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Possible reasons for low scientific literacy of Slovak students in some natural science subjects

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ABSTRACT

Background: The results of international studies have concluded the low level of science literacy in natural science subjects of Slovak students. These studies also showed that this state can be positively influenced by various innovations, which are implemented into the teaching process of above-mentioned subjects.
Purpose: The aim of this study is to identify existing problems and try to search for possible reasons of scientific literacy declination. We focused our attention toward the learning process, its elements and teacher–student interaction in this process. In our opinion, it should be possible to find some approaches on how to improve the results of the learning process and thus science literacy in the next PISA evaluation.
Sample: Our research included 62 high school teachers from Slovakia, who do teach Biology, Chemistry, and Physics.
Design and methods: The research was documented in a non-standardized questionnaire where the teachers were asked closed questions using a Likert response scale. The responses were evaluated by descriptive statistics using tables and graphs.
Results: The research presented in this paper has revealed certain issues problems in contemporary education, leading to lower science literacy of Slovak students. Research has also investigated whether teachers have sufficient knowledge and experiences with the implementation of Problem-based learning (PBL) elements in their own teaching. It was observed that students have a reasonably good content knowledge, but an insufficient procedural and epistemic knowledge therefore they are unable to utilize them in problem-solving activities.
Conclusions: Teachers were recommended to focus their pedagogical attention on the method of obtaining knowledge and the understanding problem solving in the wider context (qualitative knowledge, science understanding, scientific explanation of phenomena with its proper interpretation).

KEYWORDS

Science literacy; teaching innovations; teaching elements; problem solving

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Introduction

The student's science literacy level of OECD countries is summarized in an international study titled Program for International Student Assessment (PISA). The level of performance of Slovak students in natural science subjects is significantly lower than the average level of OECD countries (NUCEM 2015).

The OECD PISA survey is a key international educational skills assessment that has sparked educational reforms across participating countries since the launch of the results of the first assessment that took place in 2000. The 2015 round of the PISA survey was carried out in 28 EU Member States – the first time that all EU Member States are covered, among 72 countries worldwide. PISA data on educational outcomes gets collected every three years. PISA 2015 is the sixth round of this survey; it has a special focus on science performance. In the last cycle in 2015, the OECD average of scientific literacy decreased to 493 points, however Slovakia achieved 461 points (NUCEM 2015). When comparing the performance of Slovak students in PISA 2015 with previous study cycles, we can observe the continuous trend of decline in scientific literacy. However, we can also note the 8-point decrease in a total average output within OECD countries; the decrease in average performance of Slovak students is 10 points. The average score of Slovak students is below the average of the OECD countries. While in previous PISA cycles (2006 and 2009), the performance of Slovak students was the average of the OECD (level 3), since the last cycle (2012 and 2015) it decreased to level 2. In this study, we try to analyze the rationale of this state by a monitoring of PBL (Problem-based learning) components in multiple Slovak high schools.

Students with the scientific literacy level 2 have a sufficient scientific knowledge and they can provide possible explanations in familiar situations or make the right conclusions from simple monitoring or surveys. Students are capable of basic reasoning and explanation of the results of scientific research and technological troubleshooting. Students with the scientific literacy level 3 can identify clearly described scientific issues in the whole spectrum of situations. They are able to select facts and knowledge to explain phenomena, and apply simple models or research strategies. Students at this level can explain and directly use scientific concepts from different fields of science. They are able to write short explanations and decisions based on scientific knowledge and to acquire a huge amount of scientific knowledge and theories but they have particular problems (Palečková 2013):

- Own reflection on science phenomena and contexts of their examination
- Create hypotheses – Search and suggest ways of dealing with problems
- Interpret the observed data
- Formulate conclusions
- Use proofs while formulate the reasons

The aim of this study is an identification of existing difficulties and the search for potential reasons of the decline of scientific literacy. We focused our attention toward the learning process, its elements and teacher–student interaction in this process.

