asked to express their own opinion by assigning a score in the range 1-4, corresponding to the four-point Likert scale: (1) Disagree, (2) Uncertain-disagree, (3) Uncertain-agree, and (4) Agree. In Figure 2 we show the responses provided by the students of lower (top panel) and upper (bottom panel) secondary school. The squares indicate the values averaged over all upper or lower secondary students, while the diamonds are used to connect the 25 and 75 percentiles. Red and green symbols refer to pre-instruction and post-instruction data, respectively.

The analysis of pre-instruction data shows that the LS students generally do not consider science as a difficult subject to learn. Moreover, they believe that science is an interesting matter and everybody should learn it at school, because science knowledge stimulates the curiosity about how the world works and, even more important, it could be useful for our everyday life. However, despite these positive opinions about science, the students seem to do not consider the opportunity to become a scientist as a viable route to their professional career, preferring, with some degree of uncertainty, a job in technology.

Post-instruction results of LS students do not show significant deviations with respect to their pre-instruction views, with only some minor changes suggesting a slightly increase in the awareness of the difficulty of learning science and a little more consideration about the opportunity to get a job in science and technology.

The students attending upper secondary schools answered the same items and their responses are reported in the bottom panel of Figure 2. With respect to their younger colleagues, these students show a little greater awareness of the difficulty to learn science concepts and a more uncertain-agree score concerning the interest for scientific knowledge. Despite this, they believe that everybody should learn science at school. Some uncertainty is expressed for what concerns the impact of science in our way of living and health care. Even in these US students, scientific careers are not considered a good opportunity for their future employment, with some uncertainty for technology.

By summarizing the results from “My science classes” survey, we may assert that the GI-based learning path experienced by our students had a relatively modest impact on their perceptions. The students were conscious of the importance of learning science even before the beginning of their ESTABLISH experience and on the potential role science and technology may play in our everyday life. But probably they were missing the connection to some practical examples that could help to consider science so important. In this respect, by engaging the students to personally explore the methods of scientific inquiry applied to the real context of building a low energy house, this learning experience provided the students with a concrete example of how important is the knowledge of science in their everyday life. Moreover, our findings suggest that the students consider school science a different matter with respect to real scientific work. School science is only as a subject to learn, with few practical applications to the world around them, as instead in the case of the work made by scientists. The majority of students probably started this experience with the personal convincement that scientists are exceptionally endowed people, as usually considered by common people, and this is the main reason for their concerns about getting a job in science. This experience should have helped the students to realize that no difference exists between science at school and the real scientific work, and that scientists are no more than exceptionally curious people, strongly motivated to know and understand how the world works. The lack of interest showed by our students for scientific jobs could be ascribed to a misunderstanding of this point or even to other personal motivations.

The second research issue addressed by mean of the ESTABLISH questionnaires concerns the opinions the students express about science and technology (Figure 3), by focusing the following specific social aspects:

- Science and technology are important for society.
- Science and technology will find cures to diseases such as HIV/AIDS, cancer, etc.
- Science and technology make our lives healthier, easier and more comfortable.
- New technologies will make work more interesting.
- Science and technology will help to eradicate poverty and famine in the world.
- Science and technology can solve nearly all problems.
- Science and technology are helping the poor.

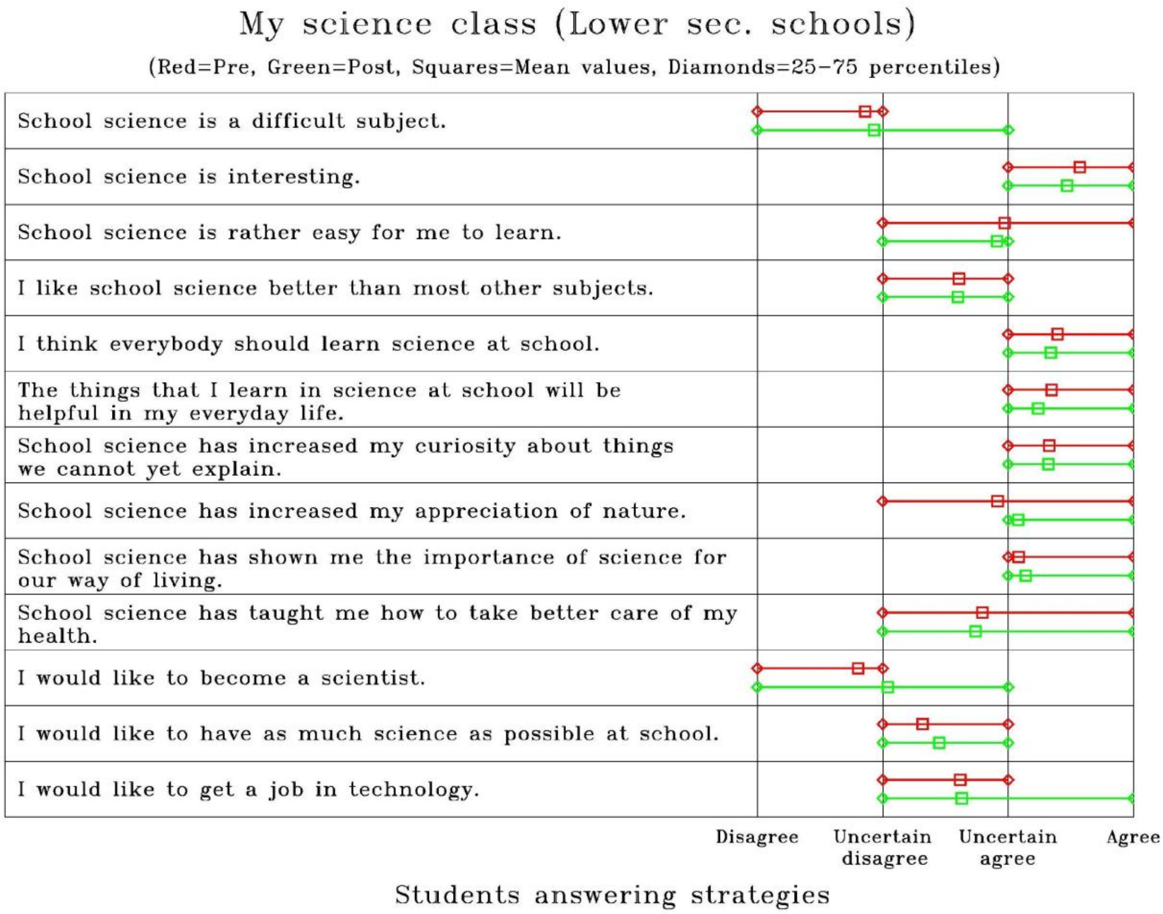

Figure 2a *Results from the ESTABLISH project in Italy. The topics within "My science class" were selected from the items of questionnaires 2A and 2B of the ESTABLISH tools for the achievement of students' feedback before and after a series of several learning units. Squares indicate the mean values and diamond the 25th and 75th percentiles.*

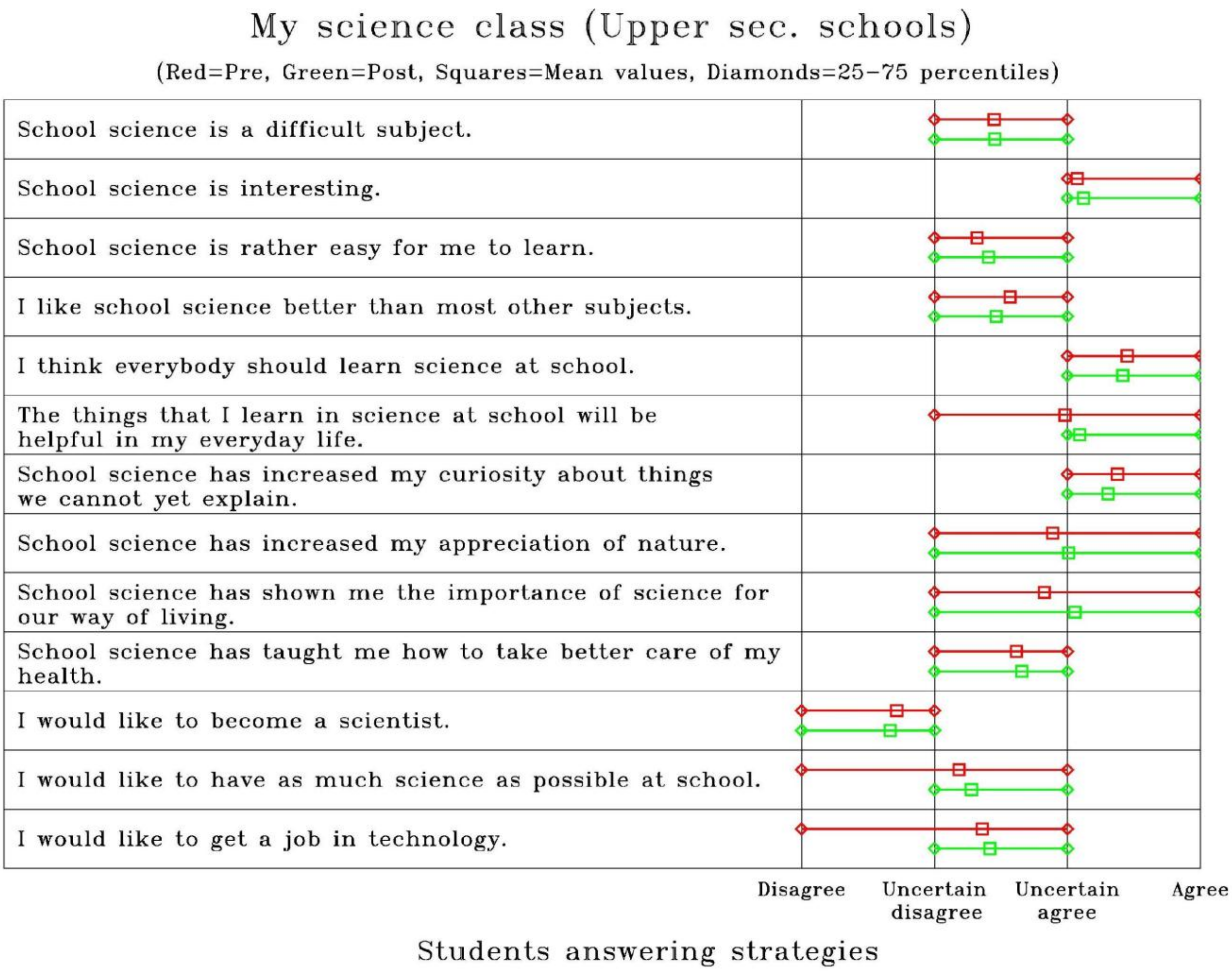

Figure 2b *Results from the ESTABLISH project in Italy. The topics within "My science class" were selected from the items of questionnaires 2A and 2B of the ESTABLISH tools for the achievement of students' feedback before and after a series of several learning units. Squares indicate the mean values and diamond the 25th and 75th percentiles.*

In Figure 3 we show the pre/post-instruction results obtained from the responses provided by LS (upper panel) and US (lower panel) students. Even in this case, an overall comparative analysis of pre/post-instruction data shows that our students maintained essentially unchanged their views of social impact of science. Moreover, we find essentially the same outcomes for LS and US students. The students already knew that science and technology are important for society, in particular for what concerns the positive impact of scientific researches in medicine and health care. However, despite these optimistic opinions, both LS and US students show some uncertainty to believe that science and technology can really help to eradicate poverty and/or solve nearly all problems.

A common part of the ESTABLISH 2A-2B questionnaires is entitled “What do I think about the following discussions?” and asks the students to express their agreement or disagreement with one student or the other who disagree about some issue. The proposed discussions focused on the following five specific aspects concerning the NOS:

- Science can be learnt only by studying textbooks, avoiding to follow own experiences.
- Remembering facts is very important to understand science.
- To understand science, the formulas are really the main thing.
- In science, the facts speak for themselves and cannot support multiple theories.
- A theory explaining experimental results cannot change.

The results of the students outcomes are summarized in Table 1, where the percentages of students in agreement with the specific statements are reported.

Table 1. *Results from LS and US students’ responses to the ESTABLISH 2A-2B questionnaires about NOS-related concepts: “What do I think about the following discussions?”*

NOS-related concepts	Percentage of agreement			
	LS		US	
	Before	After	Before	After
Science can be learnt only by studying textbooks, avoiding to follow own experiences	73%	64%	52%	31%
Remembering facts is very important to understand science	86%	72%	78%	67%
To understand science, the formulas are really the main thing	77%	61%	85%	62%
In science, the facts speak for themselves and cannot support multiple theories	55%	52%	48%	43%
A theory explaining experimental results cannot change	88%	73%	84%	65%

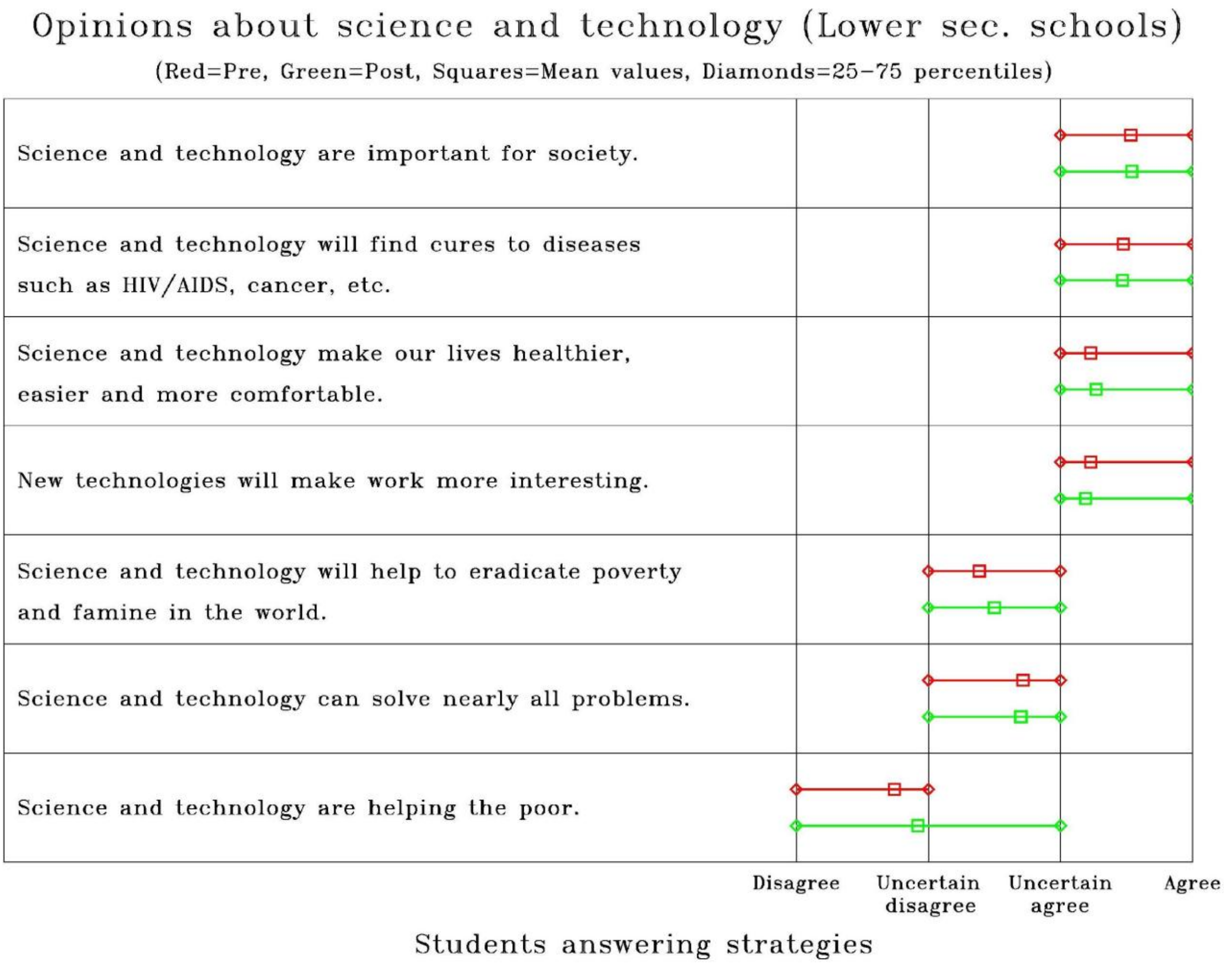

Figure 3a. *Results from the ESTABLISH project in Italy. The topics within "Opinions about science and technology" were selected from the items of questionnaires 2A and 2B of the ESTABLISH tools for the achievement of students' feedback before and after a series of several learning units. Squares indicate the mean values and diamonds the 25th and 75th percentiles.*

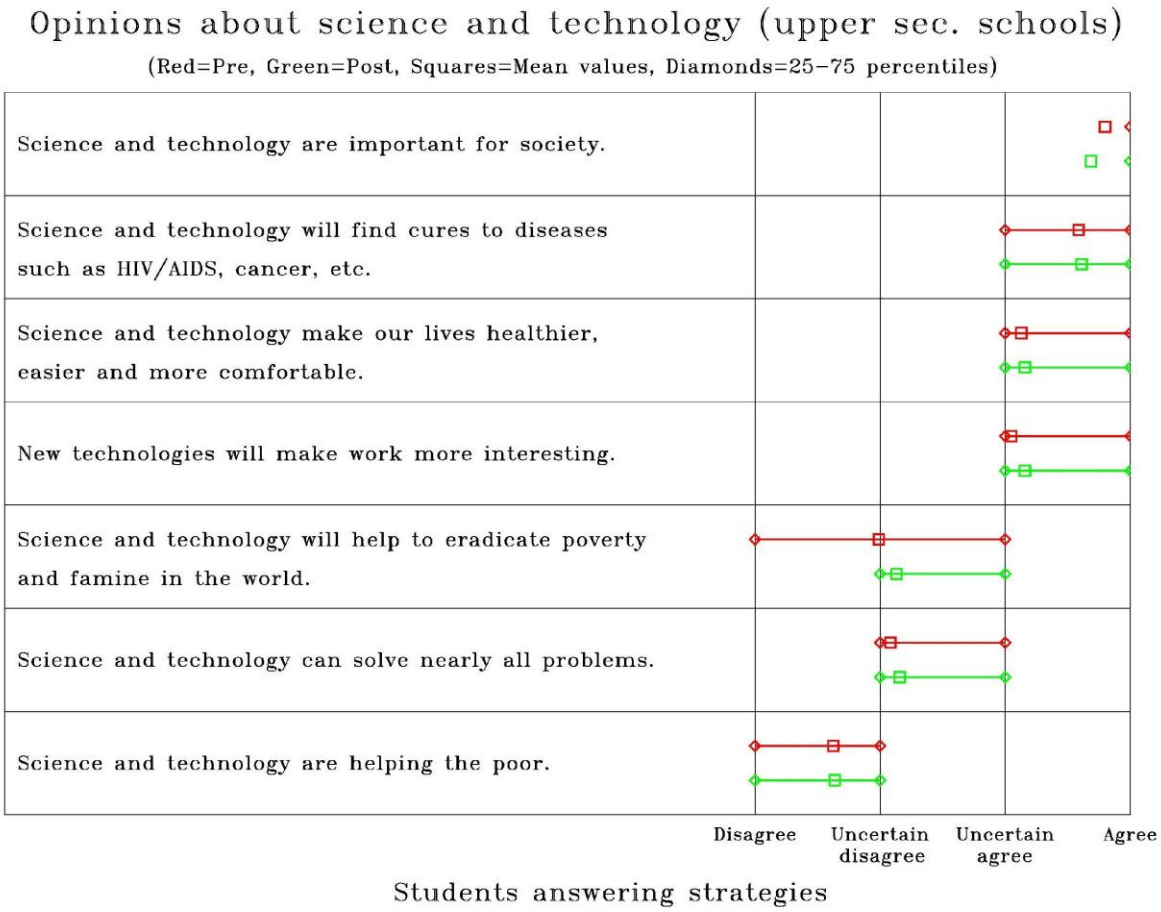

Figure 3b. *Results from the ESTABLISH project in Italy. The topics within "Opinions about science and technology" were selected from the items of questionnaires 2A and 2B of the ESTABLISH tools for the achievement of students' feedback before and after a series of several learning units. Squares indicate the mean values and diamonds the 25th and 75th percentiles.*

The ESTABLISH questionnaires focused on those aspects of NOS which are the most commonly observed in students' discussions about science. The fact of considering the textbook as a sacred oracle of absolute truths (the formulas), independently from personal experiences, or a theory as an unchangeable piece of knowledge, or the importance of remembering facts, can be considered as real cognitive obstacles to the learning process. The percentages of agreement to a given NOS concept reported in Table 1 represent the percentages of LS or US students who agreed with the idea exposed in that specific statement, respectively before and after experiencing the GI-based learning path. Our pre-activity results show very high percentages, as expected in learners who have never been involved in the practice of science. In particular, high percentages of LS and US students believe that remembering facts is important to understand science. This finding could be symptomatic of an excessively transmissive teaching approach from their instructors. The importance assigned by the students to mathematical formulas in science learning could come from a misleading approach to problem solving, in which more attention is paid to the procedure with respect to the reasoning underlying the resolution process. This finding is more evident in US students' responses, probably because in LS classes the use of mathematics to solve a physics problem is less preferred. Another difference between LS and US pre-instruction students' percentages concerns the relevance of considering the textbook the only source for learning science with respect to personal experiences. In fact, lower percentages of US students who are in agreement with the first statement are found. This is probably because older students are more used to study through multiple resources, such those that can be found on the web and, specifically in the context of learning science, many realistic simulations of physics experiments may provide the students with the awareness of importance of personal experiences in addition to the textbook.

In general, post-activity percentages are all lower than those recorded before the beginning of the project. However, this reduction is barely noticeable in LS students' percentages, while a little more evident in US students' outcomes. In particular, these latter were mostly reduced only in connection with the first, the third and the fifth statements. Globally, our results suggest that secondary school students, engaged in GI-based experiences and without any specific instruction on NOS, experienced modest changes in their views on how scientific knowledge is produced and characterized, confirming what expressed in recent literature at this regard.

A further research question addressed within the context of the ESTABLISH experimentation at secondary school has been focused on the efficacy of a GI-based teaching approach to motivate the students to learn science. Motivation plays a critical role in student learning and achievement, mainly because it is intimately related to the ways students think, feel, and act in schools. Evidence from research on student learning in general (Pintrich, 2003), and mathematics and science in particular (Schoenfeld, 1992), demonstrates that students' motivation, affect, strategies, and beliefs about knowledge in these disciplines can influence their learning and performance. The motivational issue has been already partially investigated by mean of the students' outcomes to the two ESTABLISH questionnaires, in which their opinions about their interest in science were collected. Both LS and US students asserted that school science is interesting and everybody should learn science at school. In order to deepen this aspect, in the context of the unit experimentation the students were asked to express their agreement about the following motivational aspects (selected from Glynn and Koballa, 2006):

- Intrinsically Motivated Science Learning (I enjoy learning science; I like science that challenges me; understanding science gives me a sense of accomplishment.)
- Extrinsically Motivated Science Learning (I like to do better than the other students on science tests.)
- Personal Relevance of Learning Science (I think about how I will use the science I learn; the science I learn has practical value for me.)
- Self-Determination to Learn Science (If I am having trouble learning science, I try to figure out why.)
- Self-Efficacy for Learning Science (I am confident I will do well on the science tests.)

The students rated these aspects both prior to and after the GI-based experiences of the ESTABLISH unit, by providing a percentage of agreement with the proposed statements. For each statement, the percentages provided by the students were averaged with respect to the total number of LS or US students, respectively. In Table 2 the students' outcomes are summarized, by adopting the same format as in Table 1.

Table 2. *LS and US students' percentages of agreement to motivational statements.*

Motivation-related aspects	Percentage of agreement			
	LS		US	
	Before	After	Before	After
I enjoy learning science.	79%	84%	52%	81%
I like science that challenges me.	56%	73%	48%	77%
Understanding science gives me a sense of accomplishment.	76%	91%	65%	83%
I like to do better than the other students on science tests.	81%	75%	78%	67%
I think about how I will use the science I learn	38%	78%	41%	73%
The science I learn has practical value for me.	37%	61%	44%	73%
If I am having trouble learning science, I try to figure out why.	68%	72%	62%	79%
I am confident I will do well on the science tests.	56%	77%	48%	62%

From an overall analysis of the percentages provided by the students, it seems evident that they received a positive feedback from the participation to the ESTABLISH project. Even considering that a majority of them, in particular LS students, asserted to enjoy learning science already before the beginning of this experience, the higher percentages recorded both in LS and US students after the GI-based learning path indicate a prominent appreciation of the project. Lower percentages characterize students' pre-instruction answers to the item concerning science as a challenge, probably because they connect this topic to a sort of evaluation of their learning. However, post-instruction data show an increase of these percentages, confirming the benefits of this inquiry approach to intrinsically motivate the students to learn science. Moreover, students report high post-instruction ratings concerning the sense of accomplishment they feel when they understand science. It is interesting to note that the experience of inquiry learning, by stimulating collaborative work, reduces the feeling of competition among students on science tests. The higher increases in students' percentages have been recorded in those two items that address the use and practical value of science learned at school. Finally, this GI-based learning experience seems have stimulated the students to strive further to surmount their difficulties, by achieving a higher sense of confidence to do well on science tests.

In summary, the students' answers highlight a significant result in terms of an increase of their interest and motivation to learn science, but the experienced GI-based learning path does not seem to engage enough the students to effectively impact on their vision of science and on their conceptions about the way scientific work is produced with respect to the science they study at school.

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Case Study 3: Slovakia, Italy, Ireland

Impact of IBSE methods and IBSE materials (Sound) on student/teacher learning

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Abstract

This case study reports on the use of Inquiry-based science education (IBSE) materials and activities on the concept of Sound that have been used to teach lower and upper secondary school students by teachers who have participated in IBSE teacher education (Slovakia, Italy) as well as to teach pre-service teachers (Ireland). Evidence of the impact of this approach and materials has been collected from both the participating teachers and their students and the results and feedback of this teaching approach and the impact of IBSE on the students are discussed. In particular, the impact on students' appreciation of the importance of science and technology in society, the impact on students´ inclination towards taking up careers in science and the impact on intrinsic motivation for learning science are considered.

Introduction

Educational systems within Europe are currently facing a massive shift towards the implementation of Inquiry based science education (IBSE). An IBSE approach is considered to encourage students´ active involvement in their learning compared to traditional methods. However, it is not easy to implement this way of teaching into classes since the success of the education reform movement requires consonance of many elements to be taken into account, such like improvements in in-service and pre-service teacher training, change in curricula and student assessment, instructional materials available for easy use of teachers, positive atmosphere towards these trends at school, etc. (Roschelle et col., 2000). The European 7th framework project ESTABLISH (http://www.establish-fp7.eu) is focused at supporting the use of IBSE methods into classes across Europe. Within the project, teaching and learning materials have been developed to facilitate inquiry-based learning. In order to develop teachers confident in the use of IBSE, in-service teacher training was provided to enable teachers to experience and develop their inquiry based teaching strategies using appropriate teaching and learning materials. Pre-service teachers experienced this way of teaching as well in their own process of learning science. The in-service teachers that participated in IBSE workshops have implemented the IBSE materials provided in their classroom. They were also provided with instruments in order to collect information and data about the impact of IBSE on their students. The evaluation of the impact of these IBSE materials and approaches for teaching Physics concepts was carried out and analysed for three different countries, namely Italy, Ireland and Slovakia.

Methods

In the discipline of physics the project partners are developing several units, i.e. Sound, Heating and Cooling: Designing a Low Energy House, Direct current electricity, Light: Display and Imaging Technologies, Medical Imaging. All the developed IBSE units have the same structure that involves, providing details of:

- Teacher information (Unit description, IBSE character, Science content knowledge, Pedagogical content knowledge, Industrial content knowledge, Learning paths, Assessment, Student Learning Activities
- Classroom materials involving students´ worksheets and other materials needed within the lesson.

