

Chapter #4

INQUIRY-BASED SCIENCE EDUCATION MODULES AND THEIR EFFECTS ON TEACHER EDUCATION

Josef Trna, & Eva Trnova
Masaryk University, Czech Republic

ABSTRACT

Inquiry-based science education (IBSE) is currently rated as a promising educational method in science education. Science teachers should be provided with specific IBSE teaching/learning methods, techniques and tools, especially as teacher education for the implementation of IBSE in instruction is not yet sufficiently provided. The objective of this research is the development of an IBSE teaching method, based on modules in IBSE. The second objective is the implementation of this educational method into science teacher education. This research was conducted within the PROFILES project in the European 7th Framework Programme. The basic methods of the research were design-based research and the curricular Delphi study. The outcome of the PROFILES curricular Delphi study is a set of concepts in science education which were used as the theme for the overall design-based research. The main outcomes of the design-based research are the IBSE modules, which were used as the basis for training teachers in IBSE implementation. Emphasis was given to the teacher ownership and creativity. These modules were verified by teachers in practice through their action research. The PROFILES module “Safety of the human body: swimming and diving” is shown as a specific example of the research outcomes. An important research finding is that teachers educated in this way continue to implement this innovative educational method, which they acquired during their specific training in the project.

Keywords: IBSE, module, science education, teacher education.

1. INTRODUCTION

Nowadays science, as a core part of STEM (Science, Technology, Engineering and Mathematics), pervades many aspects of human lives. STEM is vital to our future and especially to the future of today’s children. For this reason, STEM is considered to be a crucial part of education for the current and future population. There is also expert consensus that science education should be a compulsory part of the education of all children. School science education does not perform this role (Osborne & Dillon, 2008) as some curricula are conceived as basic preparation for the minority of students who will become future scientists. This approach to science education is not appropriate for the majority of students who require a broad overview of the main ideas that science offers to help them acquire an understanding of the contemporary world. This conception of science education does not support the involvement of young people in the further study of science either, due to its lack of motivation.

Educators have the task of developing effective educational methods which are appropriate for innovative teaching/learning science and including practices that promote the learning of scientific concepts and processes as well as student inquiry, thus acquainting students with scientific methods showing how scientists study the natural world.

These hands-on and minds-on practices typically fill this role in inquiry-based science education (hereinafter IBSE), which is considered a suitable method for science education (Osborne, Ratcliffe, Collins, Millar, & Duschl, 2001; Osborne & Dillon, 2008; Duschl & Hamilton, 1998; Bell, Smetana, & Binns 2005; Banchi & Bell, 2008; Marshall & Horton, 2011). IBSE is a pedagogical approach which utilizes a constructivist theoretical framework to promote student learning. The core principles of IBSE are the involvement of students in discovering natural laws, linking information into a meaningful context, developing critical thinking and promoting positive attitudes towards science.

It is now necessary to develop specific IBSE methods and tools for teaching/learning in school practice as well as suitable teacher education for their implementation, which is crucial for the effective application of IBSE. The importance of high quality science teachers was, is and will be undisputed, but the most effective ways to prepare science teachers for implementing new methods into their practice are currently under discussion (Osborne & Dillon, 2008; National Research Council, 2010; Duschl & Grandy, 2008). Based on research findings (Osborn et al., 2001; Darling-Hammond & Bransford, 2007), teachers more easily accept changes to the curriculum than demands for transformation of their teaching style; they take a stand against adapting their teaching methods (Osborne, Duschl, & Fairbrother, 2002). They have built-in beliefs about ways and what to teach which are not easy to change. The issue of teacher education became one of the issues dealt with within the project PROFILES in the European 7th Framework Programme. The ways in which to implement continuous professional development (hereinafter CPD) in order for teachers to change their beliefs and ineffective teaching methods have been investigated. Science teacher education in the frame of the PROFILES CPD was implemented over three years because most teachers require a considerable amount of time to adopt the roles, beliefs and practices that are required in IBSE. The effectiveness of the created PROFILES CPD was verified in practice. This chapter presents the research results of the implementation of innovative methods and tools in IBSE into science teaching/learning and into science teacher education (CPD).

