Modules in IBSE as Outputs of Applied Research in Didactics of Physics

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1 Introduction

Current science education focuses on an instructional environment that involve students' activities, in particular their inquiry. Some experts (Brown, 1990; Schwab, 1976) highlight engaging students in pursuing answers to questions important in their lives. Inquiry-based science education (hereinafter IBSE) dates back to Dewey (1938), who believed that students learn from their activities through extended experiences in real world problem-solving and discussion with others. This constructivist learning gives theoretical support in facilitating students in development their own knowledge through a process of interacting with objects in the environment and engaging in higher-level thinking and problem solving (Driver et al., 1994). IBSE is in general considered an appropriate teaching/learning strategy that matches with the constructivist principles of science education.

European research project PROFILES (Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science) in the European 7th Framework Programme (PROFILES, 2016) deals with supporting science teachers in implementation of IBSE in science education where the student's inquiry is a major teaching/learning objective. The PROFILES project improves the teachers' knowledge and skills in creation of scientific problem-solving and socio-scientific related learning environments. This learning environment enhance students' intrinsic motivation and interest to learn science and their individual competencies such as decision-making abilities and capabilities in inquiry.

Research in didactics of physics should bring practical application in the form of innovative educational strategies, methods and tools. Modules in IBSE are a useful educational tool which enables the practical implementation of IBSE into school practice teaching/learning physics and science. These modules were developed and verified within the project PROFILES. An imaginative core of the module in IBSE is a scenario, what is a narrative, which motivates students to solve science problems. Experiments play an important role in these modules, because they reinforce the activities of students. Specific examples of modules in IBSE with experiments is an integral part of the study.

2 Educational role of modules in IBSE

IBSE has a number of concrete educational forms, which are applied in school teaching/learning practice. The PROFILES project brought a new educational form, which hides under the name of the *module in IBSE*, which is based on social constructivism and other current ideas of contemporary science education in Europe and worldwide. The module in IBSE complies with the set of characteristics of development and implementation, because it:

- reflects the needs and attitudes of students in science education
- relates to the everyday lives of students
- strengthens and supports the acquisition of knowledge in accordance with the principle of proportionality of age, cognitive abilities and expectations of students
- integrates research approaches (IBSE), thus ensuring the development of students' skills in solving research problems
- integrates cross-curricular topics
- leads students to think about issues and responsible decision making
- focuses on the intrinsic motivation of students

The module of IBSE was designed, tested and applied within the PROFILES project. The design of the module in IBSE was based on a three-tier model (Bolte, Streller, Holbrook, Rannikmae, Hofstein, & Naaman, 2012), which allows the module in IBSE to be implemented into teaching/learning with the following structure:

1st stage of the module in IBSE:
The core of this first stage is student motivation, which is encouraged through a problem situation (Trnova, & Trna, 2015). It is necessary to motivate students to solve problems in IBSE. The specific educational instrument is a scenario, which is a story based on the everyday problems of the students' lives. The scenario brings science-social issues to teaching/learning. The scenario is designed to attract interest and evoke questions in order to find answers through subsequent students' inquiry. Very important is a module's title further amplified by means of the scenario. The title relates to the students' world, using familiar words, therefore unknown, and/or non-general scientific words are absent. We can in general motivate students through extrinsic and intrinsic motivation. For several reasons, we prefer intrinsic cognitive motivation that results in changes in student's interest. Narratives play an important role in our lives. According to Andrews, Squire, & Tambokou (2008), it is possible to accept the premise that, as human beings, we come to understand and give meaning to our lives through narratives. In the gathering and telling of "stories", we are gathering knowledge from life and knowledge about life (Bochner, 2007). People ascribe importance to ideas described in narratives because they try to find the answer to their questions or new ideas (Josselson, 2006). Purpose of the scenario is to enable a better understanding of problem issues. It makes science education more relevant, more interesting and hence more meaningful for students. The scenario is often based on students' lives and experiences. A properly conceived scenario should raise questions students want to solve. This is the advantage of IBSE because students with different levels of knowledge and skills or interests (gifted - ungifted; future scientists - non-scientists) ask and then solve different questions. Therefore it is possible to apply an individual motivational approach. After considering the scenario, students move from the situation to the research questions to be studied.