Accordingly, the unit of Sound has been the first unit to be implemented and tested in the school classroom. First, in-service and pre-service teachers participated at teacher training workshops according to agreed structure considering the national curriculum and other national specifics, e.g. participants' current experience in the field of IBSE.

Pre-service teachers were involved in introductory lectures to IBSE and 9-hours of inquiry-based labs (Ireland) with emphasis on inquiry-questioning skills. After these sessions their attitude towards IBSE was probed as well as their assessment of their conceptual understanding of Sound concepts.

In-service teachers participated in at least 10-hours teacher-training (Slovakia, Italy) to enable them to implement this way of teaching in their own classrooms. Teachers who participated in teacher training on Sound by inquiry implemented selected activities in their own classrooms at secondary level in order to gain experience (Italy, Slovakia) in this approach. After implementing this way of teaching their attitudes towards IBSE was analysed (Italy). In order to gain feedback from students they were provided tools to collect evidence about the impact on students (Slovakia), in particular on students' appreciation of the importance of science and technology in society, the impact on students´ inclination towards taking up careers in science and the impact on intrinsic motivation for learning science.

Implementation of IBSE in Slovakia

Since 2008 when educational reform was implemented into the educational system, the Slovak national curriculum gives significant attention to scientific inquiry with emphasis on students´ active independent learning. However, Slovak teachers are not educated in this approach and there is a lack of instructional materials for teachers to use in the classroom.

In the period November 2011 to February 2012, 50 secondary schools science teachers participated in 4-days teacher training in IBSE. Following on from this, 14 physics teachers implemented activities from the Sound unit into their teaching, with each teacher implementing at least 3 activities in the period of February 2012 to June 2012. A total of 202 upper secondary schools pupils completed questionnaires before and after a series of activities, while 1302 upper secondary school pupils answered questionnaires after each lesson (for detailed information about the questionnaires see Kekule, M., Žák, V., 2012).

The after each lesson questionnaire has been focused on intrinsic motivation and is based on the Intrinsic Motivation survey (Ryan, R., Deci, L. 2000). There were three dimensions assessed: Interest/Enjoyment, Perceived Choice and Value/Usefulness. The questionnaire responses show that:

In the field of Interest/Enjoyment - to what extent students like the performed activity and find it interesting – students express the provided learning activities were interesting for them and they enjoyed them (figure 1).

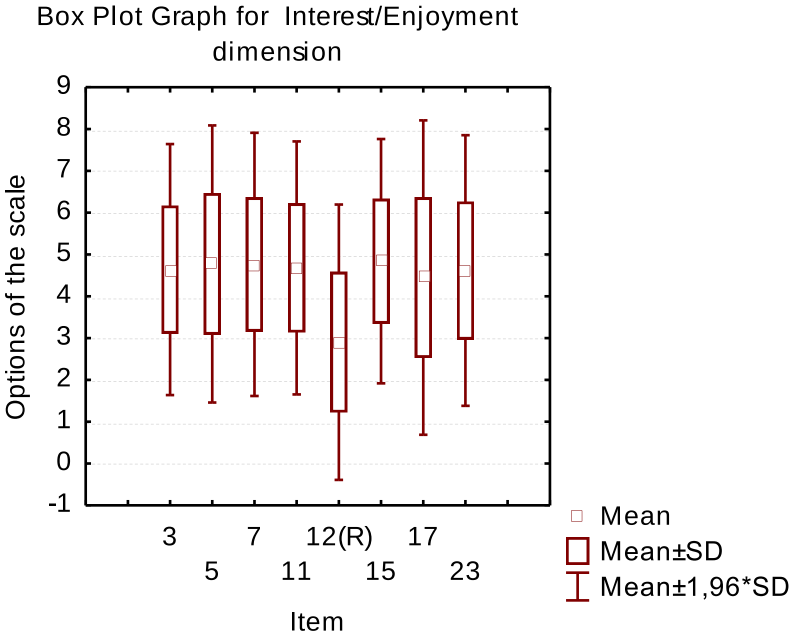

Figure 1 Results for the question items – to what extent students like the performed activity and find it interesting (each question max.7 points, item 12 has reversed score)

In the field of perceived choice – to what extent students perceive their choice when performing a given activity – students chose the middle option on average. Data indicates that the students lack of strong opinion about perceived choice (figure 2).

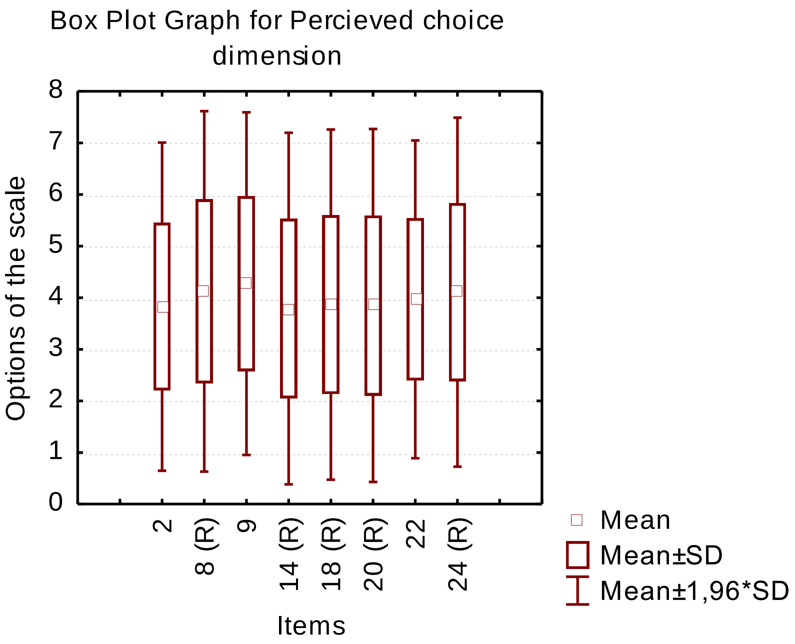

Figure 2 Results for the question items – to what extent students perceive their choice when performing a given activity (each question max. 7 points)

In the field of Value/Usefulness – how students perceive the value/usefulness of a given activity for themselves – students overall agreed with each item. The results are similar to the result of Interest/Enjoyment dimension. Students express the provided activities were slightly useful for them (figure 3).

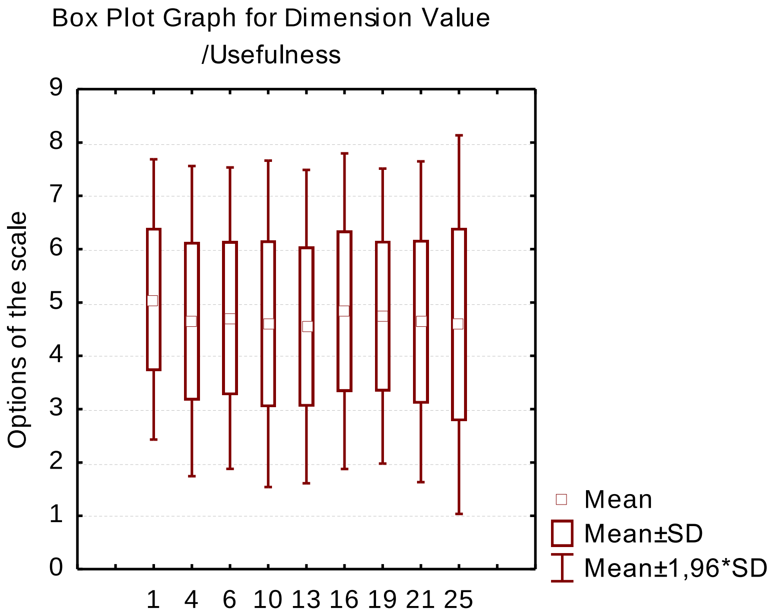

Figure 3 Results for the question items on how students perceive the value/usefulness of a given activity for themselves (each question max. 7 points)

Another set of question items was aimed at determining the level of communication during the activity (table 1). Students considered how often they communicated using a five-point scale (1-almost never, 2-seldom, 3-sometimes, 4-often and 5-almost always). The communication levels described in items 1 and 2 were perceived to happen more often indicating that students think that they talked to each other about solving problems, however, considering explaining ideas to each other, students chose the middle option on average.

Table 1. Questionnaire items on students' communication during the activity (adapted from CLES questionnaire (Taylor, P. C., Fraser B. J., & White, L. R. ,1994))

Statement	mean	St dev
I get the chance to talk to the other students.	3,83	1,06
I talk with other students about how to solve problems	3,49	1,05
I explain my ideas to other students	3,08	1,08
I ask other students to explain their ideas	2,98	1,08
Other students ask me to explain my ideas	2,80	1,09
Other students explain their ideas to me.	3,06	1,05

In the before and after whole teaching (series of activities) questionnaire several aspects were examined. The results were compared using appropriate statistical testing. A set of 16 questions were used to assess how students perceive the role of science and technology in society (table 2). Students used a four-point scale to express the extent to which they agree or disagree with the statement. The responses to these set of questions indicates that there is no statistical difference between pre and post IBSE experience responses.

Table 2. Examples of questionnaire items assessing students' perception of the role of science and technology in society (scaled 1…4, disagree…agree) (adapted from ROSE questionnaire (Schreiner, C. , Sjøberg, S., 2004))

	before		after	
Statement	mean	St dev	mean	St dev
Science and technology are important for society	3,73	0,61	3,48	0,76
New technologies will make work more interesting	3,02	0,79	3,00	0,95
Science and technology can solve nearly all problems	2,05	0,83	2,11	0,94
We should always trust what scientists have to say	2,02	0,81	2,16	0,87
Scientists are neutral and objective.	2,29	0,86	2,41	0,88
Scientific theories develop and change all the time	3,32	0,77	3,16	0,85

In the set of questions assessing student opinion about learning and understanding science (table 3), the analysis shows significant difference between responses to the pre and post questionnaires in items 2 and 6.

Table 3. Examples of test items results on opinion about learning and understanding science (scaled 1…4, disagree…agree) (adapted from EBAPS questionnaire (Louca, L., Elby, A., Hammer, D., & Kagey, T. , 2004))

Statement	before		after	
	mean	St dev	mean	St dev
When it comes to understanding physics or chemistry, remembering facts isn't very important.	1,70	1,28	2,27	1,23
When learning science, people can understand the material better if they relate it to their own ideas.	2,77	1,33	2,33	1,38
If biology, physics or chemistry teachers gave really clear lectures, with plenty of real-life examples and sample problems, then most good students could learn those subjects without doing lots of sample questions and practice problems on their own.	0,52	0,83	0,88	1,09
To understand chemistry and physics, the formulas (equations) are really the main thing. The other material is mostly to help you decide which equations to use in which situations.	1,87	1,28	1,86	1,25

There was a set of questions assessing students' opinion about science lessons and their attitude towards taking up career in science or technology (table 4). The analysis of this field shows significant difference between pre and post questionnaire in the items 1, 9, 11 and 15. Their positive attitude towards science lessons increased (item 15) however there is no significant difference in up–take of careers in science or technology after experiencing IBSE activities.

Table 4. Examples of test items results on opinion about how students perceive science lessons and their attitude towards taking up career in science or technology (scaled 1…4, disagree…agree) (adapted from ROSE questionnaire (Schreiner, C. , Sjøberg, S., 2004))

Statement	before		after	
	Mean	St dev	mean	St dev
School science is a difficult subject.	2,77	0,89	2,93	0,84
School science is rather easy for me to learn.	2,38	0,78	2,23	0,83
School science has made me more critical and skeptical.	2,05	0,93	2,38	0,85
School science has increased my appreciation of nature.	2,36	0,96	2,57	0,97
I would like to become a scientist.	1,93	1,03	2,02	1,00
I would like to have as much science as possible at school.	2,00	0,93	2,16	1,02
I would like to get a job in technology.	2,09	1,05	2,26	1,01

Based on the responses to these questionnaires it can be clearly seen that the students' opinion on the activities they carried out is positive; they consider them interesting, enjoyable and useful. There is indication of a slight impact on students motivation and attitude towards science lessons, nevertheless the impact on students views on science and its role in society has not changed, neither has their inclination towards taking up careers in science or technology.

Implementation of IBSE in Italy

Some relevant aspects of IBSE are formally present in the Italian National Science Curriculum. It is clearly stated that at the end of their studies the students should be confident with the different aspects of the experimental methods, where the experiment is to be considered a reasoned inquiry of natural phenomena, a tool for control of different interpretative hypotheses and critical analysis of data and reliability of measurement procedures. However, Italian science teachers are often not well trained in IBSE and its relevant aspects. This applies particularly to upper secondary school physics teachers that often have a mathematics degree and very limited experience in laboratory activities from their university studies.

Within the ESTABLISH project, a one-day presentation of IBSE was held in Palermo in April 2010 for in-service teachers from all over Sicily. After this event, teachers were selected and 30 teachers initially agreed to participate but actually a total of 22 participated in all the subsequent activities (12 upper secondary school teachers and 10 lower secondary school teachers).

Five "official" full days of training to the IBSE methodologies were organized, between April 2010 and November 2011 at an IBSE laboratory in the Physics Department at the University of Palermo. But many more afternoons of informal training were also facilitated for teachers wishing to practice more with the IBSE material and documentation made available on the ESTABLISH website, and with the technology based equipment available in the laboratory. This equipment is similar to that often present in the teachers' own school laboratories, but sadly hardly used due to lack of training/time/motivation.

After this training phase, the teachers used some parts of two of the ESTABLISH Units in their classrooms throughout 2012: "Sound" and "Heating and Cooling: Designing a Low Energy House". Two of the teachers subsequently incorporated the Sound Unit in their own teaching, adapting their lesson and topics taught in their classes to the relevant content and methods. Three half-day meetings were held at the end of March 2012 to review what had been done with the students and to make some needed changes and amendments to the various pedagogical activities. A further three half-day meetings were held in May 2012 and were dedicated to reviewing the final outcomes from the Unit trials and to collect teacher feedback about the actual implementation of IBSE activities in their schools.

In general, it was agreed that the IBSE activities were well fitted to the Italian Physics curriculum. It was proposed that the Units' structure needed some adaptation and, more specifically, teachers requested that more detail should be given in describing the activities to be performed and in the theoretical aspects behind the IBSE activities. Something all teachers noticed and reported was the unconditional and substantial enthusiasm of students participating in IBSE activities. The believed that the students always found that physics introduced through an IBSE methodology was more enjoyable and less difficult to follow and understand. Before starting the training phase at Department of Physics teachers answered a pre-questionnaire aimed at analyzing their views of inquiry teaching and approaches, as well as their attitudes and views towards science and teaching science. After completing the training sessions and experimenting the IBSE methodology in their classes teachers were answered a post-questionnaire to see if the IBSE training and in-class implementation was effective in modifying some aspects of their views of inquiry teaching and approaches. The comparison between teacher answers before and after IBSE activities are reported in Tables 5, 6 and 7. From Table 5 it is easy to see that after training and in-class implementation of IBSE methods and teaching units teachers seem to better understand the meaning of inquiry based education, their role as teachers in an IBSE teaching environment and the possibility to effectively perform IBSE in their classrooms. Also, after training, more teachers believe that the use of inquiry is appropriate to achieving the aims of the curriculum.

Table 5. Examples of test item results on teachers' views of Inquiry (scaled 1 … 5, disagree … agree)

Statement	before		after	
	Mean	St dev	mean	St dev
I don't fully understand inquiry based science education.	2.72	0.88	1.59	0.59
I don't fully understand my role as a teacher in an inquiry classroom.	2.27	0.63	1.50	0.59
I don't fully understand the role of the students in an inquiry classroom.	2.09	0.29	1.13	0.47
I think inquiry takes too much classroom time for me to implement	2.82	0.58	1.82	0.66
The use of inquiry is appropriate to achieving the aims of the curriculum.	4.00	0	4.5	0.51
Inquiry-based teaching is only suitable for very capable students	2.09	0.29	1.63	0.79
Inquiry will never be my main teaching method.	2.27	0.88	1.50	0.60

Fortunately, the need for links between Industry Content Knowledge and what it is taught at school was clear to the teacher sample also before the IBSE training, as shown in Table 6. Nevertheless an improvement on teachers' views about this aspect can also be considered as a result of the IBSE activities implementation.

Table 6. Examples of test item on teachers' views on Industrial Content Knowledge and Authentic Experiences (scaled 1 … 5, disagree … agree)

Statement	Before		after	
	mean	St dev	mean	St dev
I want my students to know about the latest developments and applications of science and engineering.	4.18	0.39	4.41	0.59
I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.	3.68	0.48	4.32	0.48
I often show students the relevance of science in industry	4.72	0.45	4.36	0.49
My students understand the importance of science and technology for our society.	3.09	0.75	4.00	0.75
If I had more information about industrial processes, I would use it in my teaching.	4.18	0.39	4.23	0.68

Table 7 shows that the IBSE training seems to have modified the teachers' inclination at managing classrooms where each student group is doing different activities, something not common in Italian science lessons, where a traditional, lecture-based approach is the most common one. Strangely, some confusion can be deduced from the increase in teacher sense of inadequacy when they don't know the answers to specific questions and when they are to pose questions they are unsure of the answer themselves. Maybe a longer training with IBSE methods was needed to give teacher more confidence with the typical aspects of scientific inquiry.

Table 7. Examples of test item results on teachers' views on teaching Science (scaled 1 … 5, disagree … agree)

Statement	Before		after	
	Mean	St dev	mean	St dev
If a student investigation leads to an unexpected result I should always tell the student the right answer/result.	3.95	0.48	1.77	0.75
I find it difficult to manage a classroom where each student group is doing different activities.	4.45	0.67	1.86	0.64
I am unsure how to ask students higher order questions that promotes thinking.	1.86	0.64	2.36	0.95
I have sufficient knowledge of science to implement an inquiry lesson effectively	3.54	0.59	3.18	0.79
I am uncomfortable teaching areas of science I have limited knowledge of.	3.86	0.64	3.45	0.75
If I don't know the answers to students questions I feel inadequate as a teacher	1.41	0.91	3.00	0.75
I am uncomfortable with asking questions, in my class, where I am unsure of the answer myself.	1.5	0.80	3.54	0.86

Implementation of IBSE in Ireland

The national curriculum in Ireland for lower secondary science emphasizes teaching strategies that encourages investigative work as well as experimental prescribed work. The syllabus promotes the development of logical thinking and reasoning, and skills of observation, measurement, interpretation, numeracy, problem solving and decision making. With respect to the IBSE elements there are opportunities for students to investigate their own problem by searching for information and planning investigations. Mostly students take problems assigned by the national State Examination Commission. The students' investigation plans are assessed using a summative exam/review at the end of the lower secondary level (Junior Cycle) ~15years. However, depending on teachers' capabilities to manage inquiry and such open teaching, they may wish to set the investigation so as to limit the openness of the problem, and may present the required information and experiments for the students, again limiting their opportunity to search for information, and plan their investigation. So while the national curriculum includes IBSE elements, in general, teachers are not educated at either pre-service or in-service level and there is a lack of appropriate instructional materials available to support the teaching of national syllabi.

In the period February 2012 to May 2012, 37 pre-service physics teachers participated in introductory lectures plus 9 hours of hands-on Inquiry Based Labs using materials from the Sound Unit. 39% of these students considered themselves beginners while 61% of them expressed that they had some experience with inquiry-based teaching. The Inquiry Based Labs were focusing on developing inquiry questioning skills. Before the labs sessions started, students answered a pre-questionnaire (table 5) on their views of inquiry. After completing the sessions they answered a concept based assessment (table 6) as well as a post-questionnaire (table 10) on their views of inquiry teaching and approaches.

As regards responses to questions, these pre-service teachers were positive about the values and benefits of inquiry as a methodology. Importantly, 67% believed the use of inquiry is appropriate to achieving the aims of the curriculum and 70% expressed confidence in their understanding of inquiry based science education.

However, pre-service teachers appeared unconfident and uncomfortable with delving outside the limits of their own knowledge in the classroom. 61% of teachers felt uncomfortable with teaching areas of science they had limited knowledge of and 64% admitted to being uncomfortable with asking questions where they are unsure of the answer themselves.

They were very divided in their responses as to their role as the teacher in the classroom and 54% disagreed with the statement "my goal is to transfer factual knowledge to the students" while 55% felt that teaching was more effective when all students are doing the same activity at the same time". These conflicts arise from their lack of experience in the classroom and their understanding of the state examinations in science.

Table 8. Pre-service teachers pre- questionnaire responses

I don't fully understand inquiry based science education.	70% disagreed
Inquiry will never be my main teaching method.	28% uncertain or agreed
I don't fully understand the role of the students in an inquiry classroom.	22% uncertain or agreed
The use of inquiry is appropriate to achieving the aims of the curriculum.	67% agreed
Scientific theories (e.g. atomic theory) are constant unchanging bodies of knowledge.	27% agreed
Scientific knowledge is primarily focused on knowing facts.	27% agreed
Developing students' specific content knowledge is much more important than developing their thinking and reasoning processes.	78% disagreed
Good teachers encourage student discussion on scientific topics relevant to everyday life.	95% agreed
I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.	89% agreed
Teaching is more effective when all students are doing the same activity at the same time.	55% agreed
My goal is to transfer factual knowledge to the students.	54% disagreed
If a student investigation leads to an unexpected result I should always tell the student the right answer/result.	16% agreed
I am uncomfortable teaching areas of science I have limited knowledge of.	61% agreed
I would be uncomfortable with asking questions, in my class, where I am unsure of the answer myself.	64% agreed

As the focus of these inquiry labs was to develop the student understanding of physics concepts relating to the topic of Sound through IBSE, the students were required to answer a series of questions relating to various concepts. In all questions they were asked to give and explain the answer provided. As can be seen in (table 9), understanding of concepts such as describing the production and propagation sound were well expressed but more difficult concepts such as explaining the wave nature of sound and sound as a form of energy still challenged these students and only basic understanding was evidenced.

Table 9. Post-assessment of Sound Concepts

Concept	Some ideas	Good understanding
Describe a sound wave	27%	40%
Propagation of the human voice	35%	65%
How humans produce sound	24%	73%
Speed of Sound	24%	76%
Pressure variation versus time graphs	11%	89%
Sound as wave motion	92%	8%
Sound as a form of energy	84%	14%
Posing inquiry questions on resonance	46%	46%

A set of ten open questions were presented to the students to obtain feedback on their understanding of IBSE (table 10) after completing these sessions. 87% expressed that they felt they now understood inquiry better and commented on the benefits of inquiry teaching. 97% of them identified the role of the teacher to guide/ask questions in the inquiry classroom where the students are active and self-directed. When asked what was the most important inquiry skill that they gained from these labs, the students recognized that they had developed questioning skills (48%), experience in planning and doing investigations (27%) and learning from mistakes (22%). 77% of the students were very positive about the materials from the ESTABLISH units and felt they gave them good ideas and developed understanding and skills.

Table 10. Pre-service teacher feedback on Inquiry Process

Question	Student responses
Have your opinions of inquiry based teaching changed?	87% - understand inquiry better and see benefits 13% - already thought it was good/best
Did you enjoy using the ESTABLISH inquiry materials?	77%- positive - good ideas, developed understanding, skills and doing investigations 13% - felt not good ideas or enough time
Do you understand better how to implement an inquiry based classroom?	97% identify role of teacher is to guide/ask questions and students are active & self-directed
Are you now more willing to use inquiry methodologies in your future classroom?	89% -positive- more effective/engaging, developed better understanding/knowledge. Concerns on time constraints, need for background theory and other approaches.
Do you think inquiry is more or less useful than other approaches to teaching?	65%- more useful 22% - equally as useful 13% - depends on students/topic
Do you think you have learned more about sound using the inquiry approach (versus traditional approaches)?	60% - more learnt/understood by doing 19% - same amount 14% - learn more from traditional approaches (but 3% understand more from inquiry)
In school, were you taught using inquiry approaches?	76% - no experience 24% - some in different topics/levels
How do you believe you learn best?	72% - Inquiry approaches 14% - Traditional approaches 14% - Mixture of the two
In what areas would you most like to improve as a teacher?	19% - classroom management 19% -using inquiry 22% -teaching methods & differentiation
What was the most important inquiry skill you gained from these labs?	48% - questioning skills 27% - planning and doing investigations 22% - learning from mistakes

Overall, the pre-service teachers really enjoyed the experience of Inquiry based labs and felt they had gained deeper insight into the inquiry methodology and the role of the teacher/student in the inquiry classroom. They believed it was an effective method to develop conceptual understanding and subject knowledge in science. However, their conceptual knowledge increased only in some Sound topics and deeper conceptual understanding was not achieved by all or on all topics.

Conclusions and implications

The IBSE teaching and learning materials developed within the ESTABLISH project have been successfully implemented within secondary schools physics lessons (Slovakia, Italy) and in pre-service physics teachers education (Ireland). In-service teachers participated in training workshops in order to increase their familiarity with IBSE strategies before they implemented selected activities in their own classrooms while pre-service teachers were in the role of students carrying out the activities themselves. The experiences of the teachers have been collected and reported as well as responses to questionnaires answered by students carrying out IBSE activities on the topic of Sound.

The results of discussions and questionnaires answered by second level students clearly shows their positive attitude to IBSE, they consider the activities interesting, enjoyable and useful and they even expressed a slight positive shift in attitudes towards science lessons. In their communication of science they express they have a chance and talk with other students about how to solve problems that is a good signal since the activities strongly support peer discussion as one of the important aspects of IBSE. However, there were also many items without any significant changes even after engaging in a series of IBSE activities, e.g. the impact on students view on science and its role in society has not changed, neither has their inclination towards taking up careers in science or technology.

In service teachers found inquiry teaching a rewarding teaching experience. However even after participating in training workshops, teachers still lack the necessary skills for consistent application of IBSE methods in the classroom. They will need ongoing professional development to support their increased use of it in the classroom. The pre-service science teachers also expressed positive attitudes and improved appreciation of IBSE following their experiences. They expressed that they had developed inquiry skills, such as questioning, planning and doing investigations and learning from mistakes. However, they also recognized that that required further professional development in classroom management and using inquiry and other such teaching methods. It is clear that for all teachers, that both initial and continual teacher education needs to be facilitated to support the use of inquiry and impact of IBSE in the teaching and learning of science.

Within the ESTABLISH project, several IBSE units in physics have been developed and so much more curriculum and translated materials and teacher training will be provided through the project, with online teacher training as a core aspect of this. This should certainly offer teachers on-going support beyond the face to face meetings.

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Case Study 4: Germany

Investigation of IBSE pre-conditions for teacher pre- and in-service training

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Abstract

The contribution will present an overview of the in-service teacher training opportunities provided by IPN accompanied by a more case-study-style description of an investigation regarding teacher's use of and interest in IBSE activities. Then an overview of our pre-service teacher training opportunities will be presented, followed by a case study-style description of pre-service student teachers' perception and application of research- and industry-related IBSE.

Introduction

As IBL (in German *forschendes Lernen*) is already quite common in science education in Germany, and as the majority of teachers ask for teaching material when visiting in-service teacher training workshops, workshops were not split up into separate sessions on theoretical background, modules etc. but included the different elements into each workshop. The ESTABLISH approach and material have been implemented into a state wide in-service training program called "*Transfer of scientific findings into education*" and have therefore been combined with other IBL modules, e.g. from *Chemistry/Biology/Physics in Context* -projects. The state-wide training program is organized in co-operation with the Ministry of Education of Schleswig-Holstein. Regarding this training project, ten schools had been chosen as local organizers ("Stützpunktschulen"); they invite neighboring schools for each workshop. The workshop topic is chosen by the ten schools in negotiation with us and the ministry. Every half year, all school coordinators meet with us and the ministry.

As the curriculum for pre-service teacher training at the University of Kiel had been set and accredited, elements of IBL were implemented in different existing modules of chemistry education.