2. BACKGROUND

Current science and technology are developing rapidly and they deeply affect our everyday lives and education, which has to face economic, environmental, and social challenges, to an even greater extent. Therefore, it is necessary to prepare today's students for interaction with new science and technology ideas and their applications in the future. But there are some opinions (Robinson, 2009) stating that schools educate more for the past than the future. It was always difficult to define what knowledge and skills young people would need in the future, but in this era of rapid technological development, it is even more difficult. It is necessary to consider what science education students should receive that is appropriate with regard to content and format for their future life. In this context, the structure of the curriculum, educational methods and also motivation of students are discussed. To achieve their full potential as adults, children need to develop not only a range of skills and knowledge of school subjects but also skills such as problem solving, critical thinking, communication, collaboration, and self-management, which are often referred to as "21st century skills", and which business and political leaders would like to see developed in schools. Students should acquire a set of skills including critical thinking,

problem solving, cooperation, communication and self-education (Pellegrino & Hilton, 2012). Because the socio-economic success of Europe 2020 depends on the education of the new generation, new ways of science teaching/learning which should prepare today's children for their adult roles as citizens, employees, managers, parents, volunteers, and entrepreneurs, are being sought.

In the twentieth century educators have defined several science concepts as pragmatic, humanistic, scientific, etc. But these concepts are outdated and unsatisfactory. It is necessary to find a new concept, which would meet the current educational requirements. The effort to create a new paradigm comes from the need to change science education. The current science education should be focused on the design of instructional environments that involve students' scientific inquiry, supporting understanding of science and the interest of students. An inquiry approach, if carried out effectively, offers the promise of achieving crucial aims like understanding fundamental scientific ideas; of the nature of science, scientific inquiry, reasoning; scientific competences of gathering and using evidence; scientific attitudes, both attitudes within science and towards science; skills that support learning throughout life; the ability to communicate using appropriate language and representations to a greater degree than traditional approaches to teaching and learning science (Bell, Smetana, & Binns, 2005; Banchi & Bell, 2008; Marshall & Horton, 2011). Engaging students in inquiry-based instruction dates back to Dewey (1938), who believed that students learn from their experiences gained through activities or real world problem-solving and discussion with others. This constructivist view of learning gives theoretical support to teachers in facilitating students in developing their own knowledge through the process of interacting with objects in the environment and engaging in higher-level thinking and problem solving (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

As mentioned above, IBSE is currently considered to be an appropriate method that matches the constructivist principles of science education and meets the requirements for innovative science education. Students identify a problem or pose a question, propose an explanation or solution, choose a method to test their proposal or answer their question and, through the process of inquiry, extend their knowledge and develop deep conceptual understandings (Bell, Smetana, & Binns, 2005; Banchi & Bell, 2008; Marshall & Horton, 2011; Osborne, Duschl, & Fairbrother, 2002). These activities are more student-centred than teacher-centred and are related to issues of everyday student life, therefore they support the intrinsic motivation of all students, not only those who are interested in science. With regard to teacher and student involvement, it is possible to define four levels of IBSE: confirmative, structured, guided and open (Banchi & Bell, 2008). The extent of teacher direction in inquiry based learning is a critical factor in determining the level of the inquiry. All inquiry levels include the same basic features – a central question or problem, an information-seeking phase and a concluding stage, but IBSE is arranged on a continuum, with confirmation inquiry at one end of the spectrum and open inquiry at the other (Bell, Smetana, & Binns, 2005; Banchi & Bell, 2008), which illustrates how inquiry-based learning can range from highly teacher directed to highly student directed. To keep students optimally challenged, it is crucial that teachers adjust their role while directing students from structured inquiry towards open inquiry.