2nd stage of the module in IBSE:
In this stage students are involved in their own inquiry leading to active problem solving formulated into research questions, based on the scenario. Students are expected to construct meaning in a motivational manner through exploring the scenario. The intrinsic cognitive motivation from the scenario encourages students' spontaneous participation in the processes of IBSE. This motivation is necessary to strengthen by the fact that students recognize the problem as important to them. They want to deal with it and that problem solution is appropriate for them. Finally in the 3rd stage of the module in IBSE students return to the initial scenario through which they make decisions and recommendations. Students implement their own inquiry based on cognitive learning activities, the extent of which depends on the relevant level of IBSE. Structured and guided level of inquiry of IBSE is used (Trna, & Trnova, 2015). Students' experimentation is usually applied.

3rd stage of the module in IBSE:
After doing their own inquiry in the second stage, students return to the original problem contained in the scenario. They decide how to solve the problem and how to answer the research questions. Students rationally justify their conclusions, based on the results of their own inquiry. They use the newly-acquired knowledge and skills for their decision making.

3 Structure of modules in IBSE

From a practical point of view the module in IBSE is divided into two parts:
• Student activities
• Teacher guide

In the student activities all module activities are provided, including tasks for students, descriptions and instructions for experiments, additional information, etc. Student activities contain the following parts:
• Scenario
• Problems and questions
• Tasks, experiments and measurements
• Solving problems and conclusions

The teacher guide is a methodological guide for teachers, in which student activities are repeated and accompanied by instructions and manuals for teachers showing how to lead the students in their experiments. The teacher guide has the following structure:
• Description of the module
• Methodology module
  - Scenario
  - Problems and questions
  - Tasks, experiments and measurements
  - Solving problems and conclusions
• Comments and recommendations

The teacher guide contains teaching activities graphically highlighted in the relevant parts. The teacher does not need to follow the instructions; they only serve as recommendations and for introducing good practice. They should help teachers especially at the stage when they do not have enough experience with IBSE.

4 Example of a module in IBSE

Modules in IBSE are a good educational tool for the above presented reasons. Most of these modules have an interdisciplinary character, thus they are useful in teaching/learning more science subjects including physics. As an example is selected the module in IBSE, which is suitable for teaching physics with a close link to biology. This module in IBSE has the title: “Safety in swimming and diving”. This module was created by the authors of the study and verified in practice.

Title:
Safety in swimming and diving
Scenario:
Death during diving
News from a TV broadcast: Yesterday famous singer D.N. tragically died during a scuba-diving in the seaside resort of H. Local police spokesman said that the exact cause of death will be clarified by means of autopsy ordered by the court. Senior instructor diving L.T. answered our query what can cause tragedy during diving - it may be a small injury, which is e.g. ruptured eardrum. Details will be included in subsequent news.

Problems and questions:
Students ask the following questions based on the scenario:
(a) What properties of water can cause health risks or even death of a man?
(b) Which organs of the human body and why can be damaged during swimming and diving?
(c) What kinds of swimming and diving in the water are risky?
(d) Which rules of safe swimming and diving we follow?

Tasks and experiments:
Students’ inquiry activities are the next step, when students seek information leading to a solution, discuss with peers in groups and perform experiments.

Compression of lung
Inflate the rubber balloon inside a plastic bottle (see Figure 1).

Figure 1. The balloon inside a plastic bottle

The over pressure in the bottle, caused by velocipede tire-pump, causes reduction in volume of the balloon (see Figure 2).

Figure 2. The over pressure in the bottle

After opening the bottle balloon expands again (Figure3).

Figure 3. The increasing balloon

Results and implications of experiment:

- *Deformational effect of overpressure force is demonstrated by changing volume of an inflated small rubber balloon.*
- *The overpressure under water during diving reduces the lung volume. We are able to breathe spontaneously only about one metre under the water surface. Air must be pumped into our lung by overpressure during diving. At a depth of ten metres the lung volume is reduced to half. If diver emerges too quickly, his lung can be fatally damaged.*

Decision making:
The final phase is student decision-making. In this case, students, using inquiry, came to the following decisions and recommendations:

Answers to questions:

Briefly answer the questions that you are expressed at the beginning of your inquiry.