Overview of In-Service Teacher Training Opportunities:

a. **Number of teachers:** 10-20 per workshop, total number 146

b. **Length:** 2-4 hours each;

c. **Implemented elements of IBSE:**

   Implemented aspects of the framework

   - Steps / elements of Inquiry (as presentation)
   - ICK: Frames of inquiry in research and industrial production (as presentation and discussion)
   - Teacher as Implementer (in discussion during experiments and final reflection, focusing on relating the units to the curriculum and co-operation between science subjects)
   - Teacher as Developer (only in specific groups like those working in the Science in Context project)
   - ICT (currently not included)

- Argumentation (not specifically included)
- Assessment (in preparation for the next school year courses)

Implemented aspects of the modules

- Access to complete modules through website (in English)
- 3 levels of chemistry modules in relation to the curricula / standards
- Choice of experiments to try out and discuss in the workshop (in German)
    - "Holes": Investigating properties of SAP, developing and applying models to explain structure-property-relations
    - "Chitosan": Investigating properties of Chitosan to absorb fats, developing and applying models to explain structure-property-relations
    - "Care": investigating properties of different fibres, developing and applying models to explain structure-property-relations
- Hints on industry contacts / co-operation
    - "Chitosan": reference to local company producing Chitosan, hints on further material
    - "Care": hints on material produced in co-operation with the Henkel company

d. **Units that have been used:** "Holes", "Chitosan", "Care"; "Cotton on your skin", "Pictures of myself", "Powerstation human being", "Sand and stones", "Air and flying", "Molecular Switches and other nano experiments" (ESTABLISH and Science in Context programs!)

e. **Short description of each workshop:**

- Introductory ppt-presentation: ESTABLISH framework und phases of IBL, connections to the German Science standards and curriculum topics, overview about units and levels (from macroscopic observations to differentiated model-based explanations), overview about phases of units, exemplary presentation of one unit with connection to industry, if possible (e.g. Chitosan, Care)
- Group work: testing and discussing experiments and material, discussing possible implementation in normal classes for IBL, development / exchange of ideas for leading questions initiating the investigations, exchange and development of further ideas for experiments
- Reflection and outlook: feedback on modules and experiments, discussion of ideas for the implementation in science (chemistry, biology) classes, reflection on the design of the workshop, outlook and wishes for future workshops

f. **Distributed material**

- Access to modules through platform
- Series of experiments in paper copies

g. **Evaluation:**

- In some workshops distribution of profiling questionnaire
- Oral feedback at the end
- Pre- and follow-up survey ("Spiderwebs" and questionnaire parts; **see further description of this evaluation aspect below**)
- Regular meetings (twice a year) with school co-ordinators and ministry

Detailed Description of Evaluation In-Service Teacher Training:

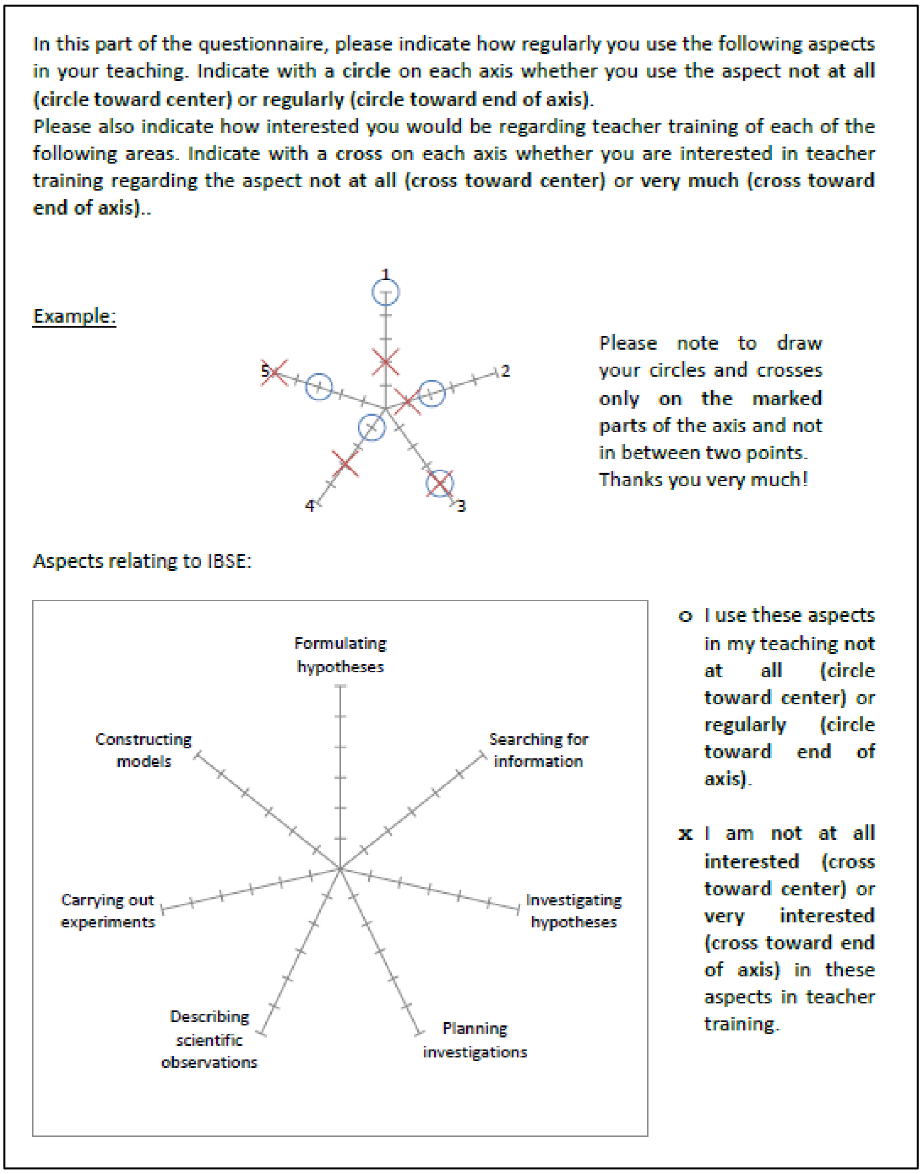
Investigating teachers' interests and experiences in using IBSE-activities

The following results are part of a survey study carried out in Schleswig-Holstein aiming at the analysis of teachers' use and interests in further education in regard to topics, methods and structures of education (PhD student: Katharina Schönau).

Around 250 teachers from different schools (all secondary level) and different areas in Schleswig-Holstein participated in the survey.

The survey was carried out as a questionnaire-study, containing classic elements and scales but also a "spider web radar instrument". In this instrument different topics like content areas or student activities are represented by an axis. The participants have then been asked to mark their regular use of various aspects (one color / symbol) as well as their interest in further teacher training (second color / symbol) for each aspect within the same instrument, whereas an indication close to the center meant low agreement and one closer toward the edge meant high agreement. Regarding IBSE, different activities had been chosen, suitable to the aspects described by Linn et al. used in the ESTABLISH project. The resulting excerpt of that questionnaire are shown in figure 1.

The results as mean values are shown in figure 2, the numbers for the variation are given in figures 2a-d. No further statistical tests had been carried out with this data. In total, most teachers state that they already use many of the given IBSE-activities in their classroom. The interest in further teacher training is at a medium to high level for all aspects. The highest perception of implementation (without statistical tests for significance) is in the areas of carrying out experiments and describing scientific observations. Experiments are also the main interest for in-service training, while searching for information is the lowest.



In this part of the questionnaire, please indicate how regularly you use the following aspects in your teaching. Indicate with a circle on each axis whether you use the aspect not at all (circle toward center) or regularly (circle toward end of axis).
Please also indicate how interested you would be regarding teacher training of each of the following areas. Indicate with a cross on each axis whether you are interested in teacher training regarding the aspect not at all (cross toward center) or very much (cross toward end of axis)..

Example:

Please note to draw your circles and crosses only on the marked parts of the axis and not in between two points. Thanks you very much!

Aspects relating to IBSE:

o I use these aspects in my teaching not at all (circle toward center) or regularly (circle toward end of axis).

x I am not at all interested (cross toward center) or very interested (cross toward end of axis) in these aspects in teacher training.

Figure 1: Excerpt of questionnaire showing the use of spider web instrument.

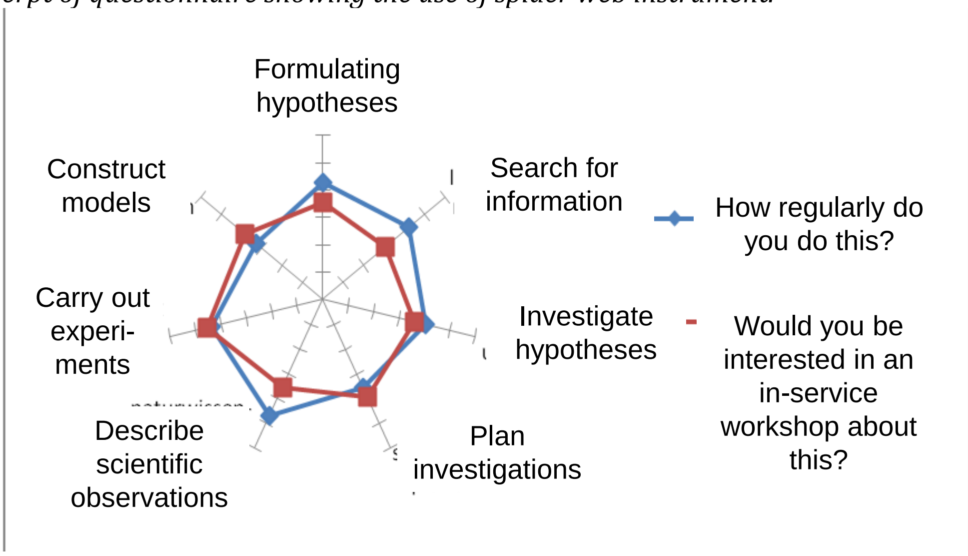
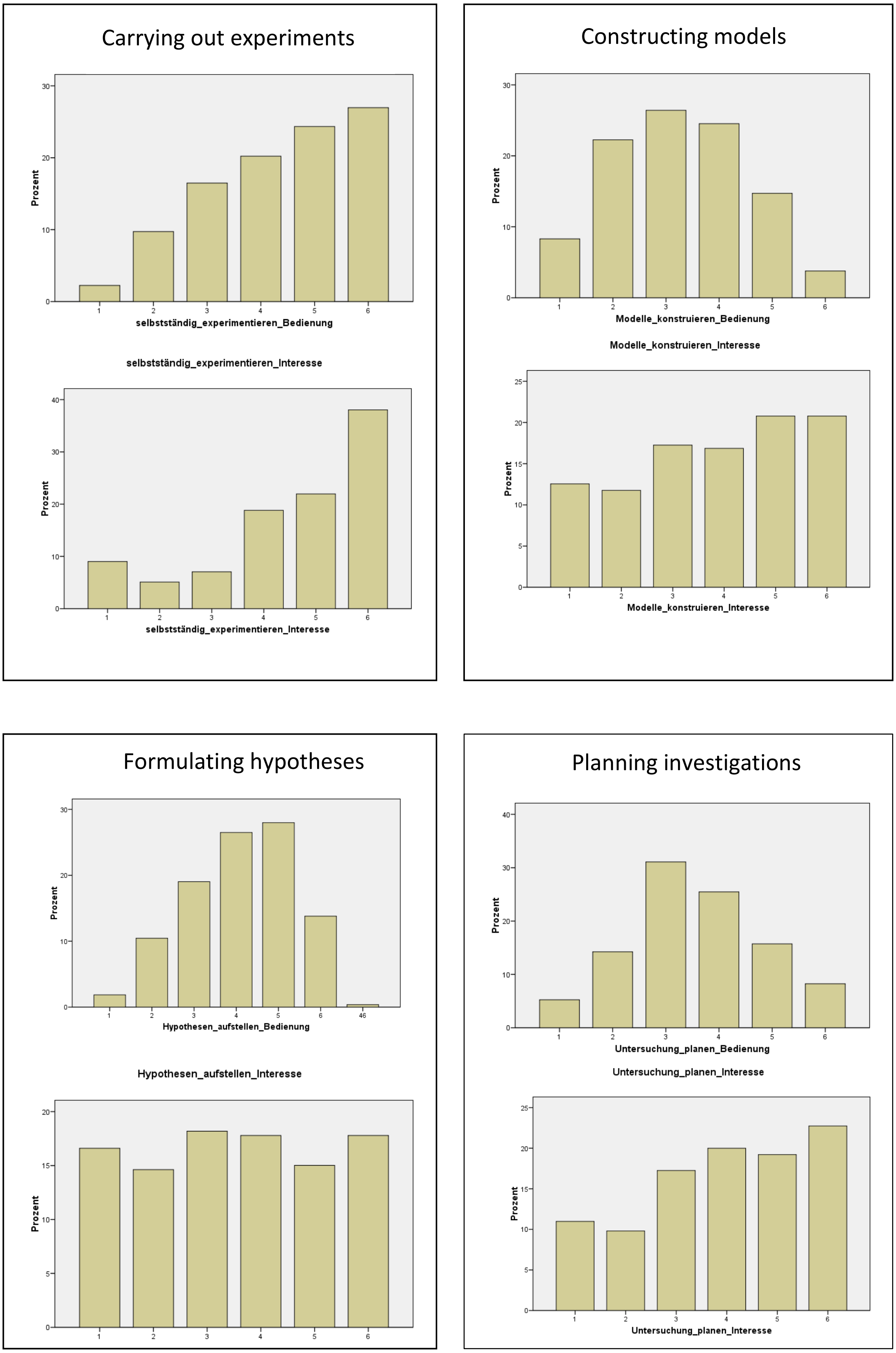


Figure 2: Mean values for self-estimated experiences and interests regarding IBSE-activities (mark toward the end of the axis means high use/interest,mark toward center means low use/interest)



Figures 3a-d: Distribution of answers for four exemplary areas (for each area: top graph shows how regularly this aspect is used in the classroom; bottom graph shows interest in teacher training for this area; 1 being least used/interested in, and 6 being most used/interested in)

A second radar was used to investigate those teachers' interests in authentic research (figure 4).

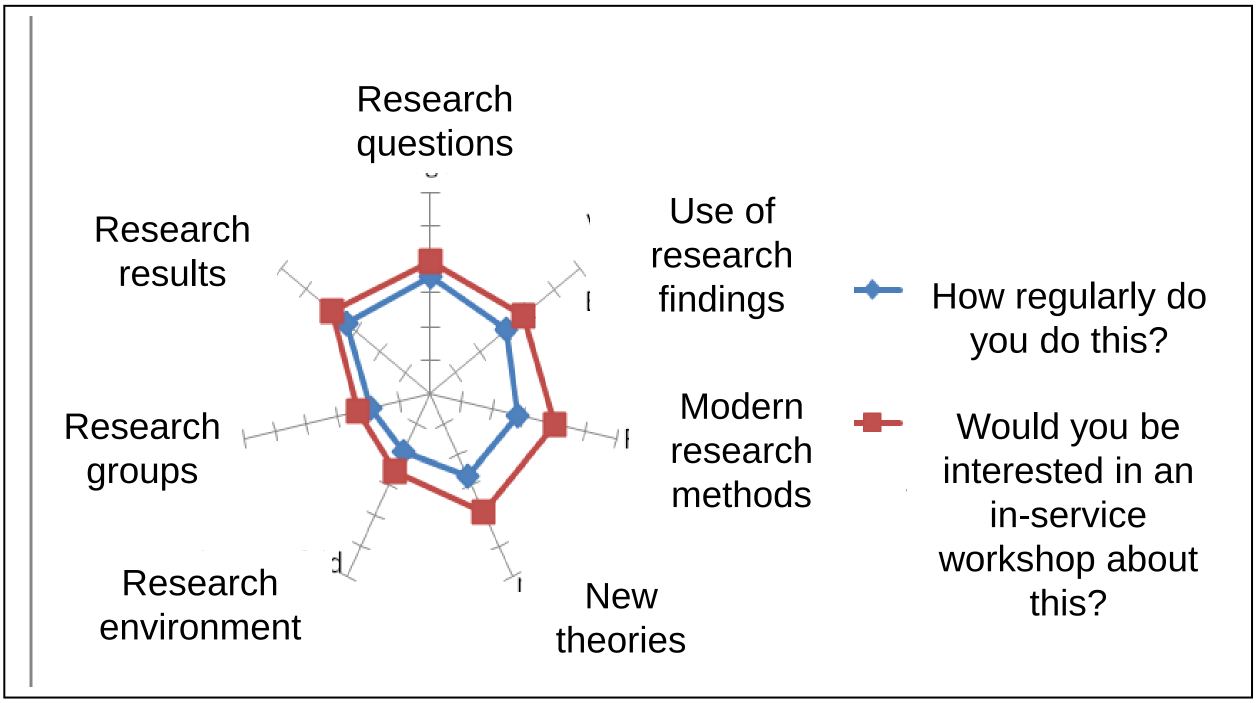


Figure 4: Teachers' use of and interests in teaching and learning about authentic research

The levels are lower in comparison to the use of and interest in IBSE teaching methods, but still around average. Only regarding the researchers' environments and groups we have to state a low interest on the side of the teachers. This is somehow understandable for two reasons: on the one hand, these aspects are difficult to teach and on the other hand those criteria might also influence students' choices of their fields of study and profession.

Apart from the IBSE aspects, the instrument was also used to assess teachers' use of and interest in teacher training opportunities for selected interdisciplinary topics, teaching approaches and teaching methods as well as forms of cooperation with other teachers and teaching institutions. Many short Likert-style questions could be administered through this instrument as it presents a somewhat intuitive visualization and might generate more of a willingness to fill in questionnaires without having to read too much text and without having the same table-based design. This flexibility makes it a quite useful instrument for assessing various different things. The instrument could also be used in obtaining beliefs and ideas of pre-service teachers and might even be used in school to offer insights into students' perspectives, thus providing an opportunity to compare a teachers' impression of his own teaching methods to what the students in his class perceive.

Overview of Pre-Service Teacher Training Opportunities:

a. **Number of student teachers:** 25-15

b. **Number of hours:** IBSE is implemented in different modules, but there is no course on IBSE only. Therefore, it is hard to say how many hours / workshops we spent. Hence, the total number of credits is given.
   - Module 1 (2.5 credits): Introduction into chemistry education: scientific methods and approaches, (students' interests and beliefs about science, curricular perspectives and syllabi)
   - Module 2 (5 credits): School experiments I: ESTABLISH day
   - Module 3 (3 credits): Approaches in chemistry education: IBSE as one major approach in Germany
   - Module 4 (10 credits): School experiments II: reflect experiments based on IBSE approach
   - Module 5 (3 credits): Tasks and assessment: alternative methods, e.g. for assessment of IBSE aspects
   - Module 6 (2 credits): Research in science education (free choice of topic)
   - Module 7 (2 credits): Extra-curricular activities: e.g. student labs

c. **Implemented core elements of IBSE:**
   Implemented aspects of the modules in School Chemistry I as an example:
   - Choice of experiments to try out and discuss in the workshop (in German)
     - "Holes": Isolation of SAP and cyclodextrines, investigating properties of SAP and Cyclodextrines, developing and applying models to explain structure-property-relations
     - "Chitosan": Isolation of Chitosan, investigating properties of Chitosan to absorb fats, developing and applying models to explain structure-property-relations
     - "Care": investigating properties of different fibres, developing and applying models to explain structure-property-relations

d. **Implemented core elements:**
   - Steps / elements of Inquiry
   - ICK: Frames of inquiry in research and industrial production
   - Teacher as Implementer (relation to curriculum, co-operation between school subjects)
   - Teacher as Developer (approaches and own development of units in M.Ed. courses)
   - ICT (currently not included)
   - Argumentation (currently not explicitly highlighted)
   - Assessment (own module)

e. **Units that have been used:** "Holes", "Chitosan", "Care"; and well implemented approaches in textbooks or teaching material (e.g. burning of a candle, the "copper letter", the carbon cycle, and many more)

f. **Short description of each workshop:**
   - <u>Module 1: Introductory chemistry education</u> (Bachelor): two sessions for introduction of methods in science (experiments and models, "Nature of Science"), related to the German Science standards

- Module 2: School experiments I (Bachelor): one session on ESTABLISH approach, units and experiments from "Holes", "Chitosan" and "care", "Polymers", comparison of research and industry, ck-background as preparation material (**see further description below**)
- Module 3: Approaches for chemistry education (Master): one session presenting and discussing the approach "forschend-entwickelndes Unterrichtsverfahren" in comparison to IBL and IBSE frameworks; two sessions on exemplary topics implemented in German classrooms; 2-4 of sessions of preparing and presenting own designs of lesson plans for inquiry based learning, context based learning and history based learning (group work)
- Module 4: School experiments II: currently in preparation
- Module 5: Tasks and assessment: different methods of assessment for different competencies, schemes for levels of achievement (e.g. levels of complexity, Bloom)
- Module 6: Task design and assessment: different formats for different (IBSE-) competencies
- Module 7: Methods or extra-curricular learning (Master): free choice of follow-up modules, e.g. designing and trialing IBL in out-of-school learning environments or developing material for student oriented methods for an exemplary IBL module

g. Distributed material

- Summary of IBSE / IBL frameworks (from ESTABLISH and German ones), overview about 5E, IBL steps and comparison of research oriented and industry / production oriented Inquiry
- Sets of experiments
- Articles on exemplary units in German
- Material produced by the students

h. Evaluation

- Profiling questionnaires at the beginning of one term (not all cohorts)
- Analysis of group discussions with leading questions according to use of IBL steps in planning an own investigation, the differentiation between research and industry oriented inquiry and the discussion of given experiments (Master Thesis Kirsten Fischmann, **see further description below**)
- Oral feedback discussion at the end of each module

Detailed Description of Evaluation Pre-Service Teacher Training:

Pre-service student teachers' perception and application of research- and industry-related IBSE (in Module: School Experiments I)

A second study, this time a case-study, was carried out by Kirsten Fischmann (Master Thesis) and Stefanie Herzog (PhD student). The aim was to investigate pre-service student teachers' perception of IBSE and their actual use of IBSE knowledge when working with their own investigation and planning activities for students.

The chosen cohort of 16 students had been in their final Bachelor year. The investigation was carried out as part of a module on school experiments. The students worked with IBSE-ESTABLISH-materials for about four hours, structured as shown in figure 5. After filling in the ESTABLISH pre-questionnaires, the students were introduced to the project ESTABLISH and to IBSE (in German “forschendes Lernen”). Divided into smaller groups, they were then given different topics.

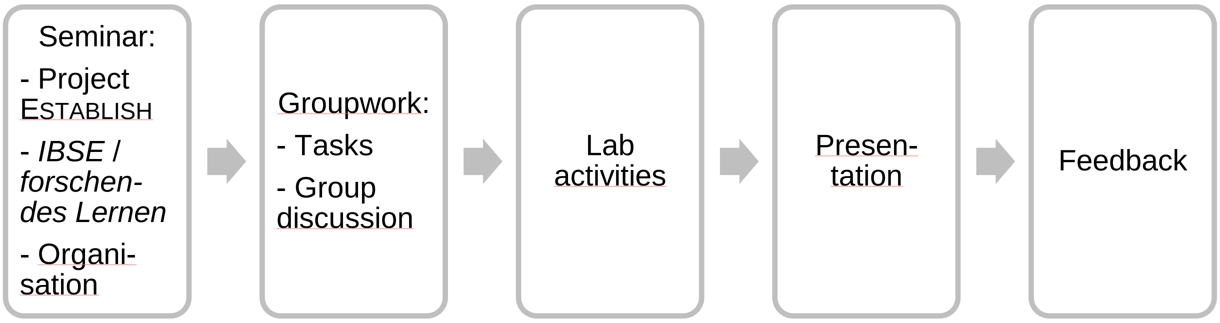


Figure 5: Case study accompanying an ESTABLISH project as part of the Module: School Experiments I

The chosen topic areas belong to the ESTABLISH-units “Holes”, “Chitosan” and “Care”. The students were provided with written information focusing on the content knowledge regarding their topics. For the following discussions within the small groups, each group was presented with several tasks that were supposed to guide the discussion.

The tasks of the group work were equivalent to the following, here exemplified for the SAP-group:

1. Think about how SAP can be used in everyday life and in which areas knowledge about SAP can be used. **Explain how SAP works.**

2. **Develop an experiment** with which students can find out which properties SAP exhibits and which investigations can provide clues for helping to explain structure-property-relations.

3. **How could you proceed in order to find out** in what way SAP can be used in products and where there might be a **need to develop those products further**?

4. **Please assign the experiments of the lab activities to the different processes (science/industry)**.

Note: the color coding in the tasks, as well as in the IBSE aspects and the short description of the results refers to the different competency areas that are described in the German chemistry curriculum for secondary education, which is something the students in this Module are familiar with: **applying chemical content knowledge**, **using scientific methods to gain knowledge, communicating within and about chemistry,** **(critical) reflection of aspects related to chemistry**.

The discussions within each group were audiotaped and were later analyzed according to the Qualitative Content Analysis of MAYRING. The IBSE aspects proposed by Linn et al., 2004, and used in the ESTABLISH project were taken as categories to analyze students' statements from the discussions (for color coding, see description above):

(1) diagnosing problems

(2) critiquing experiments

(3) distinguishing alternatives

(4) planning investigations

(5) researching conjectures

(6) searching for information

(7) constructing models

(8) debating with peers

(9) forming coherent arguments

After this discussion, each group went into the lab and had the chance to try out their ideas as well as some of the ESTABLISH materials from the relating units. At the end of the 5-hour session, they presented their findings to the rest of the cohort and filled in the post-questionnaires.

The following table gives examples of the quotes the students had given during their planning discussion and the corresponding IBSE aspects.

Table 1: Exemplary student quotes and reference to IBSE aspects

Quote (translated)	IBSE aspect
… but it is for textiles, so that you spray it onto textiles and then the smell is to be enclosed. To me that means that the smell molecules or the smell substances are usually hydrophobic substances that are enclosed in the middle, and either the smelling substance cannot evaporate or sublimate or something anymore because it is now enclosed in the middle of the ring or something like that …	**diagnosing problems**
Ok, it is definitely the case that it deacetylizes, that this here is removed by acid, or acetate is removed and is no longer present, except for this one. ….	**Using models – here solely regarding content!**
… we could fill them with water to see how much they absorb… *… press it and shake it…* *… the quantity of SAP to the quantity of water in mol …* *… if there are differences if you use salt, or I don´t know, ethanol or methanol* *… substances that change the properties?*	**Discussing of alternatives**

All aspects of IBSE could be found but on very different levels of quantity and quality. In conclusion, the results can be summarized like that:

- There were large differences between the groups, but there was no indication that groups with certain topics were better than groups with other topic (of content-specificity).
- In each task, there was a strong focus on some IBSE aspects, which could be found in the students' discussions as well.

Table 2: Comparison of expected and realized references of students' discussions

Students were asked to…	Underlying competency: Students were expected to…	IBSE aspects addressed most often in discussion; Students were actually…
…explain the function of the given substance (Task 1)	**…apply their chemical knowledge** and **…communicate within and about chemistry**	***diagnosing*** *problems*, ***constructing models*** and ***searching for information***
…develop experiments to investigate the substance's properties and to show structure-property-relations (Task 2)	**…use scientific methods to gain knowledge**	***planning investigations*** and ***critiquing experiments***, and ***distinguishing alternatives***
…discuss the usage of the substance as a product and think about further industrial developments (Task 3)	**…communicate within and about chemistry**, and …give a **(critical) reflection of aspects related to chemistry**	***searching for information***

- Regarding Task 4, asking the students to assign the experiments to the design or industrial process, most groups did not give clear arguments and criteria for assigning their experiments to either process.