However, it is necessary to educate teachers in the implementation of IBSE into student science education, because the quality of teachers is one of the most important factors influencing educational outcomes (Darling-Hammond, 2000; Hanusek, Kain, & Rivkin, 2005). In order to be successful IBSE has to be accepted by teachers, because research findings show that teachers are reluctant to accept the changes of teaching

activities, practices, and curricula which are forced upon them by administrators, policy-makers, etc. (Pajares, 1992; Raymond, 1997; Richardson, 1998; Lederman, 1999; Powers, Zippay, & Butler, 2006). Findings substantiate (Pajares, 1992; Powers, Zippay, & Butler, 2006; Marshall & Horton, 2011) the close relationship between teachers' beliefs and their school practice. Teachers have to believe in IBSE and accept it as their own teaching style. But according to Raymond (1997), there is inertia in teachers' beliefs; therefore it is important to prepare effective science teacher education in the form of CPD. If teacher education is to be successful, it is necessary to know teacher beliefs and attitudes towards science education, which is why some specific research was undertaken – a curricular Delphi study.

The development of innovative teacher education respecting new trends in science education was involved as a core issue in the PROFILES project (**P**rofessional **R**eflection-**O**riented **F**ocus on **I**nquiry-based **L**earning and **E**ducation through **S**cience) in the European 7th Framework Programme (PROFILES, 2015). The aim of this project was to find a method of teaching/learning that meets the principles of IBSE and to prepare a suitable method of science teacher education. A *PROFILES module* was developed as an appropriate specific teaching/learning instrument. Project activities also focused on teacher-participant CPD aimed at the implementation of PROFILES modules in IBSE. Teachers and participants in this CPD went through the following roles:

- *teacher as learner* - mastery of knowledge related to modules
- *teacher as teacher* - recognizing and meaningfully adopting teaching strategies for student inquiry learning and an IBSE approach to teaching
- *teacher as reflective practitioner* - developing and adapting modules based on cultural and gender needs, promoting student cooperative learning, development of strategies for intrinsic motivation, open inquiry learning, student learning classroom climate, meaningful assessment/feedback strategies
- *teacher as leader* - guiding the development of innovative pedagogical practices by other teachers, especially to stimulate autonomous learning, to guide teachers to recognize the need and approach to enhancing scientific literacy for responsible citizenry and careers

Detailed description of the objectives, methods and outputs of the project PROFILES can be obtained from <http://www.profiles-project.eu/>.

According to (Harlen & Allende, 2009), when teachers are learning to use new materials and pedagogy, their needs are similar to those of any learners, particularly the need to communicate with and have feedback from others and to have time for reflection as learners. These are more likely to be provided, and teachers are more likely to develop ownership of their learning, when professional development sessions take place intermittently over a period of time, with opportunities between sessions for teachers to practice what they have learned in their own classrooms and to share experiences from their roles as teachers or reflective practitioners with others. Implementation of this way of CPD assumes a change in teacher beliefs.

3. OBJECTIVES AND METHODS

Research questions were based on the project objectives, which were to develop an effective IBSE special teaching/learning method and to develop a teacher training method for appropriate implementation of this educational method. The first research question concerning the IBSE educational method was: *Which innovative educational method of teaching/learning science meets school practice needs and complies with the principles of*

IBSE? The second research question aimed at teacher training was: *Can teacher training in IBSE implementation affect teachers' professional and personal development?*

To address the research questions, two main research methods used were: design-based research (Reeves, 2006) and the curricular Delphi study (Osborn et al., 2001; Bolte, 2008). The main reason for choosing BDR as a research method was its close link to school practice and its developmental character. The PROFILES project was focused on the research and development of fundamental problems of school practice, specifically on innovation in science education. The main products of the research had to be verified in practical action research. The teacher-participants of the project were members of the research team as well as research objects.

Design-based research (hereinafter DBR) can be described as a cycle analysis of a practical problem, development of solutions, testing of solutions, reflection and implementation (Reeves, 2006).

In this case, DBR has the following structure:

(1) *Analysis of practical problems:* the existing educational problems in the implementation of IBSE and teacher training were identified especially by use of the curricular Delphi study which was adapted for the PROFILES project (Bolte et al., 2012). Detailed description of the PROFILES curricular Delphi method can be obtained from PROFILES (2015). The main objective of this curricular Delphi study was to find out the views of different groups of respondents-stakeholders in science education to the contents and objectives of science education in general as well as to engage them to express an opinion on IBSE and motivation. Four groups of respondents-stakeholders in the Czech Republic were questioned: 56 upper secondary school students (age 14-16), 30 science teachers (secondary school teachers), 28 science educators (university teachers) and 25 scientists (university researchers). The Czech part of the PROFILES curricular Delphi study on science education was carried out in three rounds between the years 2011-2013. The output of the second round of the PROFILES curricular Delphi study was three concepts of science education and the third round was aimed at the opinions of respondents-stakeholders on them. The views of the respondents were examined from two perspectives: reality (practice) and priorities (wishes) of science education in schools.

