The PROFILES Approach to Teaching and Learning Physics in Slovenia

Jerneja Pavlin, Iztok Devetak

University of Ljubljana, Faculty of Education

Abstract

The Faculty of Education from the University of Ljubljana participates in the FP7 project Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science (PROFILES). The project promotes Inquiry-Based Science Education (IBSE) through raising science teachers’ self-efficacy and promoting a better understanding of changes in teaching science in schools and the value of stakeholder networking. The teachers’ professional development programme started in the school year 2011–12. In Slovenia, 45 science teachers invited from primary and secondary schools participated in the project in the school year 2011–12 and 33 in the school year 2012–13, respectively. Teachers formed small groups (3–4 members) according to the level of education at which they teach (primary and secondary) and according to the subjects they teach (biology, chemistry, physics, or general science). Every small group developed PROFILES modules considering the PROFILES philosophy and the aims of the national curriculum. The teachers of physics and general science designed several PROFILES learning modules and three of them are presented in this paper. The topics in the modules presented were sound (“Can I represent a whole orchestra?”), simple machines (“Why should I sweat if it can be done with machines?”), and Ohm’s law (“Resistance, current, and voltage: brothers from the same house!”). Modules were applied in the school environment. On average, students reached comparable achievements in a knowledge test based on the PROFILES approach to teaching and the classical approach. Based on the collected data, a conclusion was drawn that the IBSE approach was accepted among Slovenian physics teachers involved in the project. Teachers also reported that this approach presented a challenge for them as well as for the students, especially for the gifted.

Keywords

PROFILES, inquiry-based science education, teaching modules, sound, simple machines, Ohm’s law

1. About the PROFILES project

The project Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science (PROFILES) is a four-year project funded by the FP7 programme of the European Commission which has started in December 2010. It promotes inquiry science education and teacher partnership. The European project involves the participation of 21 institutions from 19 different countries (Figure 1; Bolte et al., 2012). The project is coordinated by the Division of Chemistry Education of the Freie Universität university in Berlin. One of the cooperating institutions is the Slovenian Faculty of Education (University of Ljubljana). The national coordinator in Slovenia is associate professor for chemical education Iztok Devetak. The aim of the project PROFILES is to promote teaching and learning of science using inquiry-based science education (IBSE) approach. The self-awareness of the teachers plays an important role, because it is necessary to include innovative and effective teaching strategies into teaching. For this reason, every national group organized a Professional Development Programme (PDP) that was designed to meet the criteria of the PROFILES philosophy according to which the students are presented with a motivating, socio-scientific problem and engaged in discipline-specific but also general skill-developing inquiry activities in order to solve a problem. The aim of the project is also to raise teacher skills in developing creative, scientific problem solving, and socio-scientific decision abilities of the students (Bolte et al., 2012).

For the sake of clarity, the term student is used throughout the text, referring to both students of primary and secondary schools.
In the course of PDP, the teachers develop at four different levels. They first learn about the PROFILES approach for designing teaching modules at the faculty as learners. Then they design modules and apply them in classrooms as effective teachers. Later, they evaluate their work as reflective practitioners. The last role they assume is teacher as a leader. They play this role while teaching other teachers about the PROFILES approach. However, when they present the approach, a chain reaction of exchanging experience and good practices including inquiry approach is triggered (Bolte et al., 2012).

It is also known that creative, problem-based, and socio-scientific environment promotes students' motivation to learn science content. At this point, it is important to monitor internal (the students realize the meaning of learning) and external motivation (the teachers or learning materials encourage students to learn) of the students to learn science on different levels of education. Only a well-educated teacher can create an appropriate environment for students to learn science which promotes the development of competencies, such as decision-making skills and problem solving. This fits with the ideal outcome of the project: school science related to 21st century science and incorporating interdisciplinary socio-scientific issues and IBSE-related teaching (Holbrook and Rannikmae, 2012).

2. The PROFILES modules
The PROFILES modules are originally based on PARSEL approach (Parsel, 2014). In Slovenia, we also used the GALC (Guided Active Learning of Chemistry) approach to modify the modules. GALC is similar to the POGIL teaching and learning strategy. POGIL is an acronym of Process-Oriented Guided Inquiry Learning based on the cognitive theories and the research of learning strategies developed in the USA for university level chemistry (Devetak et al., 2014). If the students are involved in the learning process, they have a possibility to build up their knowledge. The modules based on the POGIL approach are student-centred where the teacher is considered a facilitator of learning. The POGIL modules enable the students to build understanding, develop higher-level thinking skills and lead them to the ability to learn and apply knowledge in a new context (Hanson, 2006).