From this case study regarding pre-service teachers' perception and application of research- and industry-related IBSE, it can be concluded that pre-service teachers know many of the IBSE aspects applied in the ESTABLISH project and use them when discussing their own investigations. The usage of those IBSE aspects does not appear to be content-specific. Students seem to find it difficult to differentiate between the research and design process and do not use argumentation in that context. Therefore, further investigations and specific training regarding industrial content knowledge and argumentation seems

Overall Conclusions

For our in-service teachers, the time frame used for the workshops seemed to work well. As they were fairly familiar with IBL, they appeared to appreciate the focus on trying out and discussing materials as well as a potential connection to every-day products and industrial design. Our pre-service teachers were interested in IBL as part of the different modules and reported that they had come to understand that IBL was more than letting the children perform experiments by themselves. As the idea of ESTABLISH and IBSE can be considered as a kind of continuation of previous IPN-projects (SINUS & context-projects) and as it has been incorporated in and linked to existing IPN-projects (state-wide in-service teacher training program and "Collaborative Research Center - Function by Switching" as well as development of own units on Energy, Survival in the cold, Cotton on my skin, Flying through the air, or Functional materials for example) both in regard to materials and teacher training opportunities, the project is likely to have a sustainable effect. Furthermore, the idea of IBL is taken up again in the ASSIST-ME-project, another EU-project in which IPN is involved in, which will investigate the assessment methods for inquiry in science education.

Case Study 5: Germany

Model and description of IBSE in MINT pre- and in- service teacher training

Martin Lindner, Stephan Domschke,. Martin-Luther-University (MLU) Halle-Wittenberg

Abstract

In the following sections, a short overview of in-service and pre-service teacher training opportunities provided by the Martin-Luther-University (MLU) Halle-Wittenberg in the federal state of Sachsen-Anhalt are described along with an exemplary pre-service teacher training unit to give an insight into the realization of those training opportunities in MINT-education (**MINT** is short for **M**athematics, **I**nformation science, **N**atural science and **T**echnology). Firstly, IBL (in German: forschendes Lernen) is already quite common in science education in Germany, and as the majority of teachers asks for student material in an in-service teacher training workshop, we did not split up the workshops into theoretical background, modules etc.; but included the different steps into each workshop. Evaluating the workshops is hard, because most of the teachers are weary of filling in questionnaires and therefore oral feedback rounds was chosen to be run at the end of the workshops and an online questionnaire was send to participants afterwards. As the pre-service teacher training, curriculum at the Martin-Luther-University Halle-Wittenberg had been set and accredited; therefore elements of IBL are implemented in different existing modules of biology education.

Introduction

Both in-service and pre-service teacher training opportunities are incorporated into STEM-education or MINT-education. **MINT** is short for **M**athematics, **I**nformation science, **N**atural science and **T**echnology.

The program aims at achieving a change in general teaching structures in scientific school- subjects which includes the promotion of those subjects in the school curriculum as well as an enhancement of general motivation for these subjects among school children.

As a close connection of school topics to the experience of day-to-day life of the children is known to be a crucial element of motivation, STEM is meant to improve this connection and enhance the children's natural interest in the different fields of the STEM-subjects.

Therefore, interdisciplinary teaching is a central element of STEM, as well as the development of settings for first-hand experience for the pupils in school, such as experiments concerning weather phenomena or the human senses. Objects from the children's day-to-day life are presented and used to explain basic technical or biological systems that lead to an increasing understanding of complex systems of life in general.

Some examples of useful topics inside the different school-subjects shall be listed here:

<u>Mathematics</u>

Football, the painting of walls or cooking can't be managed without math. Working on these topics supports the development of a structured way of solving complex problems, closely connected to day-to-day life experience.

Information science:

Modern society presents masses of different technical devices in a rapid technical progression which makes it important for young people to find a sovereign way of understanding, selecting and managing the wide range of offers.

Natural sciences:

They contain the school subjects Biology, Physics and Chemistry. The understanding of the solar system and, for example, gravity are main topics of STEM Physics-lessons. Pharmacology and the processing of food both need chemical knowledge and with the help of Biology the children are led to the basic structures of living systems, particularly in the fields of medicine and agriculture.

Technology:

Here, children discover the principle of the practical realization of Natural science, mainly the production of all sorts of machines for day-to-day life.

Why study STEM? Why teach the STEM-program?

Since Math, Information science, Natural science and Technology are of great importance for the society of highly developed countries and because qualified personnel is rare, it is important to support these fields of research and production and focus attention on the relevant subjects in schools. The German government and economy have given active support to STEM since 2008 in order to manage the expected lack of qualified personnel in the future. A major aim of the initiative is to build up school education in these subjects as well as to improve its quality.

Overview of In-Service Teacher Training Opportunities

I. Introductory Workshop at national Teacher Conference
   a. Number of Teachers: 20
   b. Time: 1h
   c. Content:
      Core element 1 IBSE (main part)
      Core element 2 ICK (discussed after group work)
      Core element 3 Implementation (exemplary video)
      Add. element 5 ICT (demonstrated)
      Add. element 7 Projects (not necessary)
      Add. element 8 Assessment (discussed after audience question)
   d. Description:
      Introductory PPT-presentation: ESTABLISH framework and phases of IBL, connections to the German educational standards and curriculum topics, overview about units and levels (from macroscopic observations to differentiated model-based explanations), overview about phases of units, exemplary presentation of one unit with connection to industry (Unit 2 Disability), group work to chosen questions of unit activities, end discussion with video of implementation in partner school
   e. Units and activities: Unit 2 Disability, Activities 1, 5, 6, 7

f. Resources: PPT, video of implementation made by pre-service teachers, models of muscles and bones, ICT Kit to measure the nerve conduction
g. Industrial links: Presented and discussed during presentation, examples of possible industry partners collected
h. Evaluation: Oral feedback at the end

II. Teacher Training at local partner school
   a. Number of Teachers: 4
   b. Time: 4h
   c. Content:
      Core element 1 IBSE (main part)
      Core element 2 ICK (possible links discussed)
      Core element 3 Implementation (asked for new subject)
   d. Description:
      We were invited by the school, to have a talk about “new” approaches in science education. Over a year, several meetings with different content were held. One part of the round table discussions has been IBSE and the ESTABLISH Project. The participating teachers were very interested in it, so in cooperation with MLU they started piloting projects with IBSE content in preparation for the implementation of a new STEM subject with pure IBSE.
   e. Units and activities: ESTABLISH Units Sound, Holes, Disability and Renewable Energy
   f. Resources: PPT
   g. Industrial links: Presented and discussed during presentation, examples of possible industry partners collected
   h. Teachers implementation: piloting of unit 2 “Disability” and unit 10 “Renewable Energy” together with pre-service teachers; increase of IBSE in classroom; integration of new electable subject “STEM” including 100% IBSE
   i. Evaluation: round table discussions, regular meetings, video study of IBSE classroom

III. Participation of In-service Teachers at ESTABLISH Teacher Conference
   a. Number of Teachers: 15
   b. Time: 3d, 6-8h each day
   c. Description:
      We invited all participants of the past teacher trainings to the ESTABLISH Teacher Conference in Dublin. Our intention was that they can get a different insight into international approaches of IBSE and education research and that future cooperation is possible as it is now.
   d. Industrial links: Industry visits organized by conference committee
   e. Teachers implementation: increase of IBSE in classroom
   f. Evaluation: Online Teacher profiling with ITQ

Conclusion of in-service teacher training opportunities:

Explicitly addressing Element 7 “Projects” was not necessary, as all workshops were project-oriented anyway. Teachers liked working with the materials and engaged in fruitful discussions. The time frames used for the workshops was also considered favorably, with a shorter length for workshops when the teachers had to travel to the location and longer training sessions for those workshops provided at the teachers’ own school.

Overview of Pre-service teacher training opportunities

a. Number of student teachers: about 200

b. Modules including IBSE:
   - Module 1 (5 credits): lecture and seminar about general didactic of biology (2+2h/week); 2nd academic year
   - Module 2 (5 credits): lab course (2h/week) & school internship (2h of teaching, 12h classroom observation); 3rd academic year
   - Module 3 (5 credits): project course (4h/week); 4th academic year

c. Short description of implementation of IBSE in modules
   - Module 1:

     Normally the lecture is structured in three parts: short introduction into topic and content (15min), self-work of teacher students at given classroom materials (60min) and final discussion with summary (15min). IBSE is implemented in the meetings about constructivism and German science standards.

     The seminar meetings are given by teams of three teacher students. They have to choose and prepare a topic. The presentations shall include 80% student activities. IBSE is implemented as own topic. This presentation includes exemplary ways to implement, develop and assess IBSE in biology classroom.
   - Module 2:

     Lab course

     In the beginning the lab course design is guided inquiry, so that the teacher students get familiar with the lab and the techniques. Step-by-step the level of inquiry increases. The last two meetings in semester are open inquiry. The teacher students have to propose and pursue their own research question(s) and experimental design within a given biology context.

     School internship

     During the school internship the teacher students are encouraged to use IBSE as often as possible. **See description of an exemplary practical pre-service teacher training opportunity below**.
   - Module 3:

     In the project course the teacher students have to prepare, conduct and evaluate own projects within a given context (mostly biology education research). All projects shall include practical tasks and cooperation between different stakeholders. The development process themselves is inquiry and following the German science standards also the learning activities shall include IBSE.

d. Implemented core elements:
   - Steps / elements of Inquiry (focus in Module 1)

- ICK (Frames of inquiry in research and industrial production)
- Teacher as Implementer (relation to curriculum, co-operation between school subjects, focus in Module 2)
- Teacher as Developer (approaches and own development of units in M.Ed. courses, focus in Module 3)
- ICT (small amount in lab course, part of some projects in Module 3)
- Argumentation (explicitly highlighted in Module 3 and internships)
- Assessment (included in all modules)

e. Used ESTABLISH Units/activities

The units “Disability” and “Renewable Energy” have been profiled within projects of module 3. The teacher students choose exemplary activities of ESTABLISH units as they prepare their presentations and projects (e.g. Holes, Blood Donation, Forensic Science, Eco Biology).

f. Distributed material

- Summary of IBSE / IBL frameworks (from ESTABLISH and German ones), overview about 5E, IBL steps and comparison of research oriented and industry / production oriented Inquiry
- ESTABLISH Units (English, the draft versions were not digital)
- Sets of experiments
- Articles on exemplary units in German
- Material produced by the students

g. Evaluation: Online profiling questionnaires & Oral feedback discussion at the end of each module

Description of an exemplary practical pre-service teacher training opportunity at the Martin – Luther – University of Halle

Figure 1 *Pre-service teachers work together with primary pupils on STEM questions.*

The project (description provided by participating pre-service teachers):

As part of a practical pre-service teacher training unit in Biology at the MLU Halle, six of us (i.e. pre-service teacher students) realized a so-called 'STEM-project' (MINT-Project) at a primary school in Sachsen-Anhalt.

At the Protestant "Martin Luther" primary school in Oppin, pupils have the opportunity to study in small and familiar teams and develop their personality individually. Basic Christian values as well as a balanced combination of traditional and modern approaches characterize the school-concept which supports the children in their individual needs and social development. The after-school care program provides music classes, sports activities and science projects for mixed age-groups.

The STEM - project was offered as a weekly one-hour class in this after-school program and participation on the side of the pupils was voluntary. Therefore the number of members of the group varied from session to session (minimum 6 pupils, maximum 10 pupils). Still, the main group stayed the same mostly, so that the tasks and units could be planned according to the needs and skills of those regular participants.

This setting allowed us to work under ideal conditions, both pedagogically and organizationally.

The course of the project/observations:

The main intention of the conductors of this STEM - project was to introduce phenomena in Natural science, their functioning, the methods of scientific research and their relevance in day-to-day life and technology. As this was a project on primary school – level, the necessary didactic reduction of the material appeared to be a big challenge for us, especially as the pupils were meant to work practically and as independently as possible. It was equally important to prevent the pupils from being bored and from expecting too much of them.

Therefore the choice of topics that were dealt with in more detail followed this list of main aspects of relevance:

- social relevance
- the pupils' day-to-day life experience
- potential application/use
- reference to environmental protection, technology, medicine and reference to the human body
- technical devices in households, medical practice, hospitals

All topics were interdisciplinary STEM - topics as well.

It appeared to be quite a big challenge for us to tackle topics we hadn't been familiar with before. Especially in the fields of Math, Information science and Technology a particularly intense preparation was necessary. Good team- work as well as the extra physical knowledge of one of the members were very helpful here and showed that team-work among colleagues of different subjects is very important for future school-teaching as well. The general interdisciplinary teaching concept is supported by the following arguments:

- Most real and relevant problems concern more than one subject
- The reference to the pupils' day-to-day life experience increases with interdisciplinary teaching (topics)
- The reference to the pupils' living reality increases

- It is never wrong to introduce interdisciplinary perspectives
- The relevance of the different Natural sciences is shown
- A more complete understanding is supported

Throughout the project, we observed that the pupils were willing to learn and understand; they were enthusiastic and prepared to approach something new. Often the pupils knew more about certain topics than we had assumed and it was easily possible to approach material on a higher level than their actual curriculum class level.

List of introduced topics:

- The human senses
- Optics and the human eye
- Sound and the sense of hearing
- Food and nutrition
- Kinematic mechaniques
- Electrostatics, electromagnetism, electric motor
- Water and its characteristics
- Weather and climate
- Air and its characteristics

The first topic "The human senses" shows the aspects listed above very clearly: obviously there is a strong reference to day-to-day life, it contains aspects that are relevant to the pupils' future professional life and the technical surrounding of day-to-day life. Moreover it serves as a very good example for an interdisciplinary topic.

The sense of taste for example can only be explained sufficiently with the knowledge of biochemical mechanisms. The explanation of the human eye and visual sense logically leads to topics like refraction and anatomy.

In connection with the olfactory sense pupils will easily learn about diffusion and the connection between the olfactory sense and the sense of taste.

The sense of hearing is yet another example of a phenomenon that can't be understood entirely from only the biological perspective but needs additional information from Physics such as answers to the questions "What is air at all? And what is sound in itself?". Basics about sound and sound conduction have to be introduced here after the necessary didactic reduction. There is also the possibility of referring to processing of signals in the brain by self-experiments about directional hearing, which will lead to the question of "Why do vertebrates have two ears?".

The sense of touch can be explained through the introduction of basic sensory physiology. Here the pupils discover for example that there is no absolute scale for their sensation of different temperature or that receptor cells are distributed in varying amount in the various parts of the body.

Apart from the interdisciplinary aspect, the aspect of the pupils' active part and first-hand experience was an obligatory aspect within our planning of the units. Experiments that the pupils could carry out themselves served as means of knowledge acquisition on the one hand and as a way of learning about research methods on the other hand.

The methodical approach used in the project sessions varied over the course of the semester according to the needs and skills of the pupils.

At first, lessons were started with a 30-minute theoretical input. Finding the appropriate level for 2nd to 4th graders wasn't easy, as most of us had worked only with higher grades until then and found it difficult to predict the young children's level of pre-knowledge and pre-conceptions in order to plan a successful unit.

The subject was introduced through videos, CDs, talk or short experiments demonstrated in front of the class. Sometimes models were used to present the most important information for the subject and the "memory game" served as a warming-up exercise. Despite the various helpful methods it became obvious that the introduction was too long and the children weren't able to concentrate any longer at the end of the 30 minutes – period.

The following phase was then used to go into the subject further by means of working at different so-called stations where the pupils worked in two groups which they put together themselves. Each group was guided along all stations by one of us who explained and helped them at each station.

That way it happened that us pre-service teachers were still talking and "teaching" too much instead of allowing the children to work by themselves. We realized how difficult it is, indeed, to get away from the traditional frontal teaching. Consequently procedures were changed to a more independent way of working for pupils, by handing out worksheets that they were able to tackle themselves or helping each other and that they could take home as a sort of research result paper.

The 30-minute theoretical introduction was also changed and was made into a much shorter 5-10 minutes impulse-phase.

In order to make the children work more actively and independently, the phase at the stations was altered a second time: the children were now put into more than two groups and one group was to work thoroughly on one station with the help of guiding instructions on paper.

At this point we realized how important it is to provide clear and simple instructions for the children that are even repeated because unclear instructions lead to a lot of speculations and a resulting commotion among the kids.

After one hour of working at their station the groups walked from station to station. Each station was presented and explained by the respective 'experts' themselves, with us adults just monitoring the progress.

This wasn't too easy on both sides as the pupils tended to start working and experimenting at the stations without even reading the instructions or listening to explanations. At the same time we as the conductors had to be careful not to answer the questions all by ourselves but remind the kids to read the instructions. In that sense the STEM - project turned out to be a true bilateral learning process.

After visiting the other stations one after the other the pupils had 20 minutes left to work at stations they had found most interesting. This procedure became a well- accepted and well- working routine which led to an increasingly active and independent way of discovering and learning among the children.

The girls developed a systematic and concentrated approach to new tasks and topics whereas the boys had a tendency to jump at the experiments and use different materials immediately and got to read instructions and tasks only later or only partly, which had a rather playful character.

Throughout the course of the project this observation led to the question of how to put together the groups of pupils. Finally it was clear that it was necessary to help them make homogenous groups in which every member got a fair chance to work individually and actively on the tasks.

The age - difference didn't seem to be relevant here as the children didn't show much difference in knowledge about the presented topics.

It should be pointed out that both sexes showed the same great interest in the presented topics. On the whole there were as much boys in the project as girls, groups with more boys were observed to be slightly more restless.

Each session was followed by a short feedback phase that had to be reorganized several times as well. Single questions such as "How did you like it today?" were rarely answered at all. The opportunities to suggest other topics, give comments or criticize weren't taken either by the kids. Finally, the use of a „Mim-dice" was rather successful: these dice show different mimics, sorts of smileys, on the different sides of the dice and the children can turn up the one that expresses their feeling or thoughts best. The sides used most were smiling smileys or amazed looking smileys.

One of our overall conclusions of this project is that STEM –project teaching needs to be based on the teacher's experience and on an effective assessment of the individual class/group. Every new group of children asks for different methods and topics which makes STEM a project that asks a lot of creativity and commitment from the teacher.

In addition to that the right choice of material, and the precise planning of how much and what can be provided at a given time forms another important element of successful teaching in STEM. That includes the production of worksheets, which should be both informative and motivating, the use of different media in the short presentation phase in the beginning of each session as well as huge variety of objects like food (sense of taste), models, videos and machines that should be worked on during the station work.

Conclusions from participating teachers:

Our concluding observation is that each of the sessions in this practical teaching exercise asked for a great effort concerning preparation of worksheets, basic research in the different subjects and the practical test runs of the experiments. Team work among us participating students, team teaching at school and skilled feedback in discussions and preparing meetings made the effort manageable.

In view of the fact that the in-service teaching job will ask the same skills and effort from us, this STEM-project was a very valuable experience for all of us. It became very obvious to us that interdisciplinary cooperation and team-work have to be the crucial elements of a modern pupil-orientated teaching system.

Case Study 6: Poland

Inquiry and assessment in pre-service chemistry teacher education

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Abstract

Aspects of IBSE were introduced at the Jagiellonski Uniwersytet in Poland to the regular pre-service teacher training for the students of Chemistry and Environmental Protection study programmes. It was achieved in several forms and stages: a lecture, laboratory classes, 2 x seminars. Besides the lecture, eight-person groups attended each class which lasted 125 minutes. A particular focus of one of the seminars was devoted to the methods of assessing inquiry skills and this aspect of the workshops will be discussed.

Introduction

Many years of our experience on conducting courses for students (pre-service teachers) and their internships at schools show that assessing pupils is the most difficult task for them. In addition, assessing the inquiry skills is also a novelty for teachers, so students did not have the opportunity to see in practice how it should be done. Therefore a particular focus of this IBSE implementation was devoted to the methods of assessing inquiry skills and this aspect of the programme will be presented;

Teaching materials used during classes:

1. General Education Core Curriculum introduced in Poland in 2009 – in order to indicate that the inquiry skills are going to be evaluated in the final exams (at the end of lower secondary and upper-secondary school), even though it will be only in the form of a multiple choice tests [1]
2. Questions from the mock lower secondary school leaving examination from biology concerning the standardization of measurement conditions [2] and final upper-secondary school examination starting from "Plan an experiment, in which…"[3]
3. A chapter from the first volume of the handbook for teachers prepared within the ESTABLISH project entitled "Forming research attitudes and inquiry skills among students in the new core curriculum" as an additional material to read and think about [4]
4. A chapter from the second volume of the handbook for teachers prepared within the ESTABLISH project entitled "Scientific inquiry in multiple choice tests", containing exemplary exercises developed by the Educational Research Institute [5]
5. Exercises from the teacher's exercise book [6]

Plan of the class:

1. The experience of students with the process of pupil's assessment was discussed with them, for example from the time when they had been pupils themselves and from the time of their practices/internship in schools being part of their preparation for being a teacher.

In general, it could be said that students had been so far familiar with the assessment of knowledge and skills only in the form of written test and asking questions by the teacher, and also a bit with the self-assessment (carried out in a very general way "What mark will you give yourself for the results of the work of yours and your group?") and peer-assessment ("What did you like and what did you not like in the presentations given by your colleagues?") in the group projects in lower secondary school.

In Poland, the assessment of the laboratory work of students has been not recommended yet, as well as using rubrics in order to evaluate pupils at the level of upper-secondary school education.

2. Mini-lecture, the example of exercise evaluating selected inquiry skills from the field of biology was selected. Biology was chosen as a case study as, in contrast to chemistry, in the general requirements for the 3rd educational stage from biology we read as follows:

„II. Knowledge of the methods of biological research
Student plans, performs and documents observations of simple scientific experiments, determines the conditions of the experiments, differentiates between the control and test sample, draws conclusions; carries out microscopic observations of fresh and fixed specimens.

And for the 4th educational stage – extended level

„III. Deepening the knowledge of the methodology of biological research
Student understands and applies the biological methodology; plans, carries out and documents observations of biological experiments; formulates research problems, hypotheses and verifies them through observations and experiments; determines the conditions of the experiments, differentiates between the control and test sample, draw conclusions from the observations and experiments carried out".

What were the issues that the attention of students was paid to?

Exercise presented to Pre-service Teachers

Year 2012 The mock lower secondary school leaving examination [4]

Information for exercise 1. and 2.

John decided to investigate whether germinating bean seeds respire. For this purpose, he prepared the experimental setup, the scheme of which is presented in the picture below

flask with limewater
germinating bean seeds
damp blotting paper

John left the setup at room temperature and after 48 hours carried out observations.

<u>Exercise 1.</u>

Two John's colleagues think that the experiment was planned improperly. They put their comments in the table below. Review the comments of John's colleagues. Choose Y (yes) if the remark is justified and N (no) - if not.

John should have also prepared a control setup with dry bean seeds Y/N

John should have repeated the experiment in order to make himself sure about the obtained results Y/N.

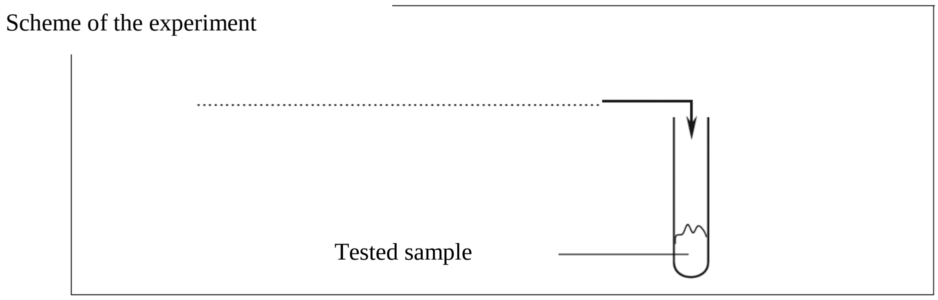
3. Discussing with students the exercise from the final upper-secondary school examination from Chemistry

Year 2011 Basic level - Exercise 33. *(2 points)*

Proteins are the basic building blocks of all organisms, they are components of natural fibres of animal origin, such as wool and natural silk. In the test tube, there is a white sample of natural silk. <u>Design an experiment which</u> will confirm the presence of protein in the sample.

a) Complete the scheme of the experiment with the name of reagent selected from the list below:

- an aqueous solution of potassium manganate(VII)
- concentrated nitric acid (V)
- bromine water



Students agreed, that exercises from the final upper secondary school examination from Chemistry despite the promising commands “plan” or “design”, actually require reproduction of the description of already known from the Chemistry lessons or textbooks experiments of a type “to reagent A add reagent B (or the indicator paper) and observe the changes (e.g. colour, temperature, precipitation, gas evolution, dissolution)”.

4. Work in pairs

Students divided into pairs got two tasks to do on the basis of the exercises received for analysis (7 exercises for choosing):

i. Decide which inquiry skills are examined in this exercises?
ii. Modify the task below in a way that it will examine the students’ inquiry skills instead of the knowledge.

Examples of the exercises received for analysis:

I. Select the correct formulation of hypothesis for the research problem in the experiment illustrated in the picture:

a) study of the process of photosynthesis in light and darkness
b) photosynthesis occurs in light and in darkness the process stops
c) an experiment with a glowing splint confirmed that in light plants give off oxygen that is a product of the process of photosynthesis
d) what is the impact of light on the process of photosynthesis

II. Assign stages of experiment listed in random order (1-6) to the successive steps of the biological experiment carried out by Jack (A-F). Put X in the correct places in the table.

Jack's experiment:

a) Jack noticed the growth of mold on moist bread
b) He wondered whether the moisture content in bread influenced the growth of mold
c) He supposes that the growth of molds is correlated with the substrate moisture
d) In order to verify this hypothesis, Jack prepared several pieces of moist bread and put them under conditions that are optimal for the growth of mold
e) Under the same conditions he put pieces of dry bread
f) The growth of mold on moist bread confirmed the Jack's hypothesis: molds grow on the moist substrate

Stages of experiment	Stages of Jack's experiment					
	a	b	c	d	e	f
Statement of the research problem						
Formulation of hypotheses						
Formulation of conclusions						
Carrying out observations						
Preparation of a control sample						
Preparation of the test sample						

III. Students planned the experiment which proved that yeast produces carbon dioxide during fermentation. They prepared the experimental setup (presented in the picture) and the control setup.

What was the difference in the control setup in comparison to the experimental one?

a) Limewater was replaced with the distilled water
b) The sucrose solution was replaced with the glucose solution
c) Yeast was not added to the solution of sugar
d) Lack of rubber stopper and tube with limewater

IV. Anne, Tom, Charles and Judy were examining the air composition. For this purpose, they sprinkled the wall of the test tube with iron shavings and put it into the beaker containing water as it is presented in the picture. After a few days, they noticed that iron was rusted and water was filling about 1/5 of the volume of the test tube.

Evaluate the correctness of the conclusions drawn by the students. Mark correct statements with 'C' and the wrong ones with 'W'.

a) Anne wrote: 1/5 of the air volume is constituted by oxygen that combined with iron.

b) Tom wrote: 1/5 of the air volume is constituted by carbon dioxide, which dissolved in water.
c) Charles stated that 1/5 of the air volume is constituted by nitrogen that reacted with iron.
d) Judy stated that 4/5 of the air volume is constituted by nitrogen and that is the reason of filling with water only 1/5 of the volume of the test tube.

Then, the students presented their answers to the above questions (Decide which inquiry skills are examined...” and “Modify the task...”) Since the same task was assigned to 2 groups, it was easier for students to evaluate their colleagues.

Analysis of students’ presentations revealed that these two tasks were very difficult for them. Even if in the analyzed task it was written “Choose the properly formulated hypothesis”, some groups of students answered that the exercise verifies the ability to perform the experiment, carry out observations and draw conclusions.

The students answers were also quite general, for example in the question “What was the difference between the control and test sample” they suggested “the ability to design experiment” or in the exercise “Choose the correct justification…” – “verifies the ability to draw conclusions”. Therefore, a discussion of the ways of assessing students with the whole group is of a great importance.