(2) *Development of solutions with a theoretical framework:* a special teaching/learning method based on all IBSE principles (IBSE module) was developed and teacher training courses for module implementation were created. At this stage, specific development of IBSE modules was conducted.

(3) *Evaluation and testing of solutions in practice:* In this step of the DBR several research methods were used. Teachers-participants of the PROFILES CPD verified the appropriateness of the modules using action research, which allowed testing and also development of modules. After implementation of the PROFILES modules, teachers-participants were asked to find out their beliefs regarding their ownership and improvement of their competences. The research PROFILES team from Weizmann Institute (Israel) developed a questionnaire with a 9-point Likert scale of responses (1 point is the minimum, 9 points is the maximum) for identifying these teachers' opinions (Bolte et al., 2012).

(4) *Documentation and reflection to produce "Design principles":* The final stage was the documentation and the establishment of new principles for the implementation of the PROFILES modules.

Within the DBR partial additional quantitative and qualitative research methods such as an interview and tests were also used.

4. RESULTS

The research results presented in this chapter were developed within the frame of the PROFILES project; however, they were acquired, processed and modified by the authors of the chapter in specific conditions in the Czech Republic. These creative research outputs include in particular the findings of the role of experiments in IBSE and their taxonomy (Trna, 2013), development of special IBSE methods for gifted students (Trna & Trnova, 2014), studying the development of teacher creativity during the PROFILES CPD courses (Trnova, 2014), etc.

When implementing the first step of the DBR (*1. Analysis of practical problems*) the curricular Delphi study was used. It brought about many findings, the main ones being the three innovative approaches to science education that the stakeholders recommended for the future. In the following part three concepts of science education as the outcome of the curricular Delphi study are presented. Brief characteristics of the particular concepts are introduced:

(A) Awareness of science in current, social, globally relevant and occupational contexts in both educational and out-of-school settings, enhancing emotional personality development and basic skills

(B) Intellectual education in interdisciplinary contexts refers to an engagement with science, its terminology, methods, basic concepts, interdisciplinary relations, findings and their perspectives, which enhance individual intellectual personality development

(C) General science-related education and facilitation of interest in the contexts of nature, everyday life and living environmental issues which take up and promote students' interests, enhancing general personality development and education

These three concepts of science education are an appropriate contribution to the current debate about the future STEM paradigm. According to some experts, we live in an era of multi-paradigms, which corresponds to our findings about the discovery of the three concepts. At this point the role of these concepts is not discussed, but it will be supplemented by stating the views of the stakeholders of the curricular Delphi study on the role of concepts (A), (B) and (C) in teaching/learning at various educational levels: pre-schools, primary schools, lower secondary schools, and upper secondary schools.

The results include descriptive-statistical analyses of the third round of the curricular Delphi study with regard to the *priority* and *reality* assessments as well as to the identified *priority-reality differences*. The analyses and descriptions are made on the basis of the total stakeholder sample (139 respondents) consisting of different sample groups (56 students of upper secondary schools, 30 secondary school teacher, 28 education researchers and 25 scientists). A questionnaire with a 6 point Likert scale was used (Bolte, 2008; Bolte et al., 2012). Respondents were asked to sign their opinion in two cases: (1) their priority and (2) their assessment of the reality of the use of the science teaching/learning concepts (A), (B) and (C). As a test to identify statistically significant differences between the assessments of the three concepts, the Wilcoxon signed-rank test was applied. Table 1 shows assessments from the priority (wishes) point of view, Table 2 shows assessments from the reality (practice) point of view and Table 3 shows assessments of the priority-practice differences of all respondents.

Inquiry-Based Science Education Modules and their Effects on Teacher Education

Table 1. Mean values of the priority assessments by the total sample regarding different educational levels and significance test values (Wilcoxon signed-rank test).