However, the scientific literacy is not a new term. Originating in the 1950s, the term 'scientific literacy' has been used to express diverse goals ranging from a broad knowledge of science to a particular purpose of science education (Bybee 1997). In 1958 Hurd provided a clear perspective when he described scientific literacy as an understanding of science and its applications to an individual's experience as a citizen. Hurd made clear connections to the science curriculum and the selection of instructional materials that provide students with the opportunities to use the methods of science; apply science to social, economic, political, and personal issues; and develop an appreciation of science as a human endeavor and intellectual achievement (Hurd 1958). The new PISA definition from 2015 describes the scientific literacy as the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen (OECD 2015). A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology which requires the competencies to:

(1) Explain phenomena scientifically
(2) Evaluate and design scientific enquiry
(3) Interpret data and evidence scientifically

It is not in our effort to precisely characterize PBL method in our research because it is debatable whether our teachers can define correctly the types of teaching methods. Therefore we focused our attention on teaching elements which are characteristic not only for PBL, but also for various innovative teaching methods, where teachers try to apply an inductive approach in their teaching. The inductive approach is generally more effective than a traditional deductive one.

How to increase the effectiveness of teaching the natural sciences subjects

New perspectives and understandings in the learning sciences about learning and learning environments, and in the science studies about knowing and inquiring, highlight the importance of learning and teaching styles in science education, harmonizing conceptual (guiding conceptions for what we need to know), epistemological (rules for what counts as knowledge), and social learning goals (communicating and representing ideas, evidence, and explanations) (Duschl 2008).

Understanding how science functions requires a synthesis of content knowledge, procedural knowledge, and epistemic knowledge. The first most familiar one – 'content knowledge' is knowledge of the facts, concepts, ideas, and theories about the natural world that science has established. Knowledge of the procedures that scientists use to establish scientific knowledge with is referred to as 'procedural knowledge'. This is knowledge of the practices and concepts which the empirical enquiry is based on (Millar et al. 1995). More recently it has been elaborated as a set of 'concepts of evidence' (Gott, Duggan, and Roberts 2008).

Furthermore, understanding science as a practice also requires 'epistemic knowledge' which refers to an understanding of the role of specific constructs and defining features which are essential to the process of knowledge building in science (Duschl 2007).

However there is no single 'scientific method' that would guarantee the development of scientific knowledge. Also, there is no single sequence of practical, conceptual, or logical activities that will accurately lead to valid claims in developing scientific knowledge (Lederman 2007).

Students acquire not only facts, but also methods of cognition. During the acquisition of new knowledge, the main emphasis is put on their independent work, one's own investigation and observation (a constructivist approach), not just a passive receiving of information (Veselovský and Gnoth 2001). According to Piaget (1970), knowledge is constructed in learners' mind through their interaction with the environment. Constructivism sees learning as a dynamic and social process in which learners actively construct meaning from their experiences in connection with their prior understandings and the social setting (Driver et al. 1994).

Students join the class with certain experiences and structures based on them. These structures are changing under the influence of new knowledge, incorporated into existing structures created before the teaching process. This structural connection between the old and new information, as well as various ways of treating the obtained facts, together with a derived new knowledge and conclusions as the consequences of intellectual activity, are active constructive processes, which may serve as a prerequisite of a meaningful teaching process.

The science education specialists agree with the theorem that the process of investigation should reflect a real science. Accordingly Ash (2003) investigation from a student point of view is shown on Figure 1: approach to study, including the process of world observation, leading to the formulation of problems and the creation of hypothesis, discovering and testing these observations, leading to its deeper understanding.

The conclusions gained in solving a particular problem within the development of science education are becoming an impulse for further solutions of problems, a deeper learning, linking natural phenomena and their changes caused by human activity.

In the school science, open-ended investigation differs from the other kinds of practical work where the students are given a few instructions about data collection, processing, and analysis to solve a problem. Students look at the problem presented to them, and use their existing contextual and procedural understanding to come up with a hypothesis first. They plan and carry out the investigation and then, as the investigation proceeds, the students evaluate the process and make any necessary changes. The decision-making, evaluation, and modification are essential to the process of investigating, and make the principal difference between an investigation and a practical task (Gott and Duggan 1996).