Conclusions and future implications

In the next edition of the course for the students the following additional materials will be used:

- materials available on the webpages of the Central Examination Board and Regional Examination Boards showing in what way the inquiry skills are going to be assessed on the final examinations.
- materials available in the electronic database of exercises developed by the Educational Research Institute
- materials developed within the FP7 SAILS project.

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Case Study 7: Cyprus

Sustainable model for IBSE in-service teacher education

Nicos Valanides, Frederick University, Cyprus

Abstract

In this description we briefly outline the structure of the program relating to in-service teachers and mainly to in-service chemistry teachers. This orientation is justified and based on three main reasons. The newly appointed teachers should necessarily have one-year pedagogical training, and this training necessarily taps on IBSE. The majority of pre-service teachers were involved and trained in IBSE aligned with the ESTABLISH approach. Nevertheless, only few of them have already entered the teaching stuff and remained unemployed, and any contribution to promoting systemic changes in teaching science, from this direction, is really minimal. Our attempts to involve physics, chemistry, and biology teachers in IBSE were exactly the same, but we would like to emphasize our strategies, activities and productive outcomes concerning the involvement of Chemistry teachers, as an exemplary case for involving other important stakeholders, in particular the Ministry of Education and Culture, in the ESTABLISH project and its IBSE orientation and other innovative elements as well.

Introduction

Cyprus is a very small country and the educational system is extremely centralized. Nevertheless, the inspectorate who supervises and controls any curriculum changes or new curriculum development and any other innovation heavily depends on teachers who are invited to work under the supervision of chemistry, physics, or biology supervisors for developing new curricula and/or classroom materials aligned with a new philosophy or orientation. The pre-service or in-service teachers are at least holders of a BA/BSc from a variety of foreign Universities, mainly from Greece, UK, USA, Germany, and other countries as well. This is clearly understandable, taking into consideration that the first University was recently established in Cyprus (1993), and, obviously, the first physics, chemistry, and biology graduates from the University of Cyprus are rather a minority among the in-service teachers. The wide variety of teachers' background is also undeniable, since they studied abroad and brought back to Cyprus a variety of experiences and innovative ideas from well developed educational systems, such as, USA, UK, and Germany. Knowing however that a lot of other teachers came from different European and/or other countries, no claim is made that all of them were equally trained or equipped. It was also evident from several national reports or from the results of several international reports that there were gaps in the teachers' pedagogical training education, since the majority of them have university degrees in physics, chemistry, and biology from the respective departments and no training to become teachers of the respective discipline. In reality, only few have been trained in pedagogy and students' ways of learning. Few years ago, the legal framework for appointing physics, chemistry, and biology teachers has changed and demands that no one can be appointed as teacher by having studied only the subject matter at any university. Those holding a BA/MSc or even a Master or a PHD in Physics, Chemistry, or Biology cannot be appointed as teachers unless they successfully complete a one-year pedagogical training, under the auspices of the Cyprus Ministry of Education and Culture. The prerequisite pedagogical training is offered in collaboration with the University of Cyprus and, recently, with other private Universities in Cyprus. Another important issue relates to the consensus of the Chemistry, physics and Biology Associations of teachers for implementing these and other changes, while the prerequisite pedagogical training was also a heavy demand coming from teachers' associations. Finally, we should also stress that there is a surplus of unemployed physics, chemistry and biology teachers, and only few of those pre-service teachers trained in IBSE aligned with ESTABLISH enter or will soon enter the teaching stall, since the number of students is progressively diminishing due to various factors affecting the Country (Cyprus), after the Turkish invasion in 1974 and its serious consequences on the Cyprus demographics that are still continuing.

Description of in-service training for Gymnasium Chemistry teachers

We initially sought and had the consensus of the Ministry of Education and Culture, who asked the respective inspectorate of Physics, Chemistry, and Biology to offer any kind of help, assistance and collaboration to the lead national ESTABLISH partner (N. Valanides), so that the objectives of the ESTABLISH could promoted.

We thus had specific and separate meetings with each inspectorate of Physics, Chemistry, and Biology. During these extensive meetings we explained and exemplified the objectives of the ESTABLISH project and we propose to each group to collaborate with us, and even take the initiative to promote theses ideas among in-service teachers and encourage them to voluntarily involved.

The Chemistry Inspectorate of the Ministry of Education and Culture enthusiastically embraced the objectives of ESTABLISH and we collaboratively started preparing materials for training chemistry teachers based on the ideas of ESTABLISH or its materials that we started localizing and transforming based on the needs of our national curriculum.

The ESTABLISH Cyprus Chemistry group organized in June 2011, in collaboration with the Chemistry inspectorate of the Ministry of Education and Culture, workshops for all the in-service Gymnasium Chemistry teachers (teaching seventh- eighth- and ninth-grade students).

The workshops were carried out in the four districts of Cyprus, in Nicosia, Limassol, Larnaca and Paphos. The workshops were based on the inquiry-based learning and teaching and covered the units "Invisible Holes and Mixtures / Separation of mixtures." The participants worked in groups and the cooperative method of teaching, named "working in stations," was followed. Different working stations were used, and the different groups of teachers were rotating from one station to the other.

Unit Invisible Holes:

For example, for this specific topic five different working stations were created, corresponding to four somehow different ideas:

- Station 1: Colored Chemical Substances in Water
- Station 2: Invisible Holes
- Station 3: Membranes in Medicine
- Station 4: Chemical Substances through membranes
- Another station relating to the separation model: Separation of ink using membranes

The participating teachers enjoyed the workshops and commented that what they learned was useful, and could help them to accordingly transform their classroom teaching and orientation towards their students. The working conditions were really collaborative and the attempt was to make the teachers feel comfortable, despite any difficulties and gain real ownership of all the activities and attempts to improve their own classroom performance, accountability and effectiveness. We also attempted to exemplify to them the necessity to move beyond cold cognition and take into consideration not only cognitive outcomes, but to also infuse in their teaching, for example, social objectives (i.e., working together, collaboration and communication), and affective objectives (i.e., curiosity interest, motivation) or societal objectives (solving problems in their homes and communities) and or cognitive skills (such as, controlling variables, reflection, critical thinking, and other habits of mind) connected with the real nature of science.

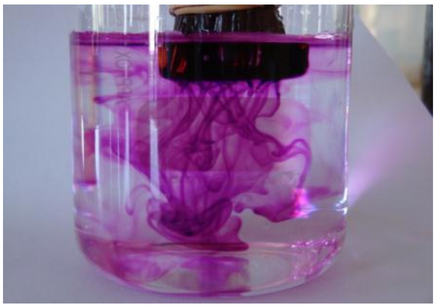
We tended to involve teachers in learning situations resembling the learning conditions that should prevail in IBSE, so that they internalize the important ingredients of IBSE in cultivating public understanding of science and the catalytic nature of science as an important tool and lever for social and economic development. The activities were carried out by the teachers themselves and constant support, scaffolding and information were offered by the inspectorate and other personnel from the ESTABLISH group. Teachers faced even unexpected difficulties, but we tried to make them feel comfortable and consider similar situations facing their students and how to move on, providing similar support and scaffolding.

A number of Chemistry teachers working either in the Gymnasium or in Lyceum enrolled for further seminars on the inquiry-based learning and teaching. They were recruited from the whole number of chemistry teachers, who were informed that they could be acquainted with a new teaching approach aligned with the IBSE of ESTABLISH. They, express their interest to attend seminars on the implementation of the inquiry-based method in the teaching of Chemistry and to become acquainted with the three different levels of inquiry-based teaching/learning approach, namely, structured, guided and open. They wanted as well to be involved in the design and development of their curriculum and other classroom or teaching materials aligned with the IBSE approach.

In these seminars, the teachers were first presented with example worksheets for promoting the IBSE teaching/learning approach using the flame test. They were first introduced to the philosophy of IBSE and its three different levels of progressive implementation and the associated skills and advantages. They were then presented with examples of worksheets aligned with the three levels of the inquiry- based approach and were instructed to collaborate and solve the following problem:

> *Bags of fertilizer containing potassium nitrate (white solid) were stolen from a farmer's storeroom. The police arrested a suspect. On the shoes of the suspect were traces of a white dust. The suspect however claimed that the white solid on his shoes was salt (sodium chloride) and he explained how this was justified. The students were asked to provide evidence using their knowledge of chemistry to investigate whether the suspect's claims were correct and to judge whether he was guilty or innocent.*

After completing the specific tasks, the participating teachers discussed in a plenary session their ideas and their new insights with the chemistry inspectorate and the ESTABLISH group, and clarified all the related issues. Then, the participating teachers were self-organized in small groups for designing and developing IBSE worksheets and materials for teaching a unit from the Chemistry curriculum in Cyprus. The different groups developed teaching materials (worksheets and organized experiments) either for a unit from the Gymnasium Chemistry curriculum (8th or 9th grade), or for a unit from the Lyceum core Chemistry curriculum (11th grade).

Two specific exemplary cases from those activities are presented from two specific groups (A or B) of teachers:

<u>Group A: Fast and slow reactions – rate of chemical reaction:</u>

The problem that teachers instructed their students to solve was, as follows:

A group of children visited two villages, both famous for their metallic bridges, which were constructed by a famous architect in 1985. The first village was located 6 km east of an industrial area, while the second was located 60 km west of the same industrial area. These bridges were exactly the same and were made of the same material, but had never been maintained. The children discovered that one of the bridges was corroded to a much greater extent than the other one. Both villages were located at the same altitude and had the same temperatures during the year. They were however affected by a wind that blows towards the east. The students as young scientists need to find out which variables / factors led one bridge to be more corroded than the other one.

<u>Group B: Natural and synthetic soaps – pH:</u>

The problem that teachers instructed their students to solve was, as follows:

The beauty column of a weekly magazine advises its young readers to pay attention and care for their skin: If you have a sensitive skin, never use soap on your face. Although the high pH of the soaps may cleanse the face thoroughly, it may also severely irritate or harm your skin. The students are consequently asked to investigate whether the advice given by the column's consultant to the magazine readers, is phrased in a scientifically correct way. It is known that soaps which have a high pH value do irritate the skin. Yet, many companies advertise that their products are suitable for use on the face.

The spirit that was constructed during the training and workshops was very productive and different groups of teachers presented their IBSE materials and curriculum units at different local (national conferences). Two other groups of teachers were selected and presented their work in the poster session of the teachers' conference in Dublin.

- Group "A" developed teaching materials (worksheets and experiments) for a unit from the Gymnasium Chemistry curriculum (9th grade)
- Group "B" for a unit from the Lyceum core Chemistry curriculum (11th grade).

Evaluation of in-service training for Gymnasium Chemistry teachers

Evidence collected from both teachers and their students via interviews and questionnaires provided support indicating that the specific approach was both more interesting and effective for attaining cognitive and affective gains among the students. Some indicative comments from students concerning the topic "*Natural and Synthetic Soaps*" that was used in Secondary School classrooms are presented as representative students' reactions:

- Florentia: "Our chemistry lesson today was very constructive*. We had the chance to research and to investigate on our own, to cooperate with fellow students, to experiment and, at the same time, we had fun*" (open inquiry was implemented).
- Eleni: "*Our chemistry lesson today was different. We learned that there are different types of soaps, that their pH varies and that soaps with a high pH can affect our skin. It was enjoyable*" (guided inquiry was implemented).
- Charalambos: "*Our lesson was very pleasant. We cooperated with our fellow students, we learned about the use of soaps and that we need to make the right choice of soap. We also had fun*" (structured inquiry was implemented).

The overall evaluation of these workshops using students and teachers questionnaires showed:

- students enjoy the IBSE lessons that really increase interest for science learning and provide enough opportunities for cooperation
- these approaches foster more positive attitudes to science
- IBSE teaching/learning are more effective in attaining the objectives of science education
- IBSE teaching/learning support the development of critical and scientific thinking

The involved teachers also identified several Challenges/issues/constrains associated with IBSE that should not be neglected as well. These are, for example

- Curriculum constraints
- Lack of time to implement inquiry
- Limited knowledge of teaching by inquiry
- Classroom management issues
- Lack of supportive school management

In-service Workshops for Gymnasium and Lyceum Chemistry teachers

The ESTABLISH Cyprus Chemistry group organized in June 2013, in collaboration with the Chemistry inspectorate of the Ministry of Education and Culture, workshops for all the in-service Chemistry teachers of Gymnasium and Lyceum (teaching years 7th, 8th, 9th 10th, 11th and 12th).

The workshops were carried out in Nicosia (two workshops) and Limassol (one workshop). The workshops were based on the inquiry-based learning and teaching and covered the units "Solar energy and Energy from Hydrogen (Fuel Cells)" with emphasis in Hydrogen Cars – generating Hydrogen from Water electrolysis / generating electricity from Hydrogen. A total number of 71 teachers, 48 teachers participated at the two workshops in Nicosia and 23 at the workshop in Limassol. The participants worked in groups.

Conclusions and implications for the future

This collaboration and mutual responsibility of the ESTABLISH group, coordinated by Professor N. Valanides, with the chemistry inspectorate in the Ministry of Education and Culture, guided by Loukia Anastasiadou, was extremely beneficial and influential. Most of the materials that have been developed have already influenced the classroom environment, since the materials were translated in Greek, they were piloted and are integrated in the official chemistry curriculum and appear on the official website of the Ministry of Education and Culture (chemistry inspectorate). See: http://www.schools.ac.cy/eyliko/mesi/themata/chimeia/drastiriotites-programmata.html

The specific website highlights a number of issues/activities linked to the ESTABLISH project, such as:

- Introduction to European project ''Establish''
- Establish Teachers' Conference in Dublin
- Workshop on "Invisible Holes and Mixtures / Separation of mixtures".
- Workshop on "Solar energy and Energy from Hydrogen (Fuel Cells)"
- Students apply IBSA in classroom: slow and fast reactions
- Students apply IBSA in classroom: soaps – pH

The mutual trust and productive collaboration between the ESTABLISH group and the Ministry of Education and Culture triggered a number of other initiatives that can continuous infuse the IBSE in the official chemistry curriculum in Cyprus.

An Establish Webpage in Greek language with all the ESTABLISH materials activities, units of training teachers, etc. is planned to be designed and developed in the near future. The specific website will make these materials accessible to the Chemistry teachers of secondary level schools.

There is also in progress to establish a Chemistry Summer school for teachers and students who have already expressed interest to continue working to strengthening the IBSE approach for teaching science in Cyprus.

Similar approaches were also followed in Collaboration with the physics and chemistry inspectorate and some really important lessons have been also learned. The restriction to chemistry education was a preference for exemplifying our way of working and the importance of close collaboration with the officially responsible for curriculum development and evaluation of physics, chemistry and biology, and does not mean that the implications of the ESTABLISH project and its IBSE philosophy on physics and biology teaching were not important.

Case Study 8: Malta

International cooperation model for IBSE Teacher Education.

Margareta Ekborg, Malmö University*; V.J. Dorenbos, CMA; Annalise Duca,AcrossLimits.*

Abstract

This case study reports on the implementation of a 3-day teacher training programme in Malta for in-service and pre-service teachers, as facilitated by two ESTABLISH partners from Sweden and the Netherlands. Each of the facilitators enriched the delivery of this ESTABLISH teacher education programme by providing their own expertise in the key areas of IBSE with ICT and IBSE with Industrial Content Knowledge (ICK).

Introduction

As the Maltese partners in ESTABLISH were to not experts in teacher education, two different approaches were adopted to providing teacher training to Maltese Pre- and in-service teachers. In 2011, 10 science teachers travelled to Dublin and participated in 3-day Inquiry Summer School provided by ESTABLISH Coordinators at Dublin City University. However, in February 2013, a 3-day teacher education programme was hosted by St. Ignatius boys school in Qormi and facilitated by ESTABLISH partners from Sweden (M. Ekborg) and the Netherlands (V.J. Dorenbos) – in a cooperation between Across Limits and the Ministry of Education. The description of this 3-day programme is reported here.

Description of IBSE teacher education programme

Day 1 - Why IBSE? and IBSE skills:

- Introduction of the Workshop by local ESTAABLISH partners from Across Limits
- Filling in the ESTABLISH Pre-workshop Questionnaire
- Introducing each ourselves and each other

Ekborg gives introductory and interactive presentation Inquiry-Based Science Education and Industrial Links

- **Key questions are: What is IBSE? and Why IBSE?**

<u>Exercise 1:</u> Ask questions.

Ekborg gives all kinds of articles with scientific content to the teachers. Ask as many questions as you can. Afterwards, see if you can divide the questions into scientific questions and other questions.

<u>Exercise 2</u>: Ask questions and plan an investigation.

Ekborg gives each group a different object with a question to find research questions and set up an investigation:

- Vanish
- Toilet paper is allowed why hand towels are not. Find out why.
- Peeling Hard boiled eggs
- Do knives get dull when washed in the dishwasher
- Does it matter how deep seeds of different size are planted?

- Do flowers really last longer when using the small package of nutrition delivered?

- ***Why inquiry-based science education?***

Ekborg presented results from international assessment studies (often over extended periods similar to studies such as ROSE, TIMSS and PISA. Results about the relevance of science education in different countries; how science education is valued by; top 10 science interests of boys, girls, teachers were shared and discussed in the context of these reports about science education in Europe with recommendations.

Finally Ekborg presented some theoretical background about questions/questioning skills in IBSE and obstacles of introducing IBSE and concluded this section with an exercise around UV-pearls.

<u>Exercise 3:</u> UV Pearls.

UV pearls get a colour when exposed to ultraviolet light and students can detect the presence of UV-light in different places or under different circumstances. With these pearls a number of experiments can be done. The assignment was to find research questions and plan an investigation which can be carried out with these pearls. As extra's teachers used a.o. sunburn cream.

- **Presentation of the unit Disability**

In the ESTABLISH project 18 different units with lesson materials have been made. In this part the unit Disability was presented in depth. Other units were available and teachers had some time later on in the programme to take a look at them.

<u>Exercise 4:</u> Important questions in this exercise are *What is disability?* and *What is a handicap?* Look at pictures and find out which handicap the persons have.

<u>Exercise 5</u>: tools for disabled.

Each group receives a number of tools which help people with different disabilities. Investigate the tools, see what they are for and which physical principle is behind them.

Find out which handicap these persons have.

Exercise 6: Muscles.

How do muscles work? (globally discussed among the teacher groups)

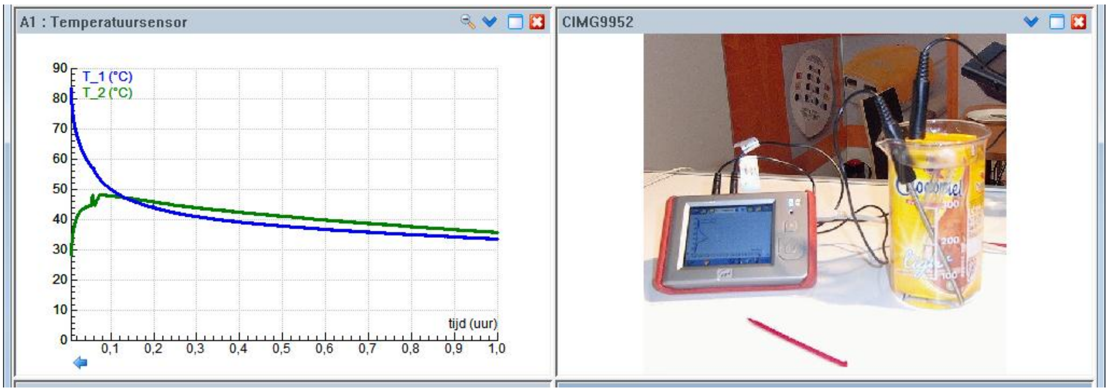
Hereafter, Dorenbos continued with the next session about Questioning Skills regarding formulating research questions and discussing teacher skills in questioning

- Copter bug. Each group got a copter bug, a paper clip and a pair of scissors.
  Exercise: Find a partner from another table. Cut out the copter bug. Together find as many testable research questions with the copter bug. After 15mins. a second copter bug with longer ears were distributed. Teachers worked enthusiastically on this assignment.

After lunch, Dorenbos wrapped up the copter bug exercise, we summed up the different questions. It appeared that the concept 'testable' was not completely clear to all teachers. Due to time constraints Dorenbos spent a few words on that, but it would have been more instructive to gather all questions on the board and discuss their testability and if a question was not testable, to try to rephrase it such that it would be testable.

Dorenbos gave short overview of student skills and teacher skills in IBSE. After that an assignment about the teachers skill asking questions was given (from Llewellyn): Mr. Poole & Mr. Rivers (two bottles with Cartesian divers were available to get a real idea what the lesson of Mr. Rivers was about). Afterwards this was finished by a discussion on the outcomes. A lot of sensible remarks came from the teachers about questioning skills.

Then he presented a graph of a temperature measurement of warming up chocolate milk in a bath of hot water. The assignment was: What kind of questions do you want to ask your students about this graph?



The teachers came up with a long list of good questions about this interesting graph and also discussed the meaning of the graphs themselves. This example formed a nice step-up for tomorrow's ICT programme.

At the end of the day:

- We inventarised if the teachers have other topics which we should spent attention to (not much came out).
- We gave the homework for second day:
  - install Coach 6 Lite
  - Think of a concrete point which you learned and want to share with your colleagues

Day 2 - ICT and IBSE

Ekborg started day 2's programme by connecting to the previous day.

Exercise 7: Think one minute about something concrete that you've learned yesterday. Then walk around and tell others about what you learned (teachers talking in an animated way).

Next a plenary session was held in which many teachers shared what they've learned in Day 1. (Video footage of plenary available).

- **Session ICT and IBSE**

Started with questions about computer situation in science in Malta. It appeared that schools have computers: laptops or fixed ones. Several teachers use datalogging systems of Fourier Systems.

Dorenbos gave a presentation *Introducing ICT in science education*, in which he made a distinction between 'informational' types of software, which is used by anyone in every-day life: document handling, presentation, e-mail, etc. vs. 'constructional' software: specialized software for constructing scientific knowledge, like the Coach software suite with tools for science investigation.

Dorenbos gave a number of examples of ICT starting from ict within the Establish units: applets from the units Medical Imaging and Forensic Science and then from Coach: unit Sound

Then a video measurement from Forensic Science. It appeared that video measurement was new to the teachers. Therefore we extended this topic with much more examples after the coffee break.

- Measuring the shape of objects: Image measurement (example: St. Sebastian cathedral Malta)
- Double Bass (hi-speed video)
- Knee jerk
- Chemical reaction with video measurement

Measurement

- Long term measurement of CO2, Light and temperature in a plant
- Heart-rate measurement

This part was concluded with an in-depth discussion of a large number of measurement examples for all subjects (biology, chemistry and physics) from a Powerpoint created for the Establish project.

After lunch, teachers worked intensively with Coach. Dorenbos took 10 €Sense interfaces and lesson materiaal for simple IBSE investigations of light, temperature and sound. The school provided some practical materials, like alcohol, ice, hot water, etc.

Teachers working on ICT activities with the €Sense interface, for measurement of light, temperature and sound.

Day 3 ICK and IBSE

An important aspect of the Establish project is to build links with 'industry'. Industry should be regarded in a broad sense: to bring students in contact with all kinds of people and companies where science is used in every-day life. Therefore this day would be spend on this topic, by making a visit to the only one brewery of Malta.

The day started by summing up the activities in the previous day and by sharing experiences of the teachers with the ICT.

Then Ekborg continued with a preparatory presentation about Industrial Content Knowledge (ICK) in view of the visit of the Brewery. During the presentation, teachers got the assignment to think of questions they would like to ask during the visit.

At 10 am we were picked up by the bus to bring us to the brewery. In the brewery we were kindly received, got the general presentation about its history and then continued to visit the old and new brewery buildings. Because of Margaret's instruction to the host at the brewery, he made sure that we were joined later on by one of the senior brewers to answer all scientific questions from the teachers. This made the visit very worthwhile, and also opened up possibilities for school visits with students, as the brewer was prepared to come to answer questions then as well.

We returned to the school to have a late lunch and then had only one and a half hour left in which Ekborg continued about the ICK and gave exercises to think of other possible targets for school visits. Next an overview of the available Establish lesson units was given, and we had 2 print-outs of them. Teachers could take a copy and were referred to the Establish website where they could download the units. After a lively discussion, the third day was wrapped up, and the participants had to fill in two more questionnaires. Teachers and people from AcrossLimits expressed their enthusiasm and gratitude after which the three-day workshop was closed by handing out the official certificates.

Evaluation of Maltese IBSE teacher education programme

Participants of this teacher education programme completed an online questionnaire several months after the workshops. They reported that they had made some changes in their classroom practice to incorporate some of the aspects of IBSE addressed, for example:

- *Changes in questioning technique - including differentiated questions in lesson plan. I try to guide pupils to the answer with the knowledge that s/he possess. Moreover I pay attention to give enough time for the pupils to think and answer.*

- *Facilitated an investigation about the effectiveness of different methods of protection against exposure to UV by skin.*
- *Included some local "news" in my lesson notes so as to start off a discussion with my students. I also will be using the paper helicopter when teaching the topic on forces.*
- *Introduced a story about a iron artefact which can was found buried in sand next to the sea shore but it did not rust so I encouraged students to ask questions which they could investigate to find out what make iron objects rust.*

When asked how their students reacted to these adaptations, the teachers responded:

- *I think they responded quite well as they participated more. Answers however wrong were redirected so they all felt that they were contributing to the lesson.*
- *They felt more involved as I was targeting different levels.*
- *They had already experienced a similar process during previous investigations carried out, so they were not particularly surprised.*
- *In the beginning to found it difficult to design their own questions but they wrote good questions and these were shared with the rest of the class. They liked this approach since they were more involved.*
- *The pupils at start were a bit reluctant but at the end they were expressing themselves quite well.*

When teachers were asked to list ways in which IBL may enhance your classroom teaching, they commented that:

- *IBL allows children to think not just listen and repeat. Better questioning techniques; more use of small experiments during lessons and use of interactive media can make learning (and teaching) a joyful experience.*
- *Yes especially use of ICT in science teaching, planning for educational site visits, and use of questioning in IBL.*
- *I realised that most of my teaching is like that, but needs some tweaking*
- *I would like to use this approach for smaller items during lessons.*
- *Very useful. I disseminated ideas gained amongst other teachers.*
- *new ideas...as a teacher one is always looking for new ideas in order to enhance teaching and learning in the classroom*
- *such approach helps the students to explore science better.*
- *In addressing pupils with different abilities, in giving enough time for pupils to think, In guiding pupils to right answer without giving knowledge.*

When asked what the focus should be for further workshops, they address aspects such as:

- *Preparation of exam questions and marking schemes.*
- *Investigations and formative assessment.*
- *More practical examples should be discussed in terms of how to use this approach in one's pedagogy.*
- *Hands on experience of Inquiry Based learning strategies*
- *New ideas on teaching - with concrete examples. Ideally these would be directly linked with our curriculum. thanks again for the opportunity*
- *Assessment and IBSE and classroom discourse and IBSE*
- *Techniques on how to motivate some pupils in being more responsible in class especially in mixed ability teaching.*

Overall the teachers reflected very positively on this 3-day programme and all but one had tried an IBL approach / IBSE activities in their own teaching over the following months. They expressed a strong interest in participating in future workshops and would like to focus on more practical examples for IBSE that they can directly use and discuss how assessment can be aligned with an IBL approach.

Case Study 9: Sweden

Inquiry and Industrial Content Knowledge in teacher education

Margareta Ekborg, Maria Sandström, Malmö University; Christina Ottander, Umeå University

Abstract

This case study deals with different ways of working with Industrial Content Knowledge (ICK) in the context of teacher education. The ESTABLISH framework for IBSE Teacher Education Programme (TEP) has the description of ICK as the second core element in the material which is developed for in-service and pre-service education. This is aligned with core ESTBALSH model for IBSE that all materials (Units) and programmes involve the engagement of key stakeholders, and in particular the scientific and industrial communities.

Introduction

Why ICK?