N = 139	Mean values (Likert scale: 1 = very low; 2 = low; 3 = rather low; 4 = rather high; 5 = high; 6 = very high)			Significance values		
Educational level	Concept A: Awareness of the sciences in current, social, globally relevant and occupational contexts relevant in both educational and out-of-school settings	Concept B: Intellectual education in interdisciplinary scientific contexts	Concept C: General science-related education and facilitation of interest in contexts of nature, everyday life and living environment	A/B	A/C	B/C
Pre-school	3.1	2.4	4.2	<0.001	<0.001	<0.001
Primary schools	3.8	3.2	4.4	<0.001	<0.001	<0.001
Lower secondary schools	4.6	4.1	4.8	<0.001	0.008	<0.001
Upper secondary schools	5.2	4.9	4.9	0.010	0.003	0.85

It can be seen that, overall, the averages of the mean values were higher the higher the educational levels are. Most of the assessments differed from each other in a statistically significant way.

Table 2. Mean values of the reality assessments by the total sample regarding different educational levels and significance test values (Wilcoxon signed-rank test).

N = 139	Mean values (Likert scale: 1 = very low; 2 = low; 3 = rather low; 4 = rather high; 5 = high; 6 = very high)			Significance values		
Educational level	Concept A: Awareness of the sciences in current, social, globally relevant and occupational contexts relevant in both educational and out-of-school settings	Concept B: Intellectual education in interdisciplinary scientific contexts	Concept C: General science-related education and facilitation of interest in contexts of nature, everyday life and living environment	A/B	A/C	B/C
Pre-school	2.1	2.0	2.8	0.238	<0.001	<0.001
Primary schools	2.8	2.7	3.2	0.284	<0.001	<0.001
Lower secondary schools	3.4	3.4	3.3	0.927	0.345	0.555
Upper secondary schools	3.7	3.8	3.4	0.713	0.003	0.002

The highest overall average of the mean values in the assessments occurred for upper secondary education. The overall averages of the mean values for the other educational levels were gradually lower. Only a few assessments differed from each other in a statistically significant way.

Table 3. Mean values of the priority-reality assessments by the total sample regarding different educational levels and significance test values (Wilcoxon signed-rank test).

N = 139		Mean values (Likert scale: 1 = very low; 2 = low; 3 = rather low; 4 = rather high; 5 = high; 6 = very high)			Significance values		
Educational level	Concept A: Awareness of the sciences in current, social, globally relevant and occupational contexts relevant in both educational and out-of-school settings	Concept B: Intellectual education in interdisciplinary scientific contexts	Concept C: General science-related education and facilitation of interest in contexts of nature, everyday life and living environment	A/B	A/C	B/C	
Pre-school	1.0	0.4	1.4	<0.001	<0.001	<0.001	
Primary schools	1.0	0.5	1.2	<0.001	0.064	<0.001	
Lower secondary schools	1.2	0.7	1.5	<0.001	0.007	<0.001	
Upper secondary schools	1.5	1.2	1.5	0.025	0.888	0.046	

The mean values of the (A) and (C) concepts were higher than (B) for most educational levels. Only A/C concepts did not differ from each other in a statistically significant way. Also, there were no statistically significant priority-reality differences in upper secondary schools.

With regard to the assessments of the three concepts by the total sample regarding different educational levels, the analyses reveal that the concepts are seen as more important the higher the educational level is. The concept assessed as most important is the concept referring to general science-related education (Concept C). The priority-reality differences indicate that for all educational levels the concepts' assigned priority is not reflected in reality (school practice).

The results in the form of these three concepts and relevant educational content were used as a starting point in the following step of the DBR (2. *Development of solutions with a theoretical framework*). The main outcome of these steps of the DBR is the **PROFILES module** as a core unit of IBSE. The **PROFILES module** has been developed on a 3-stage model (Bolte et al., 2012):

(1) Initiation of the learning happens in a familiar and student-relevant situation when students identify with this socio-scientific situation and feel that it is within their sphere of interest and action. Teachers stimulate students through a scenario. This is a narrative (story) based on everyday problems. It is designed to evoke interest and to raise questions in order to find answers.