Focusing on using science investigation to develop conceptual understanding, carrying out a complete investigation of this kind, enables students not just to do science but to learn science concepts and understand the nature of science (Hodson 2009). Students need both the understanding of science concepts (substantive knowledge) and skills (understanding

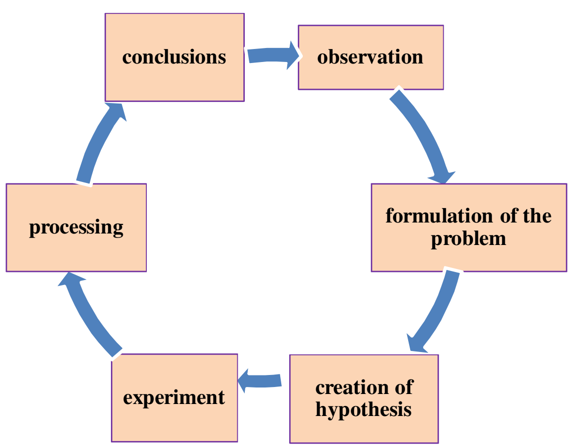

Figure 1. A simplified model of the investigation process in science, according to Ash (2003).

of science procedures) to successfully carry out a science investigation (Abrahams and Millar 2008; Roberts, Gott, and Glaesser 2010).

In discussing different types of investigation, Wellington (1994) opens up the field by proposing a typology of investigations that includes a variety of possible questions beginning with 'which', 'what' and 'how do', as well as general investigations that may include survey and project work.

Teaching as inquiry (Duschl 2008) includes identifying the degree of legitimate doubts attached to science knowledge, assisting in providing opportunities to deduce patterns and to develop intellectual capacity to inform oneself and employing a strategy of teaching that allows for discovery, focuses on the central role of discussion, and promotes effective argumentation.

Specifically, an open inquiry has been proposed as a method to enhance more authentic scientific inquiry (Duschl and Grandy 2008; Roth 2012) and promote an active and autonomous learning (Hodson 2009).

Due to their practical and investigative character natural science subjects involve the students in the process to understand more in depth phenomena in natural science subjects. Traditional education has been tended to emphasize memorization and mastery of the text. Research on the development of expertise, however, indicates that more than a set of general problem-solving skills or an array-based memory is necessary to achieve a deep understanding. Students should also learn to make good observations and inferences, and understand the role that observations and inferences play in the development of scientific knowledge.

It is feasible to find many clear methods for implementation of inspirational topics with recommended teaching innovative tasks (e.g. creative tasks, tasks against rigid thinking, exercises for flexible thinking etc.) related to natural sciences in scientific journals and textbooks. Those tasks motivate teachers to use untraditional methods but the teachers can get confused due to the amount of innovations and at the same time various methods for solving tasks do not allow a clear and unified evaluation process.

Innovations, including the implementation of new educational technologies in education, represent new pedagogical approaches and practical arrangements, pointed to the content and organization of schools, the educational process, the evaluation of students, and the overall climate of the school (Průcha, Walterová, and Mareš 2003). Frequent innovations include problem methods.

PBL is an instructional method in which students learn through facilitated problem solving. In PBL, student learning focuses on a complex problem that does not have a single correct answer. Students work in collaborative groups to identify what they need to learn in order to solve a problem. They engage in self-directed learning (SDL) and then apply their new knowledge to the problem, and reflect on what they learned and on the effectiveness of the employed strategies. The teacher acts to facilitate the learning process rather than to provide knowledge. The goals of PBL include helping students to develop (1) flexible knowledge, (2) effective problem-solving skills, (3) SDL skills, (4) effective collaboration skills, and (5) intrinsic motivation (Hmelo-Silver 2004).

Problem-based learning (PBL) is a constructivist instructional approach that is student centered and helps to prepare students as problem solvers (Richey, Klein, and Tracey 2011). In the PBL approach to instruction, an authentic, real-life problem is used to situate learning rather than exposing learners to disciplinary knowledge before they solve problems as it is done in a traditional instructional approach. PBL approach emphasizes understanding of the causes of the problem by the learners, critical thinking and active construction of knowledge that transfers to other similar problems or opportunities. Hence in PBL approach, the learners gain content knowledge as they are actively engaged in an authentic problem-solving task.

PBL is an instructional, student centered, approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (Savery 2006). Students work in collaborative groups to identify what they need to learn in order to solve a problem. Students are engaged in a self-directed learning process, applying their new knowledge to the problem, reflecting on what they have learned, and assessing the effectiveness of the strategies employed (Hmelo-Silver 2004). Problem-based learning (Hajdukovic et al. 2011) makes the students an active subject of the teaching process, as a researcher who acts on his/her own initiative, thinking, judgment, and who, on the basis of the established methods, can solve problems independently.