An IBSE approach promotes the building of knowledge trying to find a scientific answer to a scientific question in small research projects groups. The IBSE approach is learner-centred meaning that students are the guided designers and authors of the experiments that lead them to meaningful measurements and observations. These enable drawing conclusions about physics laws or understanding physical concepts prescribed by a standard school curriculum (Arlegui et al., 2010; Rauch and Dulle, 2012).

The teachers involved in the project developed PROFILES modules in small groups according to the PROFILES philosophy (Devetak et al., 2012; Holbrook and Rannikmae, 2012). Groups (3–4 members) were formed according to the level of education at which they teach (primary, secondary) and according to the subject (physics, chemistry, biology, and general science) they teach. A consultant from the faculty was included in every small group. The role of the consultant was to lead teachers during their work, share knowledge about the PROFILES approach and provide them with insights into difficulties at learning (and misconceptions) of certain physics concepts as perceived by the researchers. The teachers considered these while preparing their modules according to their own assessment. The PROFILES modules have specific parts: a front cover page and 4 sections: (1) “Student activities”, (2) “Teaching guide”, (3) “Assessment” and (4) “Teacher’s notes”. The front cover page includes a title of the module composed as a problem-posed question, the subject area and the age level of students, an abstract, the listed sections of the module, an acknowledgement with listed authors of the module, the learning objectives and competencies, the curriculum content, the types of activities, the anticipated time and the prior knowledge.
The section (1) “Student activities” includes a detailed description of the scenario and student activities, including the tasks. The section begins with a module title formulated as a problem question, which refers to a practical context. The question “Why do I learn this?” reveals the content in a socio-scientific context, which also briefly describes the possible answers to the question from the title. This is followed by the categories “Aims” and “Learning outcomes”. The aims are linked to the curricula and competencies. “Prior knowledge” shows a list of concepts necessary to understand so that student can easily follow the “Student tasks” of the module. “Literature” offers a list of additional sources where student can find information about the topic. This is followed by the “New concepts” list, which does not include definitions and descriptions (Holbrook, 2012). “Student tasks” are the most important part of the “Student activities” section. They consist of 3 parts. The first part (I.) includes scenario for leading a conversation related to student consideration of the socio-scientific context of the module. The second part (II.) consists of the step-by-step instructions for learning by inquiry and the questions related to the steps. In this part, we find practical experiments and questions which lead the work. In the end of the second part of “Student activities”, the following is listed: “Key questions”, “Exercises”, and “Do I understand?”. The students are asked to read the text thoroughly and then discuss it in groups using “Key questions”. While reading the students analyse the data and find the connections and relationships between them. This type of approach helps the students develop higher levels of thinking. The knowledge gained is evaluated by means of “Exercises” containing simple tasks. The work with “Exercises” influences the student self-confidence. The tasks in the section “Do I understand?” are a series of questions which direct the students to new knowledge and self-evaluation. The third part (III.) of “Student tasks” includes “Problems”. The “Problems” are related to the socio-scientific context of the module with the aim that the students solve the problem by decision making, synthesis and evaluation of the knowledge gained and by the transfer of this knowledge into a new context using specific strategies (Bolte and Holbrook, 2012; Devetak et al., 2014, Holbrook, 2012; Holbrook and Rannikmae, 2012). The section (2) “Teaching guide” provides guidance to the teachers on how to use the module in their teaching. It also includes the learning objectives of each lesson and competencies suggested. “Assessment” is section (3) of the PROFILES module and has 3 units: (i) the assessment based on the skills acquired; (ii) the assessment by lessons; and (iii) the assessment based on the teacher strategy. Section (4) “Teacher notes” gives background information to the teacher, such as additional information about the content, including the solved “Student tasks” from the section (1) of the module (Holbrook, 2012).