(2) In the second stage the students' triggered self-motivation encourages them to be involved in the IBSE learning process. Students realize their own inquiry-based learning cognitive activities.

(3) In the third stage, the students transfer their inquiry-based learning to the relevant socio-scientific situation encountered in the scenario and develop reasoned justification for decisions.

The PROFILES module is based on motivation and a problem scenario (Trnova & Trna, 2015). The scenario brings scientific-social issues to teaching/learning. The students create questions and problems, which are solved with the use of their own inquiry. Structured and guided inquiry of IBSE is used. Students' experimentation is usually applied. Finally, the students return to the initial scenario through which they make decisions and recommendations. Formally, the PROFILES module consists of materials for student activities and teacher guidance.

These PROFILES modules were used as the core of teacher education in the PROFILES CPD. The teacher-trainees in the project were familiarized with the PROFILES modules and their roles, and they implemented these PROFILES modules into their teaching. In doing so, the teachers modified these modules and at the end of the training they made their own PROFILES modules. The PROFILES modules were then verified by the teachers in practice through their action research. Emphasis was given to teacher ownership and creativity. The role of teacher creativity was especially supported by the creation of their own PROFILES modules. Following the PROFILES module: "*Safety of the human body: swimming and diving*" may serve as an example of developmental product of the whole DBR. This PROFILES module was developed by the authors of the chapter:

Scenario: Death when diving

News from a TV broadcast: Yesterday the famous singer D. N. tragically died when scuba-diving at the seaside resort of H. A local police spokesman said that the exact cause of death would be clarified by means of autopsy ordered by the court. Senior instructor in diving L. T. answered our query as to what can cause a tragedy when diving - it may be a small injury, e.g. a ruptured eardrum. Details will be included in subsequent news.

In this case, students usually ask the following questions:

- *What properties of water can cause health risks or even the death of a person?*
- *Which organs of the human body can be damaged when swimming and diving and why?*
- *What kinds of swimming and diving in the water are risky?*
- *Which rules of safe swimming and diving do we follow?*

The next step is students' activities where students research, seek information leading to a solution, discuss with peers in groups and perform experiments. Example of the experiment:

Experiment: Modeling of ear-drum rupture under high water pressure

Instructions for students' experimenting:

- *The basic experiment aid is a plastic bottle with a wide neck. The bottle cap is drilled and the valve of a tire is screwed into it. Overpressure in the plastic bottles in all experiments is achieved by pressing with hands or with a small bicycle tyre-pump.*
- *Instruments in plastics bottles are fixed on stands made out of copper wire, a metal stick and small wooden plates (see Figure 1).*

- Cover the mouth of the test tube with the rubber membrane (of an inflatable balloon) and secure with a rubber band. Connect the bicycle to the valve and pump - you produce overpressure of air in the bottle. The membrane under the influence of pressure is bent into the test tube. The deflection of the membrane increases with increasing overpressure (Figure 2).

Figure 1. Instruments in a plastic bottle.



Figure 2. Plastic bottle with a test tube covered by a rubber membrane.



- Replace the rubber membrane with a thin plastic membrane. Under the influence of pressure it is also bent into a test tube (Figure 3). If overpressure in the bottle is sufficiently great, the plastic membrane ruptures (see Figure 4).

Figure 3. Plastic bottle with test tube covered by a plastic membrane.

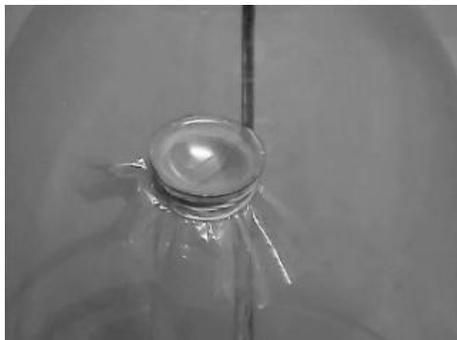
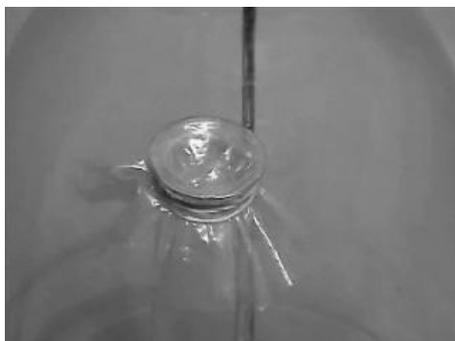


Figure 4. Plastic bottle with test tube covered by a ruptured plastic membrane.