The main purpose of a teacher in PBL is to facilitate the learning process rather than to provide knowledge, therefore, students are fully responsible for their own learning, integrated from a wide range of disciplines or subjects (Macko, Blahútová, and Stollárová 2013). Teaching based on investigation is characterized by more democratic and less coercive management of student educational activities, as describes the continuum of teaching methods according to Rogers and Freiberg (1994), illustrating the teaching possibilities of the teacher. If education is supposed to have been constructive, the role of the teacher has been changed from an authoritative mentor to a facilitator. The main purpose is to enable an easier construction of the new knowledge, based on situations created by the teacher (Doulík and Škoda 2003). PBL is easily finding ways of problem solving, which one may encounter in real-world situations (Akinoglu and Tandogan 2007). They are based on the student's own experiences, changed by the educational process. Utilization of PBL or innovative methods according to above-mentioned information leads to the fact that students should be able to form their own reflection on science phenomena and contexts of their examination, create hypotheses – search and suggest ways of dealing with problems, interpret the observed data, formulate conclusions, use proofs while formulating the reasons and therefore explain phenomena scientifically, by which Slovak students could achieve a higher level in PISA ranking.

Problem-based learning (PBL) is closely connected with science literacy. PBL is a process of involving students in doing things and thinking about the things they are doing (Bonwell and Eison 1991). The potential of PBL to contribute to the development of thinking skills and an understanding of the nature of science beyond the conventional conceptual content is a transformative feature (Allchin 2013). Students may even reflect explicitly on their experience and thereby deepen their understanding of scientific practices while improving their scientific literacy.

In the literature, there is a lack of consideration for the relationship between PBL and scientific literacy, but there are some studies revealing that PBL can positively influence the level of scientific literacy. Prince and Felder (2006) claim that these individual studies have found a strong positive effect of PBL on the skill development (Albanese and Mitchell 1993) understanding the interconnections among concepts (Gijbels et al. 2005), deeper conceptual understanding (Dods 1997), ability to apply appropriate metacognitive and reasoning strategies (Chung and Chow 2004), teamwork skills (Sharp and Primrose 2003), and even class attendance, but have not reached any firm conclusion about the effect on content knowledge. A long-term study of the effectiveness of PBL program demonstrated its superiority to traditional education in the development of the key process skills (Woods et al. 1997). PBL has also been shown to promote self-directed learning and the adoption of a deep (meaning-oriented) approach for learning, as opposed to a superficial (memorization-based) approach (Norman and Schmidt 1992).

World research has confirmed a relationship between the emotional factor in natural science subjects and the level of science literacy (Bybee and Mccrae 2011). An extensive international study (Linn, Hong, and Huang 2012) which involved 15-year-old students, explores the connection between emotions and the engagement with science. A close correlation was confirmed between the interest and enjoyment as emotional factors and science learning.

Methods

Our research included 62 high school teachers of Biology, Chemistry, and Physics from Slovakia. To secure a representative sample these main factors were taken into consideration – approbation, location, age, and gender of the respondents. Table 1 percentages display, that the majority of teachers teach Biology, and their most common approbation was Biology–Chemistry. Most of them were women (72%). We investigated the length of teaching experience and found out that most of teachers have sufficient experience in schools (47% of teachers have over 20 years experience), 16% of teachers had up to five years experience.

A non-standardized questionnaire which was used as a research tool, consisted of the closed, open, and semi-closed questions. The validity of the questionnaire was secured before the conduction of the research by expert review of teachers who work at the university (but are not our respondents) and have experience with scientific research. The reviewers monitored mainly the usage of pedagogic elements which are characteristic for innovative methods and are absent from the traditional methods to ensure the questionnaire investigates what we aim it to. Subsequently the questionnaire was adjusted to a final version.

The questionnaire was verified in a pilot study, when the copies were distributed to schools for a small sample of teachers located in one region of the county. After necessary adjustments it was distributed to teachers in all regions of Slovakia.

The aim of the research was to observe the current state of the utilization of PBL elements at primary and high schools based on the self-reflection methods used in the process. Our research was focused on the above-mentioned innovating elements of teaching aimed toward the investigative activities of the students. The empirical study was complemented by interviews with our respondents after the publication of PISA results. Their opinions were almost identical to the questionnaire results.

The teachers were asked closed questions included in the Likert scale questionnaire. The responses were evaluated by descriptive statistics using tables and graphs.

Table 1. Percentages of subjects taught.