In all Europe as well as in the US and Canada there is a worry about young people's decreasing interest in science. EU has funded several projects within FP7, in which partners in Europe work with teachers and IBSE. Research shows that young people find science more interesting and challenging if they work with inquiry. ESTABLISH is one of these projects. Some other projects are: Fibonacci, S-Team, Co-reflect, Parcel. What is unique with ESTABLISH is that in this project there is a second strategy to work with young people to encourage them to take an interest in and learn more in science. This strategy is to see to it that the students get to know what people with an education in science or technology actually work with. The students can learn that scientists and engineers are people who have interesting and important jobs, work in social contexts and that they are like most people. Another reason for working with ICK is to connect school science to reality in that you learn about situations when science is applied in different ways

National Context

The Swedish partners - Malmö University and Umeå University developed material for ICK to be used in pre-service and in-service teacher education. It is published on the website. In Malmö, two groups of teachers participated in Teacher Education Programme (TEP) in 2011/12. A full day was allocated to ICK. From these two groups a number of teachers continued and participated another course in the spring 2013. Then ICK was the content during half a day. In the course we also worked with IBSE: At the end of the course the teacher reported about work in their classrooms.

In Umeå, three groups of teachers have participated in TEP. During 2011-2012 a group of grade 7-9 teachers were involved in 4 workshops, during 2012-2013 a group of grade 4-6 teachers and a group of grade 10-12 teachers were involved in 3 workshops TEP. For the first group 4 hours were allocated to ICK and the municipality were invited. For the other groups ICK-issues were discussed during the workshops. In 2013 a group of six teacher educators were involved in three meetings of 2 hours focussing on inquiry-based ICT. In 2012-13 two groups for grade 1-6 were involved with an ESTABLISH module within the regular teacher education. Units from ESTABLISH were trialled during 4 hours in one course and 10 hours in the second group. Beside this two ICK days were included. During these days the students made study visits to a farm and a waste power station.

Implementation- Different Models

Here we report different models that we worked with in different groups. It is not a report of the full TEP- instead we have concentrated on ICK and the study visits conducted by teachers.

The two groups that participated in the TEP in 2012 both worked with several ESTABLISH units. In one group we focused more on the unit Disability and in the other group we focused more on the unit Sound.

In both groups one full day was allocated to ICK. We started by preparing a study visit. For Disability group we chose CERTEC, the Division of Rehabilitation Engineering Research in the Department of Design Sciences, Faculty of Engineering, Lund University. Here they work with research and education for people with disabilities to achieve better opportunities through more useworthy technology, new design concepts and new individual adaptations.

Here the ESABLISH teachers met research teams who develop technical aids for disable persons, such as robots, devices for mobile phones and computer programs so that you can steer with your eyes. The teams can include engineers, physiotherapists, nurses, educators and other profession depending on what project they work with. .

For the group focusing on sound we visited SVT, Swedish Television Company, in Malmö. . After a guided tour one of the sound technicians told about how they work with sound and demonstrated the equipment. So this visit had another approach. Here the teachers could see how knowledge about sound is applied.

With another group of teachers we also visited Vattenhallen, a Science Centre driven by Faculty of Engineering, Lund University. Vattenhallen is used as learning environment for pupils of different ages from preschool to upper secondary. Teachers are welcome to bring their classes to join different creative activities. Moreover Vattenhallen is used in the education of engineers and Science and Technology teachers and is open to the public in weekends and holidays. Several departments at the university have contributed their expertise and knowledge in the development of experiments and many researchers and students have been active in meetings with schoolchildren and other visitors. The overall intention in Vattenhallen is to increase the interest and knowledge in Science and Technology and inspire young people to study Engineering. Our visit at Vattenhallen contributed to the intention to show and discuss a possible meeting place for university, school, public and industry. With a similar intention, Umeå arranged two of the workshops at Umevatoriet, which is a science centre jointly driven by the university and the municipality.

In other words study visits can be conducted for different reasons, but it is important to prepare the visit and sum up after the visit and think of strategies of how to continue the work with students.

If the purpose is to connect school science with applications and to learn about the scientific process one model is to start with a number of applications and discuss scientific principles. The students can also work with processes in miniature in the classroom. They can construct low energy houses and use modern equipment for data logging to measure energy-related parameters. They can also construct cars driven by solar cells and perform all the steps from design to construction and evaluation and in the end compare with "real" sun driven cars. In chemistry class the students can make a cosmetic product in lab scale and compare with different commercial brands. These are just examples, of course there are many other activities you can do.

As an alternative to study visits you can invite a scientist or engineer to come to your class. In one workshop in Umeå the ICK content were focussed by inviting people from the municipality working with health and environmental issues to a collaborative session with the teachers. During this workshop the staff from the municipality presented areas in which they do different types of investigations. For example the sound level in canteens, music halls etc are measured with regular intervals and monthly measurements of air quality within the city are done. During the workshop several collaborative investigations were initiated and discussed. One example was that students could use different smart phone applications to measure sound level in different places in school and report to the municipality.

In the TEP we invited a professor in molecular biology from Lund University, who has worked with basic research as well as applied research. Right now he is involved in breeding of oats in order to increase the amount of beta-glycan in the seeds. He told us about his research and about plant breeding in a historian perspective and focused on modern molecular biology applied in plant breeding. The teachers asked questions and we compared IBSE to professional research in science. At the same time as the teachers learned something about modern biology and chemistry they also got knowledge about scientific processes and met a person who works professionally with science.

You can also study local industries, products or everyday activities around you related to science and technology. This could for example be the pharmacy, hairdresser, super market or the local traffic system. The students' task is to trace and discuss their findings backwards to the origin and find answer to questions like: What is being produced? Which professions are active at this work place? What educational backgrounds in the fields of science and technology do they have? How were the products developed? By whom? What science and technology is behind the product? What research related to the product, process or activity is done? What might this company do that reflects what we are teaching/learning in school?

This activity gave the participants opportunity to see the connections between industrial processes and the content of science and technology in school.

The advantage to use local industries is, that they are easy to find, well known to the students and can be visited repeatedly and in small groups.

Impact

In all three TEP the teachers worked with ICK and IBSE in their own classes and reported their work during the last day of the course.

Impact can be judged from the teachers' evaluations and how they have continued to work with the ideas that have been brought up during the TEP. According to the course evaluations the teachers were very positive to the course and its content.

All teachers reported about how they had worked with ICK in their own classes.

Some examples:

- Some had taken their pupils to the TV Company.
- One group of teachers worked with local farming industry breeding potatoes. They grew potatoes in the school and followed the process from there to study visit at the manufacturing of commercial potato crisps.
- One group of teachers worked with air, and flights and visited an airforce museum
- One teacher worked with farming and genetic animal ethics
- Some teachers used Transfer, an association of people who work with science and technology and voluntarily come to schools to lecture on their work and education.
- One teacher found a number of apps for the I-pad which all could be used to investigate different aspects of sound

As the teachers all shared these experiences they also got lots of new ideas from each other the last day of the course.

Case Study 10: Netherlands

Development and Integration of ICT into Pre-service Teacher Training in IBSE

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Abstract

In order to be able to integrate ICT tools into Inquiry Based Science Education (IBSE), teachers need much time and support for mastering ICT tools, learning the basis of IBSE, and getting experience in applying these tools in students' scientific investigation. Our project aims to develop a training course for pre-service secondary-science teachers from universities in the Netherlands on the use of ICT tools integrated into IBSE lessons. The challenges are the lack of time and the heterogeneous background of teachers, many of whom opted for teaching later in life and not immediately after university. Through iterative case studies, we collect data on the participant's learning process and outcomes to evaluate faithful implementation and effectiveness of the course. The first try-out with the course showed us the possibility within a limited time to bring pre-service teachers with different experiences to a reasonable level of competence regarding the use of ICT in their IBSE lessons. The blended setting seems to contribute to this result under the condition that students really spend considerable time outside the training sessions.

1. Introduction

Our aim is to develop a training course for pre-service secondary-science teachers on the integration of the Coach tools (figure 1) into IBSE lessons. Participants will not only learn to use the ICT tools in Physics/Chemistry experiments but also learn to apply them to teach **inquiry-based** Physics/Chemistry lessons. The dilemma is that both participants and their students have to learn many technical details (just think of video measurement as an example), and yet the focus should be on inquiry and concept learning rather than on following recipes (for doing video measurement). Participants will face science and ICT conceptual issues of using a particular ICT tool in addition to typical beginner's technical "how-to" problems. They will also have to deal with the issue of getting their students to mainly focus on minds-on science learning and meaning making rather than solving ICT technical problems. In this process, participants will need not only the ICT facilities but also much time and guidance/feedback from the course facilitators.

As in many other countries, the Netherlands has two tracks for physics teacher education:

- A bachelor-level physics-teacher education degree at a College for Professional Studies where students study both physics and education and which certifies graduates to teach at the lower secondary level.
- A postgraduate program at Universities where students must have a bachelor degree in physics and take two years of master-level physics courses, before taking one year (60 ECTS credits) of teacher education including their school internship. All coursework is scheduled on one day per week; 3 days are spent in the school; and one day is for assignments. Graduates of this program are certified to teach at the upper secondary level. Another option is to integrate the one-year teacher education within the 3 + 2 years Bachelor - Master program.

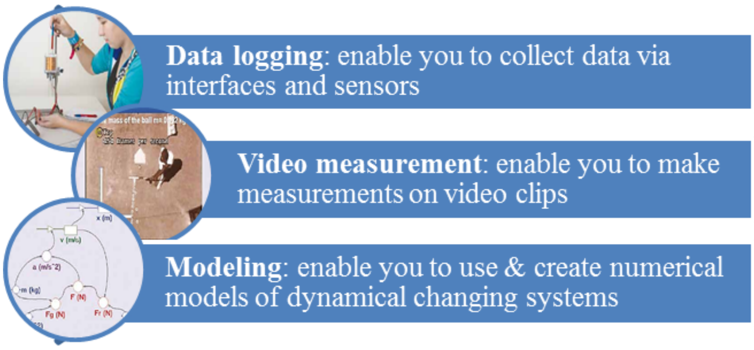


Figure 1. The three ICT tools: data logging, video measurement, and modeling within the Coach learning and authoring environment (source: Ellermeijer, 2013)

That postgraduate program is very full and does not allow much room for contents about ICT in science teaching. Furthermore, in Dutch physics and chemistry teacher education, most pre-service teachers already have a teacher appointment rather than only a guided internship due to a shortage of physics/chemistry teachers. Consequently, they experience all the pressures of a first year teacher. Therefore, to achieve effectiveness of the pre-service course on integration of ICT into IBSE, the time constraint should be taken into account.

The student population in teacher education programs in the Netherlands has changed. Twenty years ago all students were fresh master graduates. Now the majority of students obtained their master degree many years ago, then worked for 5 - 20 years in a research or an industrial job, and either by choice or through reorganizations decided to opt for teaching. As a result, participants in pre-service teacher education are very heterogeneous in terms of:

- age (22 – 50 years old),
- subject background (from just graduated to a PhD or even years of research experience in physics or chemistry disciplines),
- experience with the ICT tools (most participants know very little about video measurement and modeling; some are quite familiar with data logging; some have no experience with these ICT tools at all).

Their teaching conditions in schools are different as well. Most, but not all, have sufficient software, sensors, interfaces, computers for ICT-integrated activities, but in some schools these are well integrated in the lessons while in other schools it is rarely used. Participants teach at various levels: first or last years of HAVO (medium) or VWO (pre-university), so possibilities and demand for application of the ICT tools in class are different as well. What participants have in common is that almost all are in their first year of teaching. In brief, participants turn out to have very heterogeneous backgrounds, and the challenge is how to design an ICT-in-IBSE course that fits all.

2. Course Design

2.1. Principles underlying the course design

2.1.1. Design principle 1 about trying out classroom activities through a complete cycle of designing, executing, and evaluating an ICT-IBSE lesson

Literature on effectiveness of teacher professional development shows that a traditional training course will only be effective when supplemented by expert or peer coaching and other school-based activities (Fullan, 2007). According to Joyce and Showers (2002), effective training should include an exploration of theory, demonstrations or modeling of skills, simulated practice, feedback about performance, and coaching in the workplace. Moreover, hands-on practice is more critical than theory and demonstration in a technology-based training course (Thurston et al., 1997). It is essential to create the proper conditions for teachers personally to prepare work plans and teaching materials for their students (Borghi et al., 2003).

In a review of decades of research on laboratory use in science education, Hofstein and Lunetta (2004) reported that many activities in laboratory guides continue to offer “cook-book” lists of tasks for students to follow ritualistically. They do not engage students in thinking about the larger purposes of their investigation and of the sequence of tasks they need to pursue to achieve those ends. Students often perceive that the principal purpose for a laboratory investigation is either following instructions or getting the right answer. Students often do not connect the experiment with what they have done earlier. Abrahams and Millar (2008) summarized results of observations in 25 typical laboratory lessons in the UK:

> *The teachers’ focus in these lessons was predominantly on developing students’ substantive scientific knowledge, rather than on developing understanding of scientific enquiry procedures. Practical work was generally effective in getting students to do what is intended with physical objects, but much less effective in getting them to use the intended scientific ideas to guide their actions and reflect upon the data they collect.*

In our course, we wanted to address this issue and combine the teaching of technical mastery of ICT tools with the issue of minds-on inquiring and meaning-making in the laboratory. Therefore, we thought it should be a priority for participants to go through at least one complete cycle of designing, executing, and evaluating an ICT-IBSE lesson. This provides a condition for hands-on practice and classroom experiences for participants with all aspects of integration of ICT as lab tools into IBSE. It also creates opportunities for participants to recognize and deal with the issue of cookbook-versus-inquiry use of the ICT tools or with science & ICT issues in using a particular tool (modeling, video measurement, or data logging) in the class.

2.1.2. Design principle 2 about being aware of possibilities of the ICT tools and learning only one tool by choice

A first level of integration of ICT into IBSE is awareness of the possibilities of various ICT tools in science lessons. A second level is technical mastery of the tools. A third level is the ability to integrate the tools into the lessons to achieve minds-on inquiry and meaning making. In a course restricted to 3 sessions of 3 hours each (1 EC), participants cannot learn all of the ICT tools deeply. Consequently, we decided to aim for level 1 for all tools (figure 1) but to aim for levels 2 and 3 only for one of the three tools and then have the participants choose which tool they want to master and include in an IBSE lesson they will teach. With only one tool by choice during the course, a participant will have more time to achieve real mastery of the particular tool in both Technical Content Knowledge (TCK) and Technical Pedagogical Content Knowledge (TPCK) aspects.

Furthermore, the three ICT tools, taught in the course, are integrated in an Open Learning and Authoring Environment, Coach (Heck et al., 2009). This environment started with a vision of a hard- and software environment in which tools for measuring, data processing, and modelling are integrated in a single system that supports students’ learning in an inquiry-based approach of science education (Heck & Ellermeijer, 2010). Therefore, a user, who has experience with one tool, can learn other tools easier and faster. The assumption is then that once the participant specializes in one of the Coach tools, the perspective of using Coach makes it possible that later, based on experience of deeply learning in one tool, she/he can learn and apply other tools on her/his own. We will check this assumption through follow-up research.

2.1.3. Design principle 3 about learning through a blended setting including course sessions, in-between tasks, and an online platform with supporting materials and with close supervision

Many researchers argue that just offering training sessions as isolated events is not effective. A shortcoming of training is that it offers few opportunities for choice or individualization, so it may not be appropriate for varied levels of teachers' skills and expertise (Guskey, 2000). Moreover, the application of skills is much higher when teacher professional development includes theory, demonstration, practice with feedback, and peer coaching with follow-up (Joyce & Showers, 2002). In order for participants to retain and apply new strategies, skills, and concepts, they must receive coaching while applying what they are learning. Training sessions, therefore, must be extended, appropriately spaced, and supplemented with additional follow-up activities to provide the feedback and coaching necessary for the successful implementation of new ideas (Guskey, 2000).

The blended setting which emphasizes in-between tasks with supporting materials (besides training sessions) suits the boundary conditions of the course. It will accommodate the considerable differences of participants' background, ICT expertise, and teaching conditions in schools. Although following the same learning scenario (figure 2), participants will go into different directions by flexible options of learning contents, pace, materials, and time which fit their classroom conditions and with which they feel most confident and effective. However, a crucial issue is how to keep participants on task while participants will mostly work in distance learning mode. In this case, participants need an online platform where they can access various supporting materials and receive timely feedback and coaching from teacher trainers.

2.2. Participants' learning scenario

The course design is a proposal for implementation of the design principles. The right part of figure 2 shows the proposed training process that includes sequences of training sessions (in contact time) and in-between tasks (out of contact time). The left part presents the proposed participants' learning scenario that matches with the training process.

Participants first get an overview of the Coach tools for science teaching (creating awareness of possibilities and practicing some basic skills). Then they will personally choose which particular tool they want to learn in detail and apply in the classroom as a part of IBSE (technical mastery and integration of the tool in IBSE). Participants follow the learning process (figure 2) with main activities shown in table 1.

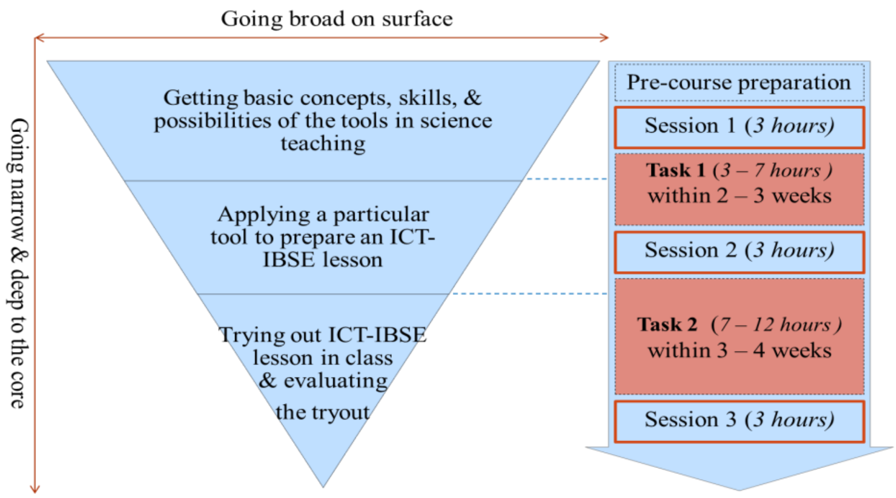
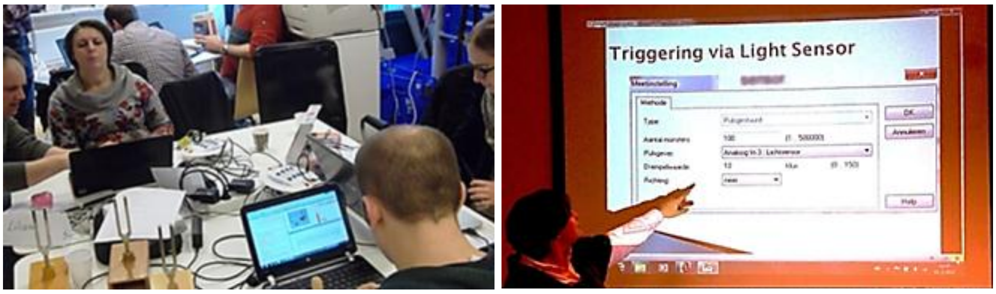


Figure 2. Participants' learning scenario and process

Table 1. Main activities during the course that link to the figure 3

Training process	Main activities
Preparation	Installing the Coach platform, trying out basic activities, and reading documents about ICT for IBSE and course information.
Session 1	Getting basic concepts, skills, and possibilities of the Coach tools in science teaching (figure 3a).
Task 1	Practicing only one tool (data logging, video measurement, or modeling) to get the advanced skills.
Session 2	With the chosen tool, preparing an IBSE lesson plan which includes ICT activities (figure 3b).
Task 2	Trying out the ICT-IBSE lesson in class (figure 3c)
Session 3	Presenting and evaluating the ICT-IBSE try-out (figure 3d)



(a) (b)

(c) (d)

Figure 3. Pictures of participants' activities during the course

2.3. Supporting materials

The in-between tasks are very important and require time, whereas working alone is hard for participants because of general time pressure and typical technical difficulties in mastering new tools. Therefore, we offer supporting materials and timely help via a Moodle platform (http://ibse.establish-fp7.eu/).

For learning to use a particular tool in both training sessions and in-between tasks, participants are advised to practice with the given Coach activities which are divided into three categories:

- Coach basic activities (figure 4) are ready-to-use activities, which introduce simple manipulation and elementary concepts related to a certain tool. These basic activities can be performed without previous instruction on the Coach platform.

- Coach tutorial activities help to improve skills and conceptual knowledge corresponding to a certain tool through step - by - step written instructions (figure 5a) and related video tutorials (figure 5b).

- Coach subject activities are ready-to-use activities, which serve as a source of ideas or as a resource for further development. These activities can be used to teach a particular subject concept.

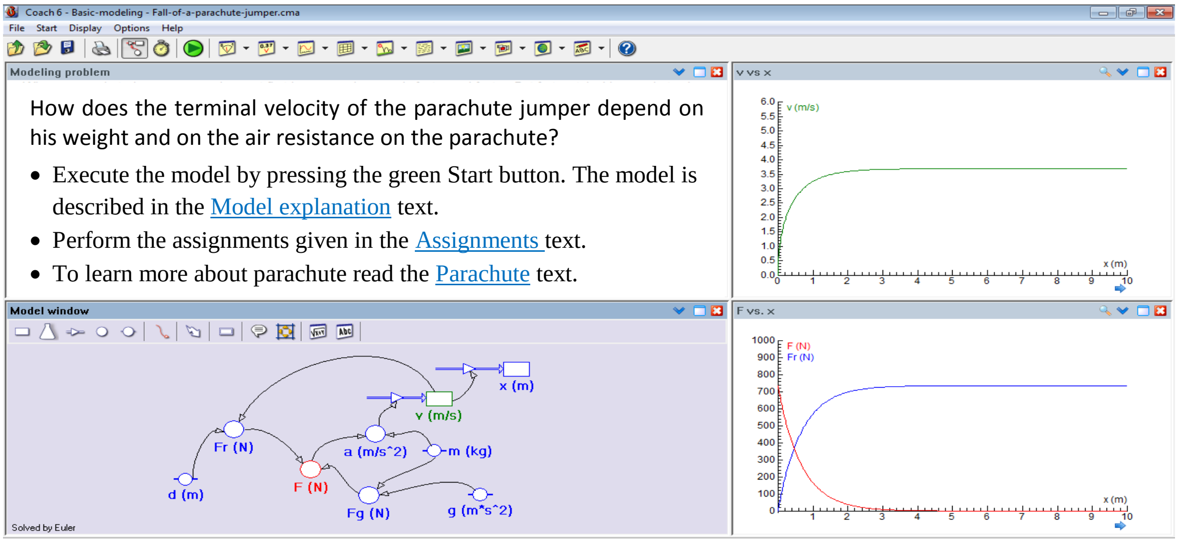
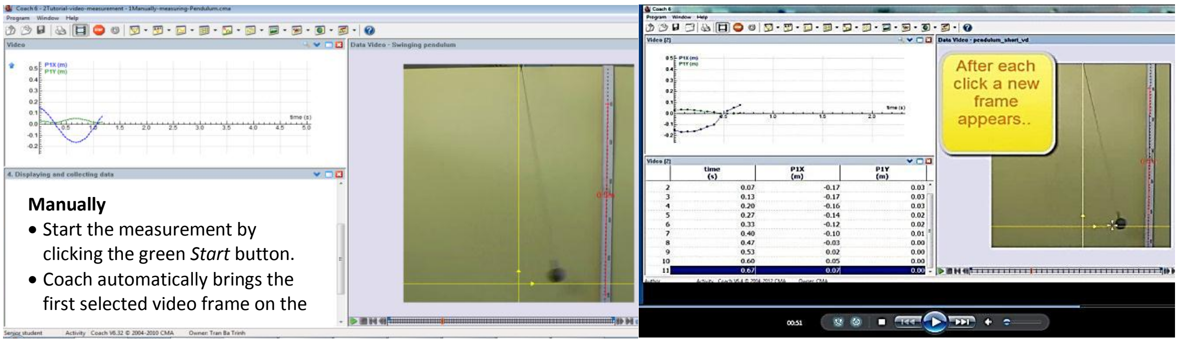


Figure 4. A Coach basic modeling activity: Fall of a parachute jumper



(a) (b)

Figure 5. A Coach tutorial video-measurement activity with written instructions (a) and video tutorials (b) For learning to apply a particular tool in the classroom, participants are provided the references (PowerPoint presentations, background articles, assignments) on the basics of IBSE, forms to design and evaluate ICT-IBSE lesson plans, and resources of sample ICT-IBSE activities on the course Moodle.

3. Implementation of the ICT-IBSE course

3.1. Assessment questions and instruments

Our research aims to evaluate effectiveness and faithful implementation of the course through case studies by two main questions: *To what extent is the course implemented as intended, and to what extent does the course have the effects as expected?* We formulated detailed assessment questions as subordinate research questions for data collection on participants' learning process and outcomes. Data analyses will help to answer the research questions in a case study and provide evidence for revising the course design, which will be subsequently executed and then assessed again in a next case study (figure 6). If the outcomes (effectiveness and faithful implementation) of the course are not yet satisfying, further cycles of the optimization process: revision, execution, and assessment need to be performed.

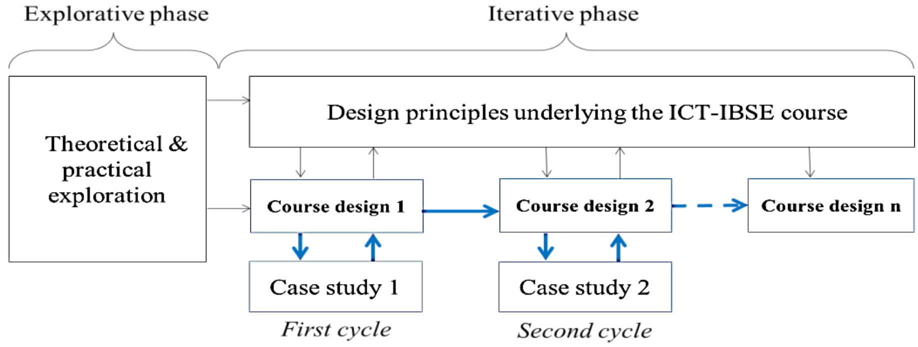


Figure 6. The assessment and optimization process of the course through iterations of case studies (adjusted from Knippels, 2002)

We designed and used a set of assessment instruments which include four main categories:

- Questionnaires: Pre-course questionnaire, Post-course questionnaire, and Follow-up questionnaire;
- Observation: Observation of course sessions and Observation of classroom try-outs;
- Documents: First task reports with the Coach result files; Second task reports: ICT-IBSE lesson plans, Coach activities, classroom videos, and try-out evaluations; Students' learning products; and Emails among participants and teach trainers;
- Interviews: Interviews with participants, Interviews with teacher trainers.

3.2. Participants' learning during the course: Outcomes from a case study

In this paper, we present data about learning process and outcomes of eight pre-service physics teachers and four pre-service chemistry teachers from two universities in the Netherlands during an ICT-IBSE course (1 ECTS) from January 28 to March 4, 2013. Data from the pre-course questionnaire shows that 75 % of participants have just taught less than one year as an internship and/or paid teacher, and others have a-few-year teaching experience (less than 5 years). Before the course, they are moderately familiar with data logging, data processing and analysis; slightly familiar with video measurement and modeling (figure 7). Their theoretical knowledge about the intentions of IBSE is good.

a) To what extent the course was implemented as intended, obstacles in its implementation

- About implementation of training sessions

Course sessions went quite smoothly, and all training contents were covered. Most plenary presentations/discussions lasted longer than intended, so time for hands-on, in-group activities was less than intended (table 2). The teacher trainers reflected that plenary time was very constraint. For instant, it often takes them almost a day of introduction and demonstration to make teachers aware of possibilities of the Coach tools in science teaching and provide opportunities for introductory guided practice whereas in this course, they only have 45 minutes for this task with the same goal.