The rubber and plastic membranes simulate the behavior of the ear-drum when swimming, bathing and diving. Water in the ear (ear canal) pushes on the ear-drum similarly to the air on the membranes in the case of our experiment. The result of this pressure is deformation of the eardrum and in the case of high pressure (overpressure) rupture of the ear-drum.

The third and the final phase was student decision-making. In this case, students, using inquiry, came to the following conclusion:

- The deformational effect of overpressure force is demonstrated by the rupture of the membrane covering the test tube made out of a piece of a plastic bag.
- The plastic membrane simulates the terminal behavior of an ear-drum when swimming, bathing and diving. Water in the ear canal pushes on the ear-drum by a heavy force. The result is the rupture of the ear-drum. The implication of this rupture is acute pain and the loss of ability to find direction. This means danger of death for the diver.

The research results of the third step of the DBR (3. Evaluation and testing of solutions in practice) also include a teachers' evaluation. After being involved in PROFILES CPD including implementation of the PROFILES modules, teachers were asked to find out their beliefs regarding their ownership and improvement of their competences. The research PROFILES team from Weizmann Institute (Israel) developed a questionnaire with a 9-point Likert scale of responses (1 point is the minimum – “very low”, 9 points is the maximum – “very high”). Table 4 shows selected items from the questionnaire and their mean values. This questionnaire was distributed to 50 teachers-participants of the project PROFILES in the years 2013-2104 in the Czech Republic.

Table 4. Mean values of teacher beliefs after PROFILES modules implementation.

Teacher Beliefs N = 50	Mean values (9 point Likert scale; 1= min.; 9 = max.)
How well can you identify a PROFILES module which is relevant to your students?	6.9
How well can you use the PROFILES modules to promote inquiry-based learning by your students?	6.5
How well can you guide students towards justified decision-making?	6.8
How well can you make an adaptation of a module to your class?	7.6
How well can you design a new module for your class?	6.8
How well can you perform reflection on your teaching?	7.0

On the base the results mentioned above, it could be concluded that teachers are satisfied with the implementation of the PROFILES modules into teaching. They believe that there has been development of fundamental student skills such as inquiry, decision-making, etc. It is very important that teachers feel an increase in their ownership and improvement of their competences. They are able to design a new module relevant to their students.

The fourth step of the DBR (*4. Documentation and reflection to produce "Design principles"*) may be summarized in several major conclusions, which are simultaneously answers to research questions:

- Implementation of the PROFILES modules is an appropriate innovative educational method of teaching/learning science; it meets school practice needs and complies with the principles of IBSE
- The scenario with a socio-scientific situation is an effective motivational tool of the PROFILES modules
- Implementation of IBSE modules into teaching/learning science meets many current science education requirements
- The implementation of IBSE modules leads to increased motivation and ownership of teachers

These design principles are supported not only by the above presented research outcomes, but also by other studies of authors of the chapter (Trnova & Trna, 2015) and their collaborators in the project PROFILES (Bolte, Holbrook, Mamlok-Naaman, & Rauch, 2014).

5. DISCUSSION

The PROFILES modules have an important role in the CPD of teachers. The project aims to improve the preparation of teachers in strengthening their competences in IBSE. The aim is also to motivate them and strengthen their ownership, as a prerequisite for professional and personal development.

Special research was focused on the development of the creativity of teachers as a significant personal and professional component and an important part of their CPD. According to Sternberg & Williams (1996) and Amabile (1998) a creative teacher is necessary for developing students' creativity. Teacher creativity is one of the core teaching factors. Quality development of teacher competences cannot exist without creativity. A hypothesis for future research is that high quality of CPD is determined by the development of teacher creativity. As creativity is a crucial factor in the multidimensional development of teacher professional competences, the role of creativity was examined in a number of partial dimensions within this development.