Curriculum subject	Biology	Chemistry	Physics
Count	48	32	25
%	77	52	40
Length ped. experience	Up to 5 years	5–20 years	Over 20 years
Count	10	23	29
%	16	37	47

For open questions, individual replies were categorized, (e.g. in question number 9 the answers were categorized according to the time expense for preparation, organization and evaluation, number of teaching hours for natural science subjects, infrastructure, discipline in classrooms, teaching materials etc.) and allocated to the categories. The representation of the different categories of responses was evaluated on a percentage basis.

Teachers were asked questions about methods of teaching in general and then they were narrowed down to specific signs. Although it might seem the questions were leading teachers to a certain answer, we had to ask directly about the usage of specific teaching features we aimed to investigate. We do not claim that the results are 100% reliable, since only a few factors were tracked, but there are many other factors effecting the results. The limitations are represented by the fact that our sample is selected only from Slovak teachers of natural science subjects who adhere to established standards for Slovak schools (Hauser 2008). The relationship between the account of used teaching methods and the actual teaching behavior in the classroom may also influence the accuracy of the findings because the teachers' responses are subjective and may intend to depict their teaching behavior in a more positive way. The reliability of the findings can also be decreased by teachers' misunderstanding of PBL elements.

The following points were investigated (Table 2).

- Whether teachers of natural science subjects have suitable information about using innovative teaching methods and whether they know how to characterize PBL elements, problem methods, and the term problem.
- How do the teachers measure their long-term educational training from university graduation, namely the training on the application of PBL elements of teaching, and how has it helped them in their practice?
- Implementation of PBL elements, innovations, and problem-solving teaching into their subjects.
- How influential are some of the characteristic elements of PBL (working with text, motivation of students to create non-traditional original solutions and its presentation by the student, self-evaluation) for teachers, whose abilities are necessary for the enhancement of the independency to successfully solve certain problems.
- How do teachers evaluate the effort of the new teaching standards to use the active, or problem-solving methods in practice?
- Whether there is a sufficient amount of study materials or opportunities to gain inspiration toward active forms of teaching.
- What are some of the limitations for the implementation of innovative methods into the educational process?

Results and discussion

Do teachers of natural science subjects have sufficient knowledge to teach natural sciences using innovative didactic methods?

In the first part of the aforementioned questionnaire, the co-operating teachers of natural science subjects were asked open questions related to their general and scientific knowledge, as well as their preliminary teaching test training. In this item, we accentuated observations of

Table 2. Survey of the questions asked the teachers of natural science subjects.

Question no.	The question expression
In the first part of the questionnaire, the teachers were asked open questions related to general and scientific knowledge, as well as their teaching practice	
1. Open question	What is the difference between classic and innovative teaching methods?
2. Open question	How do you understand the term problem in the teaching of your subjects?
3. Open question	Have you been sufficiently familiarized with the PBL method during your university studies to implement it into your school teaching practice?
The second part of the questionnaire was focused directly on the teaching process	
4. Closed question	Do you prefer innovative non-traditional teaching methods or do you use classic methods in your teaching practice?
5. Semi-open question	Do you apply PBL elements and if yes, in which phase of your teaching process?
6. Closed question	Which characteristical elements of PBL for teachers are required to enhance the student's abilities to solve problems independently?
7. Closed question	Choose the proficiencies (one or more), which (you think) are the least problematic for students.
Open questions for teachers – their opinions – problems connected with the educational process	
8. Open question	Try to briefly state why should students should be able to solve problem tasks.
9. Open question	Quote the main limitations during the implementation of pedagogical innovations and PBL in your educational practice.
10. Open question	How you noticed some opportunities to change your teaching toward problem tasks according to the new teaching standards in Slovakia?

whether the teachers have sufficient knowledge to use the innovative teaching methods and how they comprehend in particular the problem method elements in PBL. The traditional approach to teaching science is deductive, beginning with the presentation of basic principles in lectures and proceeding to the repetition and application of the lecture content by the students. Contrastingly, innovative methods proceed inductively, beginning with observations to be interpreted, questions to be answered, problems to be solved, or case studies to be analyzed, inductive teaching and learning is an umbrella term that encompasses a range of instructional methods, including inquiry learning, problem-based learning, project-based learning, case-based teaching, discovery learning, and just-in-time teaching (Prince and Felder 2006).