3. The PROFILES project in Slovenia
   Slovenia has approximately 2 million inhabitants, 450 primary schools and 183 secondary schools. The number of teachers per school years included in the Slovenian PROFILES spider web is shown in Table 1. In school year 2011–12, 45 teachers invited from 35 schools participated in the project. They were divided into small groups regarding their professional science orientation (biology, chemistry, physics, and general science) and their teaching level (primary or secondary school). A group of teachers supervised by the consultant who was appointed by the faculty developed an innovative teaching approach following the PROFILES framework. The teachers cooperated in workshops and meetings and helped gathering and reporting data as well as giving feedback with a portfolio (Juriševič et al., 2012). In the school year 2012–13, 10 teachers were members of the first PROFILES generation, while others were fresh enthusiastic teachers willing to participate and grow familiar with the PROFILES approach. The teachers who participated in the previous year were asked to function as leaders in the groups of new teachers. In the school year 2013–14, only the teachers who already participated in the project were invited. Their tasks were to upgrade and revise the existing modules, implement the modules and organize regional workshops about the PROFILES approach. The national coordinator of the project operates in the field of chemistry, which unquestionably influenced the number of participating chemistry teachers. However, enthusiastic primary school physics teachers were involved in the project as well; 4 in the first year, 9 in the second year and 1 in the third year, respectively (Table 1).

<table>
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<tbody>
<tr>
<td>Biology</td>
<td>Primary</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>/</td>
<td>1</td>
<td>/</td>
<td>1</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Primary</td>
<td>25</td>
<td>13</td>
<td>8</td>
<td>46</td>
</tr>
</tbody>
</table>

Table 1: Number of in-service and pre-service teachers included in the PROFILES network separately for each school year by professional science orientation and teaching level (Metljak, 2014)
4. The PROFILES physics modules in Slovenia

The physics teachers who cooperated in the project designed the PROFILES teaching modules covering a series of topics from the Slovenian syllabus for physics in elementary and secondary schools (Planinšič et al., 2008; Verovnik et al., 2011). The modules are related to the following topics: pressure, density, friction, resistance, motion, machines, electric charge, and electric resistance. A group of teachers in the field of general science designed a PROFILES module about sound. Three examples of the physics modules for primary school are presented in this section. They can be accessed on a Slovenian web page of the PROFILES project http://www2.pef.uni-lj.si/kemija/profiles/moduli.html. The title of the module is formed as a question and the subject to which a module refers (physics, chemistry, biology, or general science) and topic from the national curricula appear next to the title (Skvarč et al., 2011; Verovnik et al., 2011).

Can I represent a whole orchestra? (7th class, Science)

In the module “Can I represent a whole orchestra?”, the students, who already possess basic theoretical knowledge about sound, test their knowledge through experimental work (Figure 2). The knowledge about the properties of sound enables the students to investigate how sounds change due to the size of the musical instruments. The students explore string instruments, chimes bars, flutes, and drums. Every member of the group creates their own instrument. The students learn to play the instruments created. The module finishes with a short concert of the class orchestra.

Why should I sweat if it can be done with machines? (9th class, Physics)

This inquiry-based learning PROFILES module starts with a question “Why should I sweat if it can be done with a machine?”. It leads the students into a world of simple machines used by everyone without knowing why do they make our work easier (Figure 3). Simple machines are a physics topic related to work and energy. The module presents a lever (1st class), a pulley, and a slope. The students gain experimental and theoretical knowledge that simple machines simply said make it easier for people to perform work. For example, a machine can help people move or lift a heavy object, change the direction of a force, lift something heavier that a person can lift by themselves, etc. In the end of the module, the students should be able to decide and justify their choice of a machine for a given task.

Resistance, current, and voltage: brothers from the same house? (9th class, Physics)

The module “Resistance, current, and voltage: brothers from the same house?” refers to the fact that the quantities electric current, voltage, and resistance are related. Their relationship is described by Ohm’s law (Figure 4). The experiments suggested lead students to the conclusion described above. Considering Ohm’s law, a person can design electrical circuits and understand the behaviour of different electric elements. The module also presents the limitations of Ohm's law for different electric elements. The students also learn to use the resistor colour code.
Figure 2. A poster about the teaching module "Can I represent a whole orchestra?" was prepared by a teacher from the group that designed the module about sound. The poster presents 4 experimental activities related to different instruments: string instruments, chimes bars, flutes, and drums. The teachers report that the PROFILES approach of learning by inquiry is especially successful with the gifted students. For this reason, the poster was prepared and presented at the conference Motivating Gifted Students for Learning Science in 2013. The co-organizer of the conference was the PROFILES team (Dominić-Radivojević et al., 2013).