(a) What properties of water can cause health risks or even death of a man?

Answer:

(b) Which organs of the human body and why can be damaged during swimming and diving?

Answer:

(c) What kinds of swimming and diving in the water are risky?

Answer:

(d) Which rules of safe swimming and diving we follow?

Answer:

Conclusions and recommendations to the scenario:
In the left column of the table write down your suggestions and recommendations that in your opinion belongs to the scenario. Discuss with classmates and teachers about your opinions. Corrections and additions write down in the right column.

Scenario: Death during diving		
	My opinion:	*Correction and supplement after the discussion:*
1.		
2.		
3.		
4.		
5		

Module “Safety in swimming and diving” elements presented here are used to create the basic image about the modules’ form. The module of IBSE must be modified according to the specific conditions in certain classroom and in particular characteristics of students.

5 Modules of IBSE in pre-service teacher education

The modules in IBSE were included in the pre-service training of future teachers of physics and other science (including physics) subjects in the PROFILES project. We conducted subsequent research on the effectiveness of this training. The aim of this research was to verify the effectiveness of IBSE implementation in pre-service education, therefore, the research question was: What is the effectiveness of modules in IBSE implementation in pre-service science teacher education?

The research sample was composed of 36 students (pre-service science teachers) of the Masaryk University, the Czech Republic. These teacher-candidates were preparing for IBSE implementation into instruction in the university course aimed at IBSE. First they acted as learners and tested modules in IBSE created by educators to gain experience with IBSE. Subsequently, in the role of teachers they applied these modules in school practice and gained experience with IBSE teaching. In the last stage of training, based on the competences gained, they created their own modules in IBSE and they tested them in school practice mostly in structured IBSE level.

A research-method of triangulation (semi-structured interviews, questionnaire and analysis of teachers-candidates' products) was used as a specific method to answer this research question. The research was conducted within the project PROFILES in the period 2013-2015.

To determine the level of acquisition, students expressed their subjective assessment of the extent of acquired professional competences in a questionnaire. The 5-point Likert-type rating scale (*1-Very weakly*, *2-Weakly*, *3-Normally*, *4-Strongly*, *5-Very strongly*) to measure development of their professional competences were used. Table 1 compares the responses of students according to the mean of the applied Likert-type rating scale.

Table 1. Pre-service teachers' questionnaire

	Using modules in IBSE I am able to:	Mean values (5-point Likert scale; 1 = min.; 5 = max.) N = 36
1	motivate students	4,69
2	encourage students to solve problems	4,58
3	include relevant topics to students from everyday life	4,56
4	develop inquiry skills of students	4,53
5	foster creativity of students	4,47
6	implement innovations in teaching	4,47
7	foster collaborative learning of students	4,42
8	foster students' activity	4,42
9	connect theoretical knowledge and teaching practice	4,39
10	use effectively group instruction	4,39

Presented findings (Trna, & Trnova, 2016) obtained through the questionnaire were verified by the analysis of pre-service science teachers' works and participative observation. The high level of the competence to motivate students through modules in IBSE was confirmed because these modules have strong motivational potential that was proved by participative observation of students in instruction. Pre-service science teachers were strongly motivated by development of their modules in IBSE.

6 Conclusions and discussion

Applied research in didactics of physics is often criticized for development of innovative strategies, methods and tools, which are not enough effective and not applicable in school practice. It is true that this criticism is justified. Researchers in physics education and teachers in practice should find a common ground and bridge the gap between theory and practice.

IBSE is one of the most effective strategies for teaching/learning in the school practice. To make IBSE effective, it is essential for teachers to acquire the professional competency to implement IBSE consisting of a set of specific skills. Teachers need to be able to determine what level of IBSE can be used, what knowledge and skills their students acquire, at what level and in what order. The choice of contents and their transformation into a form suitable for IBSE is also important. It is therefore essential to integrate this competence in order to apply IBSE in the teacher educational programme.

It is necessary to implement these educational methods and tools into pre-service teacher education, because it is important for teachers-candidates to construct their professional pedagogical skills based on experience acquired first as learners and later as teachers when development and teaching modules in IBSE. This teacher constructivism connects teachers' own experience from teaching/learning with pedagogical knowledge and skills and creates high-quality professional pedagogical competences.

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