As for question no. 1, we observed that innovative teaching methods are understood as new, modern, interesting methods, enhancing the attractiveness of the given natural science subjects, as well as the education process for students, for obtaining their better study results and for an improvement of the social-emotional atmosphere in the class to minimize disciplinary issues. A crucial and most often used tool in PBL is it, with students solving problems, innovations of teaching content (the teaching standards of new subjects), using non-conventional organization forms (e.g. teaching in blocks), and the implementation of the elements of verified innovative programs (e.g. integrated topic teaching). Furthermore, it can be deduced from the answers, that teachers appreciate a sense and a need for innovations in the educational process as a tool for the enhancement of the motivation and the interest of students.

The result of the questionnaire displayed an unsatisfactory understanding of the term 'problem'. Based on the answers to question no. 2, we observed that 86% of teachers understand the principle of PBL. They understood correctly that it is a situation where a student should find a way of solving in the first place, because his state of knowledge does not allow him to solve the problem. The productive intellectual activity must be utilized to find a correct solution to the problem. Respondents perceive the term problem as the connection of theory with a real world (75%), improving creativity and independency (65%), a presentation of one's own work (52%), work with the utilization of various sources of information (50%), team work, where each student contributes to the correct solution with his partial contribution (42%), the development of a combination of skills (31%), using knowledge from another subject – inter-subject relationships (25%), a tool for the verification of the obtained competencies of students (23%). Some teachers have mistaken the problem method with active techniques, where the topics are presented by a classic method with active didactic elements e.g. graphical illustrations and demonstration experiments (14%). Some questions or tasks often contribute to the confusion (14% of teachers do not correctly understand the concept of problem or problem method).

Most of the teachers stated in the answers to question no. 3 that they have not been familiarized with the innovative, problem teaching methods (65%) during their university studies. This is caused by the fact that in the past, university studies aimed toward more specific knowledge from given subjects. Some teachers declared obtaining reasonable information on PBL, during their professional practice at schools (45%). Current teachers who have been working in the education sector for a long time have a chance to increase their education expertise by accomplishing 2 final state attestations and by participating in various conferences and scientific seminars. Therefore, we can assume that they have some knowledge regarding new pedagogical methods and approaches and it only depends on their efforts and motivations how they utilize it.

Use of innovative methods and the characteristic elements of PBL by teachers of natural science

As many as 75% of teachers prefer innovative (non-traditional) methods (question no. 4) in their pedagogical practice. Even though these methods are of various amounts and quality; it demonstrates that teachers are trying to enhance the quality of the educational process. Approximately half of the respondents (48%), think that innovations depend on the personality of the teacher as the main force for a qualitative change of teaching. This fact also supports the observation that teachers expressed their personal drive and their own motivation to do something innovative in the first place. We can conclude that most of the answers present the idea that the interesting and creative teaching makes the educational process more effective and also has a positive effect on the class discipline and the class atmosphere.

Majority of the respondents (86%), said that they are using some elements from PBL in their subjects (question no. 5). We have identified in which phase of the teaching process teachers use the problematic methods and PBL elements (Veselovský and Gnoth 2001). Motivation (introduction) part – prepares students for active learning curriculum. Students need to be interested in learning. Significant elements of motivation are able to combine theory with practice, to raise various problem situations, students experience etc. Exposure section – introducing to students to a new content of the lesson. At this stage, we use a number of methods. The students should get the right idea about the course, acquire the learned curriculum. Fixation part – at this stage, it is necessary to use a number of methods, but above all to ensure that repetition and consolidation of the curriculum is realized especially in new, changed situations and conditions. Diagnosis section – examining acquired knowledge, skills, and habits. The application phase of the learning process ensures the immediate use of knowledge, skills, and habits in a particular activity.

As it can be seen from Figure 2, PBL is used during practical exercises in the phase of application, when the student is placing the obtained knowledge to his wider area of the given matter. A higher number of teachers (49%) use PBL in the application part periodically, and 42% often, while in the motivation phase 25% use it often and 22% of the teachers use it periodically. It is constructive that teachers place problem solving into the application part for a practical verifying of knowledge to improve experimental skills, which is effective especially in chemical experiments.

The issue of teaching styles is a very wide topic. Sometimes, it is rather difficult to identify and quite exactly name the teaching method used by the teacher, therefore, in the question no.6, we have focused our attention to specifying the teaching elements characteristical for PBL, as well as problem solving by an active student investigation.