Table 2. Time consumed for main activities during the training sessions

	Intended	Implemente d	Participants preferred
Plenary introduction and demonstration about the ICT tools (first session)	45 minutes	55 minutes	Less time (-0.18)
In-group learning of basic skills with particular tools (first session)	**90 minutes**	**70 minutes**	**More time (+0.64)**
Plenary discussion on the first in-between task (second session)	40 minutes	50 minutes	Less time (-0.45)
Plenary instruction to develop IBSE lesson with the tools (second session)	50 minutes	55 minutes	Less time (-0.09)
In-group preparation of a Coach activity and an IBSE lesson plan (second session)	**90 minutes**	**60 minutes**	**More time (+0.64)**
Plenary discussion on the second in-between task (third session)	100 minutes	70 minutes	Less time (-0.45)
Plenary discussion on added values of the ICT tools to IBSE (third session)	15 minutes	15 minutes	Less time (-0.55)

Ranking: less = - 1, unchanged = 0, more = 1

In the post-course questionnaire, we asked the participants "*Suppose the total time for our ICT-IBSE course is unchanged, how do you prefer to change the time consumed for each activity in each session of the course?".* The participants chose "less" (-1), "unchanged" (0), or "more" (1). The responses (right column of table 2) shows that participants desired more time for hands-on activities such as in-group learning of basic skills with particular tools in the first session and in-group preparation of a Coach activity and an IBSE lesson in the second session. Through interviews and questionnaire as well, we learned that participants wanted us to give detail feedback/comments on individual participant's reports rather than just only in the plenary discussion.

We expected before the session 3, all participants would finish their tryouts in school. In fact, there were only 2 participants who implemented their ICT-IBSE lessons and 7 in total 12 participants submitted their lesson plans. Consequently, we had to follow participants' tryouts for around one month and a half after the course (not as intended). This fact was caused by objective reasons (e.g. school scheduling) rather than subjective ones from participants, but most participants, who had late tryouts, did not have opportunities to present their mini projects and receive peer feedback from other participants. The first author attended and video-recorded almost all classroom tryouts, and then interviewed participants. We found out a few obstacles to their preparation and implementation of ICT-IBSE tryouts as follows:

+ Lack of Windows PCs and CMA interfaces, sensors in some schools

+ Room in the physics curriculum/ school schedules in the intended time (3 weeks, 11/02 – 04/3/2013) was rather limited for tryouts of some participants. For example, a participant chose to use the data logging tool to teach the topic of ultra sound. In the intended time, he had to finish other planned contents for the school exam and teach prerequisite concepts related to sound wave.

+ Although participants, working in school as teachers, are quite independent in teaching, they still have to consult the school mentor for lesson plans, contact the technical assistants for teaching equipment arrangement, and discuss with their students for planning. These appointments and preparations also take time.

+ Secondary students are quite familiar with data logging, but slightly familiar with video measurement and especially unfamiliar with modeling. Consequently, participants choosing video measurement or modeling faced extra difficulties.

+ Preparation of participants before the course was limited. We sent necessary documents and guidance via email beforehand, but due to first-year teaching pressure, they did not spend appropriate time to read the course program, background articles, PowerPoint presentation, or to practice simple Coach activities as expected. Even for some participants, after the first session, they still were not clear about the main task of preparing, executing, and evaluating an ICT-IBSE lesson in their own schools. Therefore, they did not have enough time to think and prepare the idea for applying an ICT tool to teach a certain topic.

- Implementation of the in-between tasks

Regarding time, the course is counted for 1 ECTS, 28 hours, so besides 9 hours for live sessions, we expected participants to work for 19 hours individually. We asked participants about how long they had spent for each assignment, and received the answer that on average, the participant spent about 2 hours for pre-course preparation, 3.5 hours and 7 hours for the first and second in-between tasks. In practice, the time they worked in distance, 12.5 hours, is less than we expected. To support, motivate, and keep participants on track, in addition to supporting materials and timely help for participants' assignments, we emailed participants before each important deadline for submission, accomplishment as well as sent reminder emails to someone not finishing yet. We asked them, "*To what extent did the following factors* (table 3) *influence your motivation/effort to finish the in-between tasks?*", and for each factor, the participant chose one of the ratings, "*not at all influential*" (1), "*slightly influential*" (2), "*moderately influential*" (3), "*very influential*" (4), and "*extremely influential*" (5). Data shown in table 3 indicate three most influential factors on participants' distance learning, which are about awareness of benefits of performing the tasks, sufficient working conditions such as time, equipment, and school supports, and timely help from teacher trainers. The online platform was the least influential factor.

Table 3. Influences of some factors on the participant's distance learning during the course

Factors	**Rating**
Your awareness of benefits of performing the tasks	3.83
Working conditions such as time, equipment, and school supports	3.67
Helps from teacher trainers when you encounter difficulties, and then ask them	3.5
Emails somehow reminding you about the task	3.42
The requirement that you must present your task results in the meetings	3.33
Task descriptions including deadline	3.18
The online platform where you may find solutions for your problems by yourself	2.5

1 = not at all influential, 2 = slightly influential, 3 = moderately influential, 4 = very influential, 5 = extremely influential,

Through interview, participants also complained that the online platform we arranged for them did not help. It was not well structured, unattractive, and inconvenient to access. We set the forum in Moodle, required them to upload their task reports and share their problems there, so all other participants can access to discuss and comment. However it did not work. The history section of the Moodle platform showed that they only logged on the Moodle platform to download the supporting materials and upload their reports as we suggested. Participants preferred emails for contacting teacher trainers.

11 participants (out of 12) managed to finish the task 1 about learning technical skills to use a particular ICT tool, and 11 participants could accomplish the complete cycle of designing, trying out, and evaluating an ICT-IBSE lesson (task 2). One participant postponed his tryout because the school does not have the interface and sensor he needs for his ICT-IBSE lesson plan. We expected participants to choose only one particular tool to practice (task 1) and apply in an inquiry based lesson (task 2). In fact, some participants did not follow. For task 1, they preferred to learn a new tool to them (e.g. video measurement or modeling), but for application of ICT tools (task 2), they chose a more familiar tool to both themselves and their students (e.g. data logging).

Through interview and questionnaire, participants reflected that they liked the blended setting and in-between tasks. Some participants' comments were:

+ "*The blended setting offers you the opportunity to work in your own time*", Amy

+ "*I prefer the longer timeframe it gives you time to work at home and make a real product instead of rushing through something. I just wish we had more feedback for the personal project (3rd session)*", Matt

+ "*With the blended setting, you have more time to actually develop and carry out a lesson plan.*", Sander

b) To what extent the course had the effects as expected and reasons for not realized effects

- About the TCK domain (ICT skills and knowledge)

According to participants' self-reports via the pre-course questionnaire and post-course questionnaire, participants' familiarity with the Coach tools in general increased (figure 7). We also could check this improvement through our observation of participants' manipulation with the tools and their Coach result files (with which we can learn what a user can do with the tools besides data from her/his Coach activities). Most participants stated that the given Coach activities at three levels (basic, tutorial, and subject) were really useful training materials for them to study Coach skills on their own.

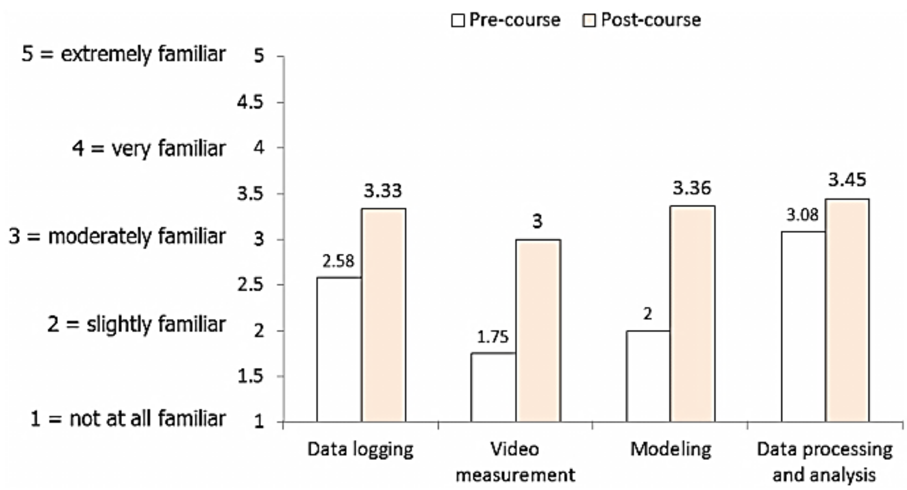


Figure 7. Participants' familiarity with the ICT tools before and after the course

Participants' gains of mastery of their chosen tool were different. A few participants reached the advanced level of using ICT tools as they developed their own, new ICT activities with little or no support from the teacher trainers. Some participants only learnt basic skills and used an existing Coach activity for their tryouts.

- About the TPCK domain (applying the ICT tool in IBSE lesson)

The ways participants applied the ICT tools in inquiry-based science teaching were quite different. They preferred to set up their tryouts in the context of one lesson with a whole class or of a school project for a few weeks. However, for some participants, it was rather hard to arrange their tryouts. For example, one participant had to try out with a different class because in his own class the intended topic had been taught already. In some cases, participants could not find any room in curriculum or school agenda for tryout with a whole class, so they used a small group of student volunteers for their tryouts. These efforts proved that they were motivated to apply the ICT tool they had learnt in teaching. Based on availability of ICT tools in the school, topics of the ICT-IBSE lesson, levels of students, etc., participants prepared the lesson plan following different types of IBSE such as interactive demonstration, guided inquiry, or open inquiry (table 4).

Table 4. Participants' ICT-IBSE tryouts in schools

	Type of tryout	**Planned lesson**	**Implemented lesson**
Participant 1	School project	Guided inquiry	Cookbook lab/Guided inquiry
Participant 2	Small group	Guided inquiry	Guided inquiry
Participant 3	A class	Guided inquiry	Guided inquiry
Participant 4	A class	Guided inquiry	Guided inquiry
Participant 5	Small group	Guided inquiry	Guided inquiry
Participant 6	Small group	Guided inquiry	Guided inquiry
Participant 7	A class	Guided inquiry	Guided inquiry
Participant 8	A class	Guided inquiry	Interactive demonstration
Participant 9	A class	Guided inquiry	Interactive demonstration
Participant 10	A class	Interactive demonstration	ICT part did not work.
Participant 11	School project	Open inquiry	Guided inquiry

Besides the theoretical framework on IBSE, we also provided participants a form for an ICT-IBSE lesson plan which is based on main phases of an inquiry process. In lesson plans, participants presented quite clear inquiry ways by which they aimed to teach a certain topic with a particular ICT tool. Through our observation of classroom tryouts, participants' tryout self-evaluation, and interviews, we could judge how the lesson plan was implemented in class. Data shows that there was still a gap between lesson plans and their classroom implementation just like in most literature (Hofstein & Lunetta, 2004; Abrahams & Millar, 2008). Some ICT-IBSE lessons were implemented not as intended by participants. For instance,

- Participant 3 (table 4) arranged three ICT activities for students, but the student could complete one or two. The teacher did not give sufficient time for explanations of assignments and for students to familiarize themselves with the modeling tool.
- Technical troubles with computers happened. The participant 10 (table 4) could not find the cause, so the ICT part did not work at all, and an important idea of the lesson was not tried out.

- Participants 8 and 9 (table 4) prepared ultra sound sensors for groups of students and asked them to determine the shapes of some hidden objects. In the tryout, students did not come up with the idea of the experiment and were not familiar with the software as well, so the teacher had to come to each group for explaining and raising detailed questions to motivate them to get involved in the inquiry process. Consequently, the plan was guided inquiry, but the implementation was more or less interactive demonstration.
- Through a school project, participant 1 (table 4) required students to design an experiment to measure capacitance of capacitors (phase 1), and then with given equipment (circuit components, sensors, software, etc.) they had to execute the experiment design to measure some capacitance and write reports (phase 2). Some students accomplished the phase 1 with good theoretical preparation and experiment design, but others did not have feasible plans. Before attending the lab activities (phase 2), students had to submit their plans. To make sure almost all students would finish the project with good reports, the participant 1 gave students a very clear cookbook instruction for experiment set-up and execution. Consequently, for students who did not prepare a good idea about the experiment, they had to read the instruction carefully and simply follow the recipes to come to expected data on capacitance. In this case, the participant's project plan was guided inquiry, but in the implementation, many of her students actually performed cook-book lab activities.

After the course, all participants appreciated the added value of the ICT tools in science teaching. Through a question in the post-course questionnaire, we learnt that most of the participants were confident, on their own, to learn and apply other tool(s) which they did not study yet within the course (Figure 8). We will perform the follow-up study to learn if they practically learn and use the ICT tools in their teaching after the course.

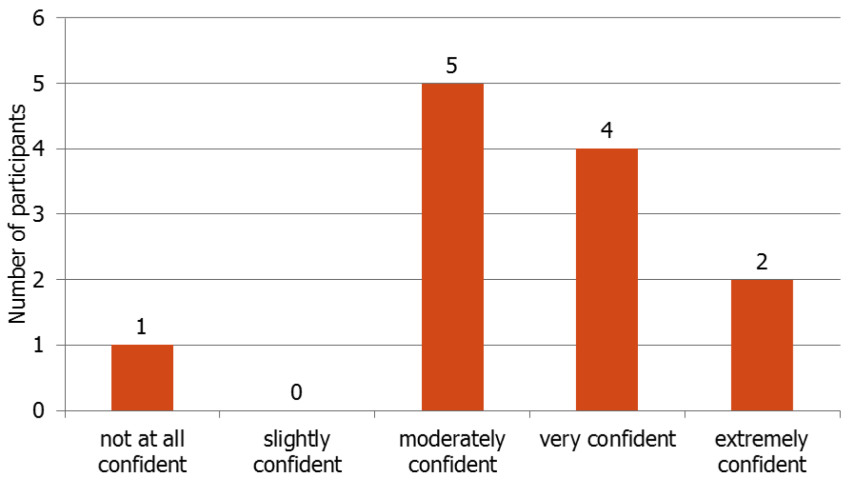


Figure 8. How confident participants are in learning & using the other tool(s) which they did not study during the course (a question in the post-course questionnaire)

Conclusion

The first try-out with the course showed us that it is possible within a limited time to bring pre-service teachers to a reasonable level of competence regarding the use of ICT in their IBSE lessons. The blended setting seems to contribute to this result under the condition that students really spend considerable time outside the training sessions. Already the course is trialed for as an in-service course in Kosice, Slovakia. Other case studies are planned in Palermo, Italy and Hanoi, Vietnam and further rounds of development are planned based also on trials in the Netherlands.

Final conclusions on the effects of the course will be based on long-term effect measurements: will the teachers be able to master the other tools on their own, how much do they really implement ICT in IBSE way in their lessons. These results will be published in coming years.

Acknowledgement

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Case Study 11: Estonia

Adapting ESTABLISH Units for use in Tertiary Healthcare Education

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Abstract

The goal was to develop and implement an Establish module-based course which promoted among the students an interest in science learning and supported them to apply knowledge and skills in new real life situations. This study reports on research carried out the suitability of on ESTABLISH modules (Units) for adaptation in a tertiary level healthcare education programme for raising students levels of scientific literacy.

Introduction

Tartu Healthcare College has six curricula at the tertiary level. All curricula are based on an understanding of school science subjects. For example, outcomes of the Curriculum of Environmental Health include an understanding of human being as a biological-psychological-social entity; possessing an ability to define problems, to analyse and evaluate relevant solutions; to assess environmental health risks, all of which include a complex understanding of biological, physiological, physical, chemical and socio-cultural aspects of the living environment and their impact on human health plus measures to reduce risks (Tervisekaitse spetsialisti… 2013). A further example can be taken from the curriculum of Bio-analysis, where outcomes include the provision of reliable bio-medical analysis results and an understanding of health problems associated with different analytic determinations. These include operating and understanding complex equipment, reliable sampling techniques, good team-work skills, etc. (Bioanalüütiku õppekava… 2013). Professionals in the field of health care at any level, or in any profession must be able to understand the complex characteristics of human beings and their environment, to make decisions, think critically and solve problems. All such skills are closely related to an enhanced level of scientific literacy (SL), which involves, among other things, scientific knowledge, ways of thinking, the ability to explain scientific phenomena, and undertake socio-scientific decision making (Holbrook & Rannikmäe, 2009, Choi *et al.* 2011) or "systematic thinking" as described by Choi *et al.* (2011).

In endeavouring to achieve such outcomes within 3 years of study, the college relies on a strong secondary level education (high school, gymnasium). However, findings suggested that the students' high school science knowledge and skills are questionable. Research by Teichmann & Kübarsepp (2008) show that science and technology students have weak understanding of scientific concepts, and they lack psychosocial skills when beginning their tertiary level studies.

To raise levels of scientific literacy (SL) and increase student motivation, Rannikmäe *et al.* (2010) describe effective use of modules, based on a model of moving from a socio-scientific issue towards science conceptual learning through first establishing a scientific problem, then learning the science through an inquiry learning process. The modules developed during the ESTABLISH project are designed according to these principles so as to promote inquiry learning and an understanding of technology and industry-related aspects in science lessons and hence can be expected to be appropriate for also raising students levels of scientific literacy at the tertiary level.

The goal of the research and research question

The research question was to determine if the ESTABLISH modules (Units) were suitable for adaptation in a tertiary level healthcare education programme for raising students levels of scientific literacy? The goal was to develop and implement an Establish module-based course which promoted among the students an interest in science learning and supported them to apply knowledge and skills in new real life situations.

Methodology and course design

The participants were volunteer students who had graduated from secondary school and were continuing their education in the healthcare college. There were 22 students initially, but not all of them decided to follow the whole course after the first session and hence participated in only some of the modules. The students undertook a 30 hour course and their levels of SL were measured before and after the course. After the course, a semi-structured, focus-group interview was carried out, similar to the method used by Raved & Assaraf (2011), in which, everyone could express their opinions, feelings and beliefs related to the course. According to the pre-course SL measuring results, the students, who attended the course, had higher average results than was the college average. The same time within the experimental group the variation of the test results was significant. Participating students were mostly from the curricula of Bio-analyst, but some were also from Environmental Health, Nursing and Midwifery curricula.

- The course had pre-determined outcomes which were related to an understanding of the basics of science, with strong emphasis on chemistry.
- The course was voluntary and no credits were awarded, so the motivation to participate was coming only from students' own interests
- Six students who were most active and participated in most of the modules participated in the post-course interview. Two of these students had very high SL test results; three were at an average level and one was slightly below average.

Choosing the modules for a course and designing the course

Modules chosen from the ESTABLISH project are presented in the Table 1. Criteria based evaluation is undertaken on all those modules. All estimations are based on the curricula and resources available in Tartu Health Care College. One criterion was the choice of modules by students. Students could choose (by voting) their perceived, more relevant modules and even parts of the modules, according to their interests.

The suitability of modules is evaluated by the tutor and/or student using a Likert-scale: 5-extremely suitable, 4- very suitable, 3- suitable, 2- somewhat suitable, 1-not suitable. For example: the module, Chemical Care, is very relevant for the course, related to- the topic of chemical/physical interactions, and therefore is estimated to be "extremely suitable," according to the goals of the course; parts of the module on Sound and Light has important content for the Environmental Health students' curriculum, but less relevant for other aspects of the overall programme and hence less relevant for the current course outcomes. Therefore the module is estimated to be only „suitable," according to the curricula and "somewhat suitable" according to the course outcomes.

Table 1. Criteria-based evaluation of modules.

Criteria, relevancy	Cosmetics	Blood donation	Ecology	Photochemistry	Chitosan	Water	Light	Sound	Polymers	Chemical Care	Exploring Holes	Medical imaging	Forensic
Relevant context for health care	5	5	3	3	4	4	4	4	3	5	4	5	4
Relevant content (according to the curricula)	5	5	5	4	4	4	3	3	4	5	3	5	5
Relevant content (according to the course outcomes)	5	2	2	3	4	4	2	2	4	5	3	2	2
Resources needed (Material base)	3	3	3	4	3	3	4	4	3	5	3	2	2
Chosen/voted by students (students inerests)*	N/A	11-12	10	9	8	7	1	4-5	4-5	11-12	2	3	6
Chosen	**Yes**	**Yes**	**Yes****	**Yes**	**Yes**	**No**	**No**	**No**	**No**	**Yes**	**No**	**No**	**No**

*Students' votes were graded by popularity - the highest points are for the most popular module

**Module was later dropped due to lack of time and low relevance for the subject

One of important characteristics – time needed for studying the module, was eliminated, as all modules were considered to be adaptable according to the available timeframe. Only one module was proposed by the author as extremely relevant, with strong coverage of planned topics and outcomes of the course. That module was "Cosmetics."

The modules were adapted to give even more relevance and more related context to tertiary healthcare students, according to their curricula and participants' interests. More emphasis was also given to motivation, self-directed studies and reflection as a crucial part of learning. The modified modules followed the original principles of inquiry-based approach in science education.

Adapting the Modules:

"Cosmetics" was an ideal module to cover the topics of solutions, emulsions and surfactants, structure and polarity of molecules based on the structure of the atom, hydrogen bonds, lipids, waxes, etc. and also social issues, health safety and quality of cosmetic products, industrial approach, etc. Its relevant context was very suitable for the course curricula and compared with other modules, fewer modifications were introduced. Nevertheless, creme presentation/ marketing was removed and the cosmetics industry discussion shortened At the same time, examples were added from the pharmaceutical industry and medical testing principles and ethical considerations were introduced with the lotions tested on human skin. Not all resources needed were readily available in the college and some additional investment was undertaken for purchasing oils and emulsifiers. As some students did not have prior experience in laboratories, it was important to choose a module with relatively straightforward labwork. More time than initially planned was dedicated to test out different formulas for cremes, so one module from the initial choice (Ecology) was dropped from the course. Immediate feedback suggested the topic was not sufficiently relevant and motivational for male students. Nevertheless the module fulfilled three criteria perfectly, and with some additional resources made available it was seen as motivational for most students that participated in sessions.

The Chemical care module has three sub-units and a choice was made to cover the topics of acids and bases, solutions and detergents (surfactants) to fulfil the criteria for relevance for the course and curricula. Chemical safety and legislation (CLP, REACH) related discussions were added. No additional resources were required (besides those already present in the College). This module was chosen by the students, and was very suitable to fulfil all the criteria established. As the first lesson showed that too much discussion and self-directed study was not sufficiently motivational, most activities were practical and discussion was carried out during and in between the practical tasks. If there was a need for further information, it was presented during the practice and then acted on immediately. This method seemed to be much more suitable and interesting for students. The students gave good feedback on the module and it was considered motivational.

The Blood donation module was also shortened – the study visit, conference and interview were left out and other activities optimized. Due to the nature of the Health Care College, some activities were more efficient and visual than others. Students had the opportunity to see a real blood sample under the microscope and with the help of a trained Bio-medical science professional, to determine their own blood type. On the other hand, the suggested substitutes for blood samples were not tested. As the module only covered the topics of different biomolecules, other topics, like coagulation, were introduced. In terms of criteria fulfilled, this module is seen as very relevant for health care students; it can be linked with many topics in the curricula, but in relation to course outcomes, it was estimated to be only somewhat suitable, for the reason that these themes are taught in many other courses and they are not directly related to the outcomes of this particular course. The module was still motivational for students and adaptable into the course, with more emphasis placed on biochemistry. This module had strong emphasis on students' career choice and promoted understanding about the importance of the inquiry approach in daily life.

In the Photochemistry module, sub-units, I-III, were shortened and sub-unit III omitted. Students found the relatively difficult construction of a spectroscope which was not so perfect, but definitely working, very interesting. What made this module easier was the appropriate equipment available in the college – even two different spectrophotometers were available to measure the spectre and absorption of the colourful solutions and to determine the concentration of the solution. The module was well suitable, in terms of coverage, as some curricula (Bio-analysis, Environmental Health and Radiography) are related to physical research methods, or physical risk factors. It was estimated as only suitable for a within college context, as some curricula do not use these topics. The module covered topics related to solutions, concentration, light, spectre, but as only a few of these were expected outcomes for the course, the module was estimated as only suitable, in terms of relevancy for course outcomes compared to other modules. Students (especially Bio-analysis students) also saw the connection with their curriculum, but it was less motivational for Nursing and Midwife students. According to the students' feedback, their motivation to understand and learn about technological aspects of medical apparatus became evident and they recommended this module to be part of their compulsory learning.

The Chitosan module was the last adapted module. The module was very suitable in terms of relevancy to health care, relevancy to each curriculum and to the outcomes of the course. It covered the topics of hydrocarbons and hydrogen bonds and gave students possibilities to discover and think. Chitosan was not available in any pharmacy, preparation of chitosan was quite technical and probably would not be that motivational in relation to the time it took to complete the module. Therefore the author, herself, decided to prepare chitosan for the lesson out of crustacean cells and only include the parts on chitosan testing. The extraction of Chitosan consumes substantial amount of chemicals for the small amount of chitosan produced and the extraction took several days. Therefore, the module was estimated to be only suitable according to the resources criteria. However, testing the chitosan was motivational and interesting for the students. Students developed themselves an option to show how best to modify the module to make it more relevant for compulsory courses. This module made possible a value related socio´-scientific discussion; for example, about anorexia-related issues, which were highly relevant at the adolescent level, and for which healthcare specialists must be ready to interfere and help by giving advice where needed.

General observations, findings from interviews and discussion

Six students were interviewed after the course, using semi-structure questions:

- Did you like the course; if so why?
- Did this course give a different image about school science education?
- Did you see the course modules relevant for your further studies and life?
- Did you learn scientific ideas during the course? How about interdisciplinary thinking?
- What do you recommend to change in the course? Did you enjoy independent thinking and possibilities to collaborate with other students?
- Did you gain knowledge about links between industry, technology, science and career choices?
- Do you recommend this course to other students? If so, why?

ESTABLISH modules included relevant real-life based scenarios and they were very adaptable into the context of the health care curricula. Students' initial motivation for learning science related topics was relatively low (both at school level and also at tertiary level) because they often failed to see the relevance of SL in their particular area. These perceptions were changed after the course. Students found the course different, motivating and interesting, but still difficult, as it involved more self-directed work and independent thinking. The students were generally satisfied and motivated by the course, as it was a different approach to learning comparing with other courses in the college. Interviews with these students revealed that sometimes students could not understand what was expected of them due to the nature of group tasks in the modules. They expected more direction and help from the teacher than was intended in the modules. This showed that students were not prepared for an inquiry-based approach that was more than a structured approach. The students were reliant on the instructor and did not possess sufficient self-confidence. However, the students stated that it became easier for them during the course as they became more independent. The courage and confidence to solve problems and make decisions on their own was raised substantially.

The curricula of applied higher education are outcome-based. Some outcomes are more general and more suited to inquiry-based learning. But some outcomes require acquisition of key knowledge and skills. The syllabus of the current course also includes additional specific outcomes that need to be fulfilled. Therefore it is unavoidable that a more emphasis is put on content and learning certain laboratory skills leaving less time and attention to inquiry development, independent thinking and problem solving. In this context, too many modules are chosen for the limited timeframe, and as a consequence the modules are shortened too much.

Conclusions and suggestions

- The course showed that as the contexts of ESTABLISH modules were very universal, these modules, with some modification, were relevant and applicable for tertiary level healthcare studies.
- Modules were effective in motivating and encouraging students, for developing inquiry skills and directing students towards more independent studies.
- It was considered essential not to overload the course and leave enough time for each module to be undertaken properly. The practice, discussions and self-study should be simultaneous.
- Teacher should try the experiments out first; however this took time and used resources that were usually scarce.
- Some themes and parts of the modules could be, and already were, adapted into regular tertiary curriculum subjects.
- Teacher should suppress the natural desire to give students ready-made solutions that they were usually expecting, even if problem solving by students seemed to be too time-consuming.