Figure 3. “Student activities” section from the PROFILES module “Why should I sweat if it can be done with simple machines?”. The module title written as a problem question is presented in the document on the left, followed by the part “Why do I learn this?” (Zakaj se to učim?). The categories “Aims” (Učni cilji), “Learning outcomes” (Učni dosežki), “Prior knowledge” (Predznanje), “Literature” (Viri), and “New concepts” (Novi pojmi) are listed at the bottom. In the document on the right, “Student tasks” (Naloge za učence) are presented.

5. The experiences of Slovenian teachers acquired with the implementation of 3 PROFILES physics modules

Purpose and methodology
The PROFILES physics modules described in the previous section were evaluated. Based on the data and the feedback of the teachers collected, we wanted to assess the efficiency of the PROFILES approach to teaching. Our research questions were as follows: (1) Are there any significant differences in achievements on examination between the experimental and control group?; (2) How does the PROFILES approach of teaching work in practice?
Methods
The research was based on the quantitative and qualitative research approach. The descriptive and the causal-
quasi-experimental research method were used.

Sample
The research included the students of 7th and 9th class (188 in total). The students were divided in a control (CG) and experimental group (EG). The topic “sound” was applied in 3 7th classes with 63 students in total \( N \text{ (CG)} = 22, N \text{ (EG)} = 41 \). The topic “simple machines” was implemented with 69 students from 4 9th classes \( N \text{ (CG)} = 30, N \text{ (EG)} = 39 \). The topic “Ohm’s law” was introduced in 6 9th classes comprising 125 students \( N \text{ (CG)} = 56, N \text{ (EG)} = 69 \).

Data collection
The data was collected using a test of knowledge and teachers’ portfolios were used. The SPSS software was used to analyse the data (knowledge tests). The frequency distribution of the attributive variables, basic descriptive statistic for numerical variables, and \( t \)-test were used.

Figure 4. Part of the “Student tasks” for students of the PROFILES module “Resistance, current, and voltage: brothers from the same house?”. In part I (I. del), the students find a scenario. In part II (II. del), a theoretical background and experimental tasks related to A. voltage/current – a resistor, B. voltage/current – a bulb and C. resistors colour code are briefly described.

6. Results and discussion
The modules designed were evaluated. The information on student knowledge was gathered by knowledge tests. Teachers' observations and findings, students' feedbacks and their achievements in the knowledge tests were presented in teachers' portfolios. The summarized findings are presented in this section.

Student understanding of specific physics concepts introduced by the PROFILES modules
After the module concerning to each of the 3 topic groups (sound, simple machines, Ohm’s law) was applied in the experimental group, the differences in student achievements (the average number of points expressed as a percentage) in both the control and experimental group were not statistically significant (Table 2).

Table 2. Differences in the average number of achieved points in the test of knowledge between the experimental (EG) and (CG) control group

<table>
<thead>
<tr>
<th>Topic</th>
<th>Group</th>
<th>M</th>
<th>SD</th>
<th>( t )</th>
<th>( df )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound</td>
<td>CG</td>
<td>70</td>
<td>15</td>
<td>0.109</td>
<td>61</td>
<td>0.913</td>
</tr>
<tr>
<td></td>
<td>EG</td>
<td>70</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple machines</td>
<td>CG</td>
<td>70</td>
<td>16</td>
<td>0.691</td>
<td>67</td>
<td>0.492</td>
</tr>
<tr>
<td></td>
<td>EG</td>
<td>66</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ohm's law</td>
<td>CG</td>
<td>68</td>
<td>25</td>
<td>0.498</td>
<td>123</td>
<td>0.619</td>
</tr>
<tr>
<td></td>
<td>EG</td>
<td>66</td>
<td>28</td>
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</tbody>
</table>
Physics teachers’ experiences with PROFILES implementations

We also analysed portfolios prepared by the teachers. Some of the findings discovered in the analysis of teachers’ portfolios are presented here. The teachers observed that the students had positive expectations before the start of working with PROFILES modules. The introductory part of the module in a form of a story presented a powerful motivational tool for the students, because this type of story from everyday life connects the physics content with the daily life of the students. Unfortunately, the teachers report that students’ interest was only short-term. Each of the 3 PROFILES modules is planned for 4 school hours. Physics and science are on schedule 2 hours per week, thus students tended to forget a lot from one hour to the other. It turned out that the students were on average tired of working with modules and lost an overview on the content, whereas the work was fragmented. Some students also asked the teachers why they stopped explaining the content. This clearly shows that students are not familiar with the PROFILES approach and they missed the classical approach of teaching, where the teacher explains the topic and they make notes.