From Table 3, one can derive rather interesting facts. It is very positive that practically all of the respondents are focusing their explanation in the teaching process on the real-world problems. It should be emphasized that teachers try to logically prove an answer or solution of the presentation and prefer clear procedures on how to achieve the solution of a problem. Only 55% of the respondents create problem situations, which is fundamental in PBL. The remainder of the respondents use it sporadically, which are not effective for the development of abilities to solve a given problem. This state could be explained by a low amount of teaching hours, a weak motivation and low experience of the teacher to use these methods. For an evaluation of the procedure leading to a problem solution, a self-evaluation of students

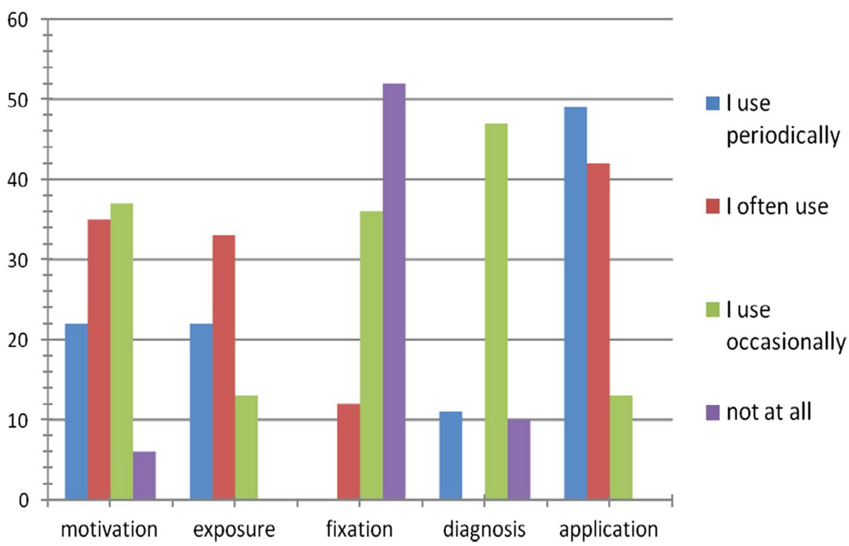

Figure 2. The dependence of PBL elements on the phase of the teaching process.

Table 3. Survey of answers to question no. 6.

Teaching elements	(%) Typically	Partially	Probably not	Not	Do not know
Focusing on real-world problems	88	12	0	0	0
Creating problem situations	55	42	1	2	0
Support non-formality and spontaneity	31	69	0	0	0
Motivation toward non-traditional problems solutions	19	63	5	8	5
Work with text	20	50	10	20	0
The involving of argumentative answers	67	27	0	6	0
Solution presentation	73	13	4	10	0
Students' self-evaluation	33	60	4	3	0
Supporting of IT	35	55	3	7	0
Team work support	63	37	0	0	0
Creating problems not presented in textbooks	19	63	0	6	12

is very important. The student should evaluate the steps of a solution, evaluate the possibilities, priorities, processes etc. 33% of teachers periodically involve the self-evaluation from students, and 60% only sometimes.

Furthermore, we observed that 19% of teachers periodically and 63% partially motivate their students to create non-traditional problems, not present in conventional textbooks in order to develop creativity. It is connected with informal communication and argumentation related to the diversity of solutions. 31% always and 69% partially support non-formality in argumentation.

Many failures of students, during complex problem solving, are caused by insufficient work with text and argumentation to prove their solutions. Work with text aimed toward proper questions related to formulate ideas of the whole text, is a solid method for the enhancement of abilities for problem solving. Many students are unable to withdraw substantial information from the text and relationships connected with the problem. According to Gavora (2008), the reader at the highest level of reading literacy is able to treat the information from the unknown text and should understand the text in detail as well as consider to substantial facts. Only such a reader can critically evaluate and formulate hypotheses. We had also observed a very negative fact: only 20% of teachers work with text together with the students and 50% only sporadically sometimes (30% do not work with text). As the respondents stated, the cause may be in the lack of time or the student's indolence. The next prerequisite for the successful solution to a problem is the ability to present independently one's own solution. We think that an enhancement of presentation skills is the main purpose of the current education in Slovakia; therefore, it is very useful to monitor the intellectual processes of a student step by step. They may make some modifications in certain phases of the solution and plan a more effective procedure to reach the solution. It is encouraging that 73% of teachers support a periodical development of this ability, only 14% do not involve it. As explained above, a logical explanation of the phenomena is crucial in this approach. Most of our respondents (67%), always support this activity, and 27% sporadically involve a logical