The extent to which the implementation, modification and creation of new modules affected the creativity of teachers was investigated through conducting a case study of teacher-participants of PROFILES CPD (Bolte, Holbrook, Mamlok-Naaman, & Rauch, 2014). Creativity plays a decisive role in this development (Lin, 2011), and as this case study documents all creativity, elements mentioned by Guilford (1980) were developed:

- Resourcefulness (the ability to create a wide flow of ideas): *The teachers themselves demonstrated their development from self-efficacy from the CPD to teacher ownership of the PROFILES ideas evidenced by creating a new module.*

- Readiness, perceptiveness (the ability to modify ideas or jump from one idea to another): *The teacher was able to exhibit sufficient ownership of PROFILES ideas changing the form of experiments and worksheets according to changing conditions when testing out the new module.*

- Originality (unusualness of ideas): *The teacher created a completely original PROFILES module, which was still related to the underlying philosophy.*

- Imagination (production of ideas that are not obvious at first sight): *The teacher created a new PROFILES module with a difficult connection of the topic with daily life.*

- Endeavour (creativity is not only inspirational, but also hard work): *The teacher worked all the time with passion, alone and very hard.*

The research has led us to conclude that PROFILES CPD can affect not only the development of professional competences of teachers, but also the development of major components of their personality, including creativity (Trnova, 2014). The outcomes of the research confirm that using the PROFILES modules during teacher CPD may cause positive changes in the development of teacher creativity and ownership.

6. CONCLUSION

It was confirmed by the use of the curricular Delphi study that current science education needs innovation and that IBSE seems to be a suitable innovation because of strong motivational and constructivist effectiveness. It arouses intrinsic motivation among students and supports them in learning about scientific inquiry and the nature of science. Similarly, it can be concluded that the education of teachers for IBSE is a suitable method for their professional and personal development.

The main outcome of the presented design-based research is the development of the PROFILES module as an important tool of innovated science education. This research has enriched the theory of IBSE by developing of the rules to which belong in particular:

- implementation of the PROFILES modules with the scenario with a socio-scientific situation is appropriate innovative educational method of teaching/learning science meets school practice needs and complies with the principles of IBSE

- implementation of IBSE modules into teaching/learning of science meets many current educational requirements and leads to increased motivation and ownership of teachers

Based on the presented design-based research outcomes, two important roles of the PROFILES modules were verified:

- streamlining of science education students, with an emphasis on their motivation and activity

- development of teacher professional competences and personality

The results of the research should be implemented in the theory of science teacher education. In the preparation and implementation of training courses for teachers attention should be paid not only to innovative educational methods for students, but also to teacher professional and personal development.

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AUTHORS INFORMATION

Full name: Josef Trna

Institutional affiliation: Faculty of Education, Masaryk University, Czech Republic

Institutional address: Porici 7, 603 00 Brno, Czech Republic

Short biographical sketch: He is an associate professor of physics/science education and the ex-dean of the Faculty of Education, Masaryk University. He holds PhD in physics education and MA in mathematics and physics education. In doctoral studies he focused on motivation in physics education. He is experienced in secondary school mathematics, physics and science teaching. His main research domains are: motivation of students in science education, IBSE, diagnostics of students' skills in science education, simple school experiments, educational video programs, curricula designing, education of gifted students, design-based research, connectivism etc. He co-operates with science educators and researchers on many projects including the project PROFILES. (Web: <http://www.muni.cz/people/2027>)

J. Trna, & E. Trnova

Full name: Eva Trnova

Institutional affiliation: Faculty of Education, Masaryk University, Czech Republic

Institutional address: Porici 7, 603 00 Brno, Czech Republic

Short biographical sketch: She is a senior lecturer of chemistry/science education at the Faculty of Education, Masaryk University. She holds PhD in chemistry education and MA in chemistry and biology education. She is experienced in secondary school biology, chemistry and science teaching. In doctoral studies she focused on development of students' skills in chemistry education. Her research focuses on sustainable development education, IBSE, E-learning, development of students' skills in science education, learning tasks in science education, education of gifted students, design-based research, connectivism, teacher education, creativity in education etc. She has wide experience in science teacher continuous professional development and she participated in several European projects in science education including the project PROFILES.
(Web: <http://www.muni.cz/people/26136>).