The teachers suggested the use of PROFILES modules during a science day, where students can work with a single module without breaks. They also reported that it is sensible to provide a theoretical introduction of the new content before the work with the module. The teachers reported that despite the carefully designed teaching modules the nature of some contents is still too abstract for the low-ability students. Such students require teacher explanation on elementary level, which is, in turn, contrary to the IBSE approach.

The teachers report that learning in the course of PROFILES modules revealed comprehension difficulties with many students. Furthermore, the students encountered difficulties while solving tasks related to the reading of the data from tables and graphs and draw graphs, because they were not familiar with this type of data manipulation. Quite often, the students did not read the instructions for performing the experimental tasks carefully, which resulted in inappropriate measurements. The teachers have to encourage the students to grow familiar working with a text so that they are able to extract the key information as well as information necessary for their further work. In this way, the students develop the competency of finding key information in a text.

The teachers had high expectations related to the assimilated knowledge of their students. But the achievements of the students were not as high as they expected, because the questionnaires presented an unnecessary burden to a significant proportion of the students. The achievements of the students who participated in the PROFILES modules are comparable to the achievements of the students in the control groups, although, in both cases, only the lower learning domains were examined. Observing the students during the independent experimental work, the work efficiency with high ability learners was detected. The work with modules presented them with a challenge; they were effective and deepened their understanding. The teachers also report that the understanding of the content was lower with the low-ability PROFILES learners compared to the low-ability learners from the control group. The students worked with text and data. These types of activities were time-effective for high ability learners, whereas the low-ability learners were lost in the abundance of data. The activities planned were too time-consuming for them.

Teachers’ observations about student achievements were also statistically confirmed (Table 2). However, little interest of students to cooperate in collecting data partly limits the conclusions. From the perspective of checking the implementation efficiency of the PROFILES approach, we need to reconsider how to ensure consistency and motivation for collecting data. Although the results do not show any statistically important differences between the experimental and control group, the teachers welcome the PROFILES (and therefore IBSE) approach, especially for gifted students. However, the results were also influenced by the duration of the PROFILES implementation. Because the innovation was implemented only by 2 PROFILES modules in each classroom, the impact of the PROFILES approach results on the achievements in the test of knowledge cannot be fully described. More PROFILES modules (one per day) should be implemented into classroom work so that the overall effect of the approach on knowledge could be assessed. While designing the PROFILES modules, the teachers used research data about students’ understanding of certain physics concepts and misconceptions according to their own assessment, which limits the conclusions about the assimilated knowledge of students as well. It would be also interesting to measure the influence of student’s interest and attitude to group learning on students’ achievements in the tests of knowledge as well. All these findings show guidelines for future research that would enable a more comprehensive evaluation of the PROFILES modules impact on the motivation to learn science and the achievements in the tests of knowledge.

7. Conclusion
This paper briefly presents the PROFILES project. In the project, the PROFILES modules were developed by the Slovenian primary and secondary school teachers. The modules promote the IBSE approach. In Slovenia, a few science teachers developed physics modules. The PROFILES modules about sound, simple machines and Ohm’s law and their evaluations were presented in the paper. The results showed comparable achievements in the knowledge test related to the PROFILES approach of teaching and the classical teaching approach. It was also shown that the PROFILES approach of teaching was well accepted among the teachers and gifted students. On the other hand, the teachers should present the importance of learning approaches that are emphasised by the PROFILES strategy to the students in a way that students would understand their enthusiasm over an innovative approach and make an effort to learn in a social context cooperatively. However, further research is necessary to properly understand the impact of the PROFILES approach on the motivation for learning science and as well as on the achievements in the tests of knowledge.

References


**Affiliation and address information**

Jerneja Pavlin  
University of Ljubljana  
Faculty of Education  
Department of Physics and Technical Studies  
Kardeljeva ploščad 16  
1000 Ljubljana, Slovenia  
E-mail: jerneja.pavlin@pef.uni-lj.si