During the course, the modules were adapted to consume optional amount of time, suit the outcomes of the curricula and tested, This prepared the way so that they could be put together for a registered, optional course, with suitable amount of credits awarded to successful students and included it in the regular curriculum. For such a future course, a new syllabus with more general outcomes would be needed with less ESTABLISH modules included. Preliminary plan for the next course have already been established and included the "Cosmetics" module with more emphasis on motivating male students and "Chemical Care." The modules "Blood Donation", "Photochemistry" and "Chitosan" were also under consideration and would be put to the vote by students, so that they could participate in the choice of modules according to their interests. In the respect, the modules which were not tested in this course "Water in the Life of Man" and "Polymers around us" would also be considered.

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Case Study 12: Estonia

Enhancing students' interests in science and technology careers based on ESTABLISH units

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Abstract

This paper describes an optional course which was designed and carried out in one Estonian gymnasium for 11th grade students (N=62). The aim of the course was to develop students' science knowledge through integrating different science disciplines with each other and with technology, engage students in issues related to the impact of science and technology on everyday life and develop students' ability to make responsible decisions related to these issues. In addition, it was intended to stimulate students' interests towards science and technology related careers;. the main focus of the current case study Four learning units developed by different partners within the framework of the EU FP7 project ESTABLISH where adapted and taught within the optional course among Estonian gymnasium level students., 11th grade students' interest in science and technology related careers was measured by means of a pre- and post questionnaire. For validation purposes four students (two boys and two girls) were interviewed after the course. It was concluded that as a result of the course, students' attitude (both, boys' and girls') towards science and technology related careers became more positive. Moreover, the learning units helped to broaden students' understanding about the diverse field of technology and how science and technology are inter-related.

Introduction

Globalisation and the wider and meaningful use of technology are changing the way we think, learn and work. Students need to be prepared for a problem-oriented and technology-rich world so much so that success in the labour market lies in „being able to collaborate, communicate, share, and use information to solve complex problems, in being able to adapt and innovate in response to new demands and changing circumstances, in being able to marshal and expand the power of technology to create new knowledge and expand human capacity and productivity" (Binkley et al., 2010).

These skills, necessary for all people, are extremely important for engineers and scientists. At the same time, according to an European Commission report *Science Education Now: A Renewed Pedagogy for the Future of Europe* (EC, 2007), research carried out by Teppo and Rannikmäe (Teppo & Rannikmäe,2008) and national PISA reports (Henno, 2010), there is a serious decrease in young people's interest in science and technology related studies and careers.

Many studies have shown that, while girls are as competent as boys in the science disciplines, they often tend to believe that science and technology are not relevant to their future career goals, or they do not find the learning contexts interesting (Hsi, Linn & Bell, 1997; Lent et al., 2005; Seymour & Hewitt, 1997; Linn, 2003; (2008). The concern is that as a consequence of the poor interest in science by boys and even more by girls, the result is a decline in Europe's long term capacity to innovate and undertake high level research (OECD, 2006).

In order to address students' lack of interest in science- and technology-related studies, context-based, or science-technology-society-based (STS) approaches in science education, have been promoted during the last decades (Aikenhead, 2005; Bennett, Lubben, & Hogarth, 2007; Euridyce, 2011; Holbrook & Rannimäe, 2010). These approaches incorporate students' everyday experiences and highlight contemporary societal issues such as ethical, or environmental concerns, and, as Gilbert (2006) suggests, develop critical thinking skills and social responsibility. In fact, it is claimed that the STS movement aims to promote „practical utility, human values, and a connectedness with personal and societal issues, all taught from a student-centred orientation" (Aikenhead, 2005, p. 384). During the last decade, the STS movement has been developed further and in Europe several EU projects, like PARSEL, ESTABLISH, PROFILES have focused on these earlier mentioned issues (Holbrook, 2008; www.establish-project.eu; www.profiles-project.eu). In Estonia, a special optional course "Science – Technology- Society" has been launched, based on the philosophy of 'education through science' and its operationalisational model (Holbrook & Rannikmäe, 2010, www.oppekava.ee)

In the current case study, the problem of increasing high school students' low interest in science and technology-related studies was addressed through using learning modules, developed by the partner universities of the EU FP7 project ESTABLISH (and adapted for use in Estonian schools to meet the goals of the optional course.

Industry and technology-related context and well presented interdisciplinary science content form an unique base for using ESTABLISH modules for introducing science and technology-related careers to students.

The principal investigator and the designer for the current case study was a physics teachers who himself participated in earlier ESTABLISH in service programmes and became interested in the purposeful use of ESTABLISH modules in everyday teaching.

The following research question was posed :

Is there any change in students' interests in science and technology- related careers through the implementation of the optional course?

Methods

Sample

The participants of this study were 11th grade students (N=62), divided into four groups and taught by two science teachers from one and the same school. This high school (in Estonian "gymnasium") was typical of many schools throughout Estonia. The extent of the teachers' teaching career was, respectively, 24 and 22 years.

Design and implementation of the course

The four modules, developed by the partner universities of the EU FP7 project ESTABLISH and adapted by the research team for the purposes of the current approach, were taught within the science-society-technology optional course in the same school. This course was designated as a compulsory optional course for these 11th grade students.

modules chosen by the research team were as follows:

- Medical imaging

- Greenhouses on Mars?!
- Chitosan – fat magnet?
- Why to make home-made cosmetics?

Four aspects were emphasised in the modules:

- It is intended that introduced problems have importance in society more generally, as well as being relevant to students' lives so as to further motivate them to learn science content in depth.
- Science content is embedded in and related to technological applications.
- Within every module, science and/or technology related careers are introduced.
- Inquiry learning? and learning through technological design play an integral role in every module.

A short overview about the module - „Why to make home-made cosmetics?" is given as an example (see also Figure 1):

At the beginning of the module, through small video excerpts, students are introduced to wayscosmetic products are made on an industrial scale, as well ashow cosmetics can be self-made at home. Students are subsequently asked (a) to put forward as many questions and ideas regarding the topic as they can and (b) to think about pros and cons of both: industrial and self-made products. The cosmetics industry is projected to students as providing a diverse image about industry, taking away an image of heavy dirty, noisy and manpower demanding processes and promoting industry as clean, involving scientists and designers, including ICT design elements, and requires attention to marketing..The cosmetics industry highlights also the possibility of creating one's own small business as a so called "private industry"

1) The next stage takes students into IBSE, where they are invited to design their own cosmetic cream. Students through an inquiry approach. test familiar mixtures (utlising necessary background knowledge about the main principles of solubility), how the structure of matter is related to the properties of matter, and the main principles of making an emulsion cream; plus the role of different components (oil, water, emulsifier, preservatives,tc) in a product. After testing the products (simple lotions with indentifiable well known, familiar components) on their skin, they are guided to recognise that their skins differ, thus also learning about the structure of skin, and how different ingredients act on and in the skin. They are guided to acknowledge the professional demands of staff in beauty salons, which demand science knowledge and an understanding of why the ingredients of lotions need to be published on product covers.
2) To design their own product, students are guided to carry out an internet search or/conduct, at home, a literature review. Students design their own cosmetic cream and conduct an experiment to make theie product. After making the cream, students are asked to work out the criteria and tests to identify the quality of the product. At this stage, students work as an industrial team, sharing tasks and the different types of inquiry activities acknowledging that one of them is acting as a leader.
3) The next step is to design a commercial advertisement for the product in the format of a booklet, video excerpt, or a poster. This is followed by all groups introducting their commercial to the whole class leading to a whole class discussion and peer assessment by the groups. In

this stage, students are introduced to jobs in the marketing and publicity sectors – these also demanding science knowledge and inquiry skills.

4) The unit is finalised by individual assignment:in which every students is asked to find information about one profession related to the cosmetics industry (cosmetic formulator, process engineer, etc.).

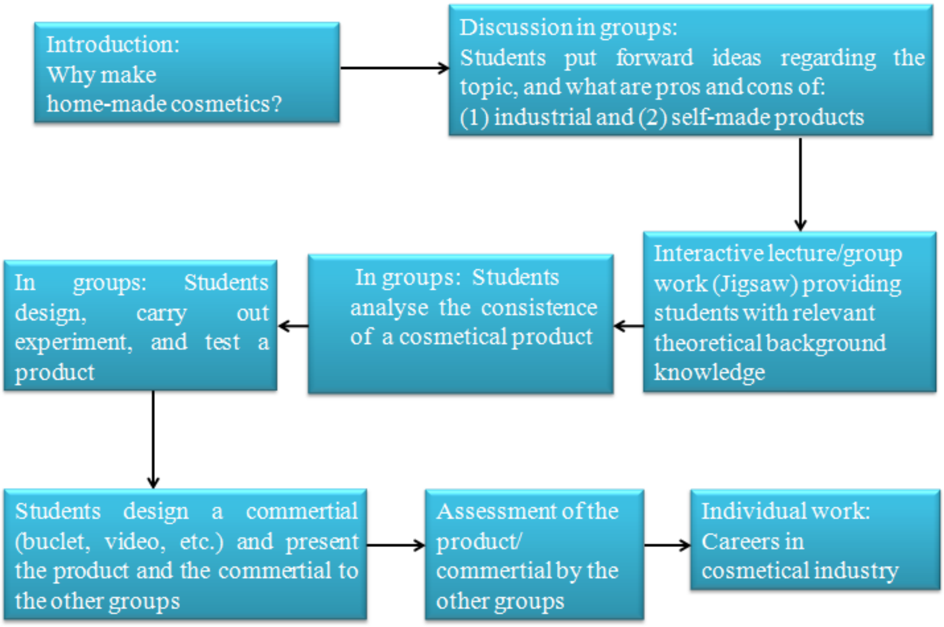

Figure 1: Learning sequence in the module „Why make home-made cosmetics?"

During the module, students implement and develop their creative thinking skills, and apply their gained science knowledge to designing process. Moreover, making an emulsion cream from simple ingredients on their own and starting to market the product, provides students with a good possibility to develop their entrepreneurship skills and initiatives.

The other 3 ESTABLISH modules were implemented in a similar fashion to the one described above. All target relevant professions, as well as a number of sub-professions, which may not be so attractive without greater familiarity and provide insights where it is possible to progress into different, new interdisciplinary areas

Instruments

The students' questionnaire consisted of two sections: the first section asked students to write down their personal data while the second part asked students to estimate their interests in future careers, using a four point Likert scale. The instrument was implemented before and after teaching of the modules. In addition, after finishing the course, four students (two boys and two girls) were interviewed using a semi-structured questions.format . The interview questions were looking towards students' ideas about science and technology related careers. The interviews lasted 15-20 minutes. All interviews were audio recorded, transcribed and analysed.

Results and discussion

In the pre- and post questionnaires, students estimated their interest towards identified and, as much as possible. different fields of future careers (tables 1 and 2). As seen from the table1,an increased interest in science, and even more in technology, careers was found for both, boys and girls. An especially remarkable change was among girls in the areas of engineering and technology, which might be influenced by the context of the modules: Accordingly to Teppo & Rannikmäe(2008), girls are highly interested in beauty and medicine, while the cosmos and mysterious/criminal actions related problems keep interests of both boys and girls high.

Table 1. Students' attitude towards future careers, before and after the course (N_{boys}=28; N_{girls}=34)

Statement	Boys before	Boys after	Girls before	Girls after
In the future, I would like to work in science related areas	2.38	2.70	2.10	2.42
In the future, I would like to work in medicine	1.75	1.80	2.72	2.75
In the future, I would like to work in social areas (economics, justice, etc)	2.50	2.52	2.60	2.60
In the future, I would like to work in engineering and technology	3.00	3.50	1.70	2.32
In the future, I would like to work in music and art	1.20	1.23	1.40	1.40

Table 2 shows that students' attitude towards science and technology-related careers, has in general, increased, while there was minimal or no increase in attitudes towards careers in medicine, social areas, music and arts. Music and the arts were little, if at all, touched in the modules, whereas at the same time, medicine, economics and law have always been among the favourites for students' career choices.

Table 2. Students' attitude towards future career, before and after passing the course (N=62)

Statement.	Increased attitude N	No change N	Decreased attitude N
In the future, I would like to work in science related areas	18	38	4
In the future, I would like to work in medicine	5	22	2
In the future, I would like to work in social areas (economics, justice, etc)	3	25	3
In the future, I would like to work in engineering and technology	24	30	5
In the future, I would like to work in music and art	3	58	1

Interviews conducted with selected students supported our findings. Below are given selectedstudents' statements derived from the interviews to the question What did you learn about science and technology related careers?

.:*I thought ... that one should learn physics in high school to become a physicist, but now I realise that it may not be so straightforward, even those interested in medical studies and what is even more surprising, even music, should do well in physics.* (Male student 1)

I am interested in technology and I would like to become an engineer or something, so this was exactly for me... (Male student 2)

I never thought that there are so many different professions related to the cosmetic industry, I thought there are only people behind the conveyor belt... and, furthermore, you can use your imagination as well... (Female student 1)

I have thought about technology as man's world,, but now by studying cosmetics ... and the radiation module – how physics helps us to save our live, I think technology is, as well, for women... (Female student 2)

As seen from the excerpts, students had quite simplistic understanding related to science and technology careers – e.g. physics learning is seen as necessary only for becoming a physicist. Even if having an interest in technology studies, students often lack of knowledge related to the different sub-areas within the field as illustrated by male student 2. Still, and it could be considered as a positive effect of the course, students broadened their understanding about science and technology related careers, recognising (female student 2) that it could be for men as well for women and understanding that creative thinking plays an important role in designing processes (Female student 1).

Conclusions

Based on the results, it was concluded that the approach used played a role in developing students' (both boys and girls) positive attitudes towards careers related to science and technology.. Moreover, the course helped to broaden students' understanding about the diversity of the field of technology and how science and technology are related to each other. It is suggested that while teaching science topics, students should be informed about the professions related to the topic, allowing them opportunities for knowledge-based (vs. accidental or random) choices when graduating from school.

Evaluative comment by the principal investigator: Without in-service provided in the framework of the ESTABLISH project, it had been impossible to adapt modules for targeted use at the gymnasium level. The modules give freedom for furthers adaptations and equip teachers with more than the nessesary ideas, background and of great importance. motivating teachers to seek more evidence related to careers in industry and how these are related to school science learning. I would recommend all teachers to collect feedback from students to convince themselves of the success of such teaching and look forward for further modifications based on students' needs.

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Case Study 13: Czech Republic

Implementation of IBSE teacher education and national impact of ESTABLISH

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Abstract

This contribution deals with evaluation of benefits and impacts of the ESTABLISH project in the Czech Republic. First, it describes the situation in the science education in the Czech Republic in the time when the ESTABLISH project started, which was characterized by a first phase of school and curricular reform based on implementation of so called Framework educational programs (FEP).The reform required teachers to use modern teaching strategies and methods which support deeper and active involvement of pupils into education process. From this point of view, the inquiry based science education (IBSE) is one of the important approaches to fulfill requirements of the reform and ESTABLISH project provided very useful framework to teachers in the form of educational and methodical materials and support in implementation of the reform and IBSE into school routine. This report also describes the forms and frameworks of preparation and implementation of the educational and methodical materials in a form of educational units, and in the form of teacher´s educational program (TEP), which was important for education of teachers how to use IBSE in their practice. The cooperation with Czech companies and educational institutions and the future possible impacts of the ESTABLISH project are also discussed.

Introduction

In 2009, saw the beginning of a new era in implementation of school and curricular reform in the Czech Republic. In this year, all the secondary schools were obliged to start teaching in correspondence with so called School educational programs based on Framework educational programs (FEP), which in outline delimit the content and recommend the forms, methods and attitudes of education. The outcomes of the education are not evaluated just on the basis of knowledge acquired by pupils, but, also, by development of so called student´s key competencies. The key competencies "are a set of knowledge, skills, abilities, attitudes and values which are important for the personal development of an individual, his/her active participation in society and future success in life". Their selection and conception are based on which competencies are considered to be important for education.

The educational and curricular reform (and hence the FEP) supports implementation of new strategies of teaching which involve pupils more and support their own activity. With respect to that, inquire based science education (IBSE) showed to be a very suitable approach allowing to fulfill the requirements of FEPs. However, in the Czech Republic, in 2010, when the ESTABLISH project started, the inquiry based science education (IBSE) in science branches was not developed very much. The IBSE approach was not often applied in schools and teachers were not much informed about the IBSE way of teaching, in particular, there were only a few courses on IBSE in pre-service teachers' curricula and courses on IBSE for in-service teachers were rather rare. There was a deficiency of suitable educational materials, teacher's guides as well as methodical and theoretical materials, which could help teachers in implementation of IBSE into regular science education. In addition to that, the situation in research devoted to IBSE was in the beginning. There were only rough approaches regarding the ways how to assess and evaluate the IBSE and the effective ways in implementation of IBSE in science education still remained to be tested and evaluated. The ESTABLISH project provided necessary support to introduce the IBSE approach into primary as well as secondary school education and helped to some extent to solve some issues mentioned above.

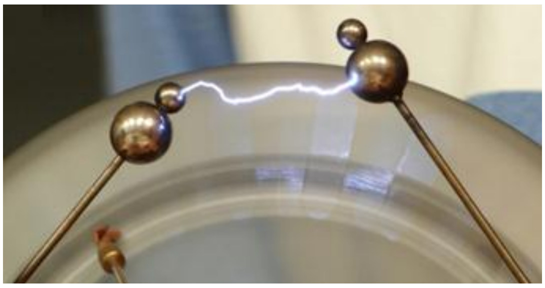
Unit Development and piloting

The format of educational IBSE units focused on important topics in physics, chemistry and biology, provided teachers with a very efficient tool to implement and use IBSE in their everyday "teacher's life". The units were prepared with respect to the needs of the teachers, so as they contain the theoretical and practical activities, theory and methodical materials for teachers, author´s notes etc., hence, the prepared units are relatively complex materials, and their users - teachers - can focus their attention on the implementation of IBSE into education. The authors from Charles University (CUNI) prepared or participated in design and preparation of three units – Water in the life of man, Polymers around us and Direct current electricity.

The unit Water in the life of man was prepared during the years 2011 and 2012. Based on the results of a pilot study in April and May 2012, the first reviews and comments of both Czech in-service teachers and also a group of Slovak experts, the unit was modified and completed in June 2012. It was subsequently translated into English and placed on the project website. Preliminary research of unit took place in somatology teaching at High school of nursing Ruská in Prague, Summer School IBE in biology and seminars Observation and experiment in school practice for pre-service teachers of biology.

The work on the development of Polymers around us unit started at the beginning of year 2011 and continued in the period of July 2011 – June 2012 in cooperation with the solvers from P. J. Šafárik University in Košice. An extensive material with three subunits has been created. This unit was finished in the spring 2012, translated into English and placed on the project website. Subsequently, it was piloted and fine-tuned based on the results of the pilot runs and suggestions of the ESTABLISH solver team, especially the new activities related to natural polymers have been added. Pilot runs were done at four schools in the Czech Republic – one primary school (Basic school Žernosecká, Prague), three grammar schools (Grammar school of Pierre de Courbertin in Tábor; Grammar school Písnická, Prague; Grammar school Zatlanka, Prague) and one secondary vocational school (Masaryk chemical secondary school, Prague). The total amount of students participating in the pilot runs was 126. Adjustment of all three Polymers subunits continued throughout second half of 2012 and beginning of 2013.

In the framework of the ESTABLISH project, 18 units have been prepared. All the prepared units were translated to Czech language, some of them are a part of an educational platform. Cooperating Czech teachers also participated not only in ESTABLISH Units preparation; they were also a part of the testing of ESTABLISH units from other authors, in particular of the units Disability, Blood donation, Exploring holes and Chemical care. Usually, the evaluation and testing of the unit activities covered more than 100 students and 3-4 schools.



Unit Blood donation was tested in teaching biology at five secondary schools in Prague, specifically on Grammar school prof. Patočka, Grammar school Na vítězné pláni, Business Academy Kubelíkova, Private high school of Tourism Arcus and High school of nursing Ruská in Prague.

Five teachers were involved in the project and the following nine activities were verified: Appeal for donating blood, Looking up information, Study visit at a transfusion center, Separation of blood constituents, Scientific conference, Interview, Determining blood types, Is Pavol the father?, Is it possible to produce artificial blood? Unit Disability was tested in somatology teaching at High school of nursing Ruská in Prague by one teacher. Three activities were tested: Receptors, nerves and nerve impulses, Why do we breathe? How is the pulse and respiratory rate affected by different activities? The unit Exploring holes was tested in basic school Žernosecká in Prague, grammar school Písnická in Prague, grammar school Tábor and Masaryk chemical secondary school in Prague; unit Chemical care was tested in grammar schools Malá Strana Grammar school in Prague, Botičská Grammar School in Prague and Masaryk chemical secondary school in Prague.

Implementing Teacher Education Programme

Not only the units prepared in the framework of ESTABLISH project increased interest in IBSE. Another important part of the project was a Teacher´s Education Programme (TEP). TEP prepared in the framework of ESTABLISH project has been modified with respect to Czech conditions and applied and tested in group of science teachers in case of both pre-service and in-service teachers. For pre-service teachers, the program ran two hours per a week during half a year. For in-service teachers, the program ran during weekends. The time schedule respected specific needs of both teacher groups. Despite the different time schedule, the contents and methodology of both programs were the same. As our main goal is to present the IBSE methodology to teachers, we led the lessons mostly with the same method. So during the course, teachers were suddenly in the role of their students. We aimed at their deeper understanding about benefits and disadvantages of teaching by IBSE method. During the program, we focused on developing various scientific ideas in participants.

The program included cooperation with industry fields at various levels. For example, companies provided materials from their own sources for the teachers (Meopta, a.s., Silon, s.r.o., etc.). Or we ensured several excursions for the participants not only in the industrial area (Silon, s.r.o., Coca-Cola Czech Republic…), but in museums and state institutions as well (SÚRAO – State institution for treatment of radioactive waste repository, Water treatment museum in Podolí, Prague). For example, the teachers visited the Police museum, where they also participated in a seminar about forensic biomechanics.

We consider these activities very important not only because of their educational aspect, but also because they provide the necessary contacts for teachers. They can use them further in their teaching practice. Hence, also a discussion and own activity of the participating teachers were important aspects (and parts) of the TEP. With respect to that, the specialized "discussion" activities were organized. They were Markets of ideas of chemistry and physics teachers and teachers also met in the framework of long-term project Heuréka, where the teachers mostly presented their ideas and educational methods. In the framework of these activities, the elements from TEP were successfully implemented and these activities further supported implementation of IBSE into science education.

Impact of ESTABLISH approach and resources

First, the Czech teachers (pre-service as well as in-service) were suspicious and they did not believe in IBSE efficiency. Regarding the activities, they suggested some questions which can be put by students and they wanted us to give answers. Nevertheless, we told them, that their students have to find the answers to the questions. And teachers can just help them in their way to find the answers and the truth. Finally, the majority of teachers understood that in implementation of IBSE, they have to change their attitude and begin to work in a new way, and now; the task of the teacher is not just to reveal the fact but to help the student to explore, explain and understand. Some of them started to introduce the ESTABLISH units in their lessons, at least some activities. The majority of teachers in TEP understood the principles of IBSE and evaluated the course positively. Nevertheless, what they mentioned as a disadvantage of IBSE is, that this way of education is time consuming and it requires the students to be motivated to some extent, which not always corresponds to the situation in the classes.

An invisible outcome of the ESTABLISH project is also the broadening and deeper cooperation with companies, which were suppliers of educational accessories (for example, Meopta company supplied lenses, mirrors and other optical elements; AV-media, Profimedia and Edufor helped with sensors and accessories, educational tools etc.), and a variety of aspects especially attributed to unit preparation were discussed and implemented into the units, which were enriched with industrial as well as practical issues. For example, the cooperation with the company Silon Planá helped in preparation of the unit Polymers around us, the cooperation with the water company Veolia (and particularly with their museum of water treatment) led to the enrichment of the unit Water in the life of men. Also, during the translation of the other ESTABLISH units, the units were adapted to the Czech conditions with the help of Czech companies. The cooperation with the companies was also appreciated by the teachers because it provided them with links to the employment of knowledge to common life and practice and other benefits, for example links to their possible excursions. Namely, the biology teachers were surprised by the possibilities of the implementation of industry content in the curriculum because it is not currently used in Czech biology education.

Broad cooperation has also been established with other educational institutions in the Czech Republic. One of the most important ones is the cooperation with the National institute of Education, which is an institute of the Ministry of Education, youth and sports of the Czech Republic (MEYS). This institute is responsible for the updating of the methodical as well as educational content of the curriculum and it creates conditions and recommendations for how to implement the updates into the Czech curriculum. The outcomes of the ESTABLISH project are hence important sources of the implementation of IBSE into Czech curriculum.

In the last year of the ESTABLISH project, a close cooperation with the Depositum Bonum Foundation has been established, in particular in the framework of the project Elixír do škol (Elixir into schools). The Depositum Bonum is a foundation supporting implementation of science education into schools through educational centers and meetings with science teachers and it represents itself as a new important type of stakeholder. During the meetings, the IBSE and outcomes of the ESTABLISH projects were/are presented and disseminated and they are an important base for the success of the project. The results of the ESTABLISH project were also important for the cooperation with science centers and museums (Science center IQpark in Liberec, National technical museum in Prague), for example in the design of some activities and exhibitions.

Conclusions and future implications

Thanks to the ESTABLISH project, the awareness about IBSE was successfully disseminated in the Czech Republic. The dissemination has been made in three main channels. Among the students, especially during the evaluation of the IBSE units and the implementation of units by teachers, among teachers, in the framework of TEP and specialized periodical courses for pre-service teachers and in the international scientific community. The basis, results and outcomes of the ESTABLISH project were presented at international and national scientific conferences and during fruitful discussions on IBSE issues a variety of ideas, suggestions and recommendations were distributed throughout the scientific community and reflected, for example, in courses at other universities.

The scientific community in the Czech Republic can also benefit from a wide research (including connected sources and references) made on the field of the evaluation impact of the IBSE approach on pupils. In the framework of the ESTABLISH project, a variety of new scientific tools has been designed and tested as they showed a scientific value. They mostly deal with the evaluation of the impact of IBSE on pupils, especially with respect to their motivation, nevertheless, the tools can also be used for the evaluation of the students' ideas about scientific tools and methods, which is not currently in the center of attention of the scientific community in the Czech Republic.

Without a doubt, the results and outcomes of the Establish project for education in the Czech Republic in the future provide us with a wide field of applications. The prepared IBSE units are published at the Establish educational platform and are also available in form of .pdf file, so they are easily available for teachers. The units contain a wide set of activities covering all the science branches and themes, as well as interdisciplinary topics. The teachers, especially those who attended and/or participated in TEP, will surely use them in their science subject lessons and employ them implementing the IBSE approach in science education. TEP or its elements are/will be used for a variety of courses on IBSE for in-service teachers held at Charles University and/or by cooperating partners e.g. the Depositum Bonum foundation.

The IBSE also became an integral (and important) part of the curriculum for pre-service teachers in the framework of their preparation for their future job at a university. Regarding that, IBSE will surely be a topic for new bachelor, master and Ph.D. theses. In the framework of the ESTABLISH project, two Ph.D. theses and three master theses on IBSE have been defended, the others are in course. In the framework of these theses, the new materials will be prepared, and also the materials created in the framework of the ESTABLISH project will be refined and broadened while experience from the preparation of the ESTABLISH units will be used. Elements of IBSE are/will be also implemented into curricular documents in the framework of cooperation with MEYS and its institutes.

In conclusion, it can be considered that the Establish project was/is/will be an important contribution in implementation of IBSE in education and educational system in the Czech Republic and its results provide a solid base for teachers in the employment of IBSE in science education in the Czech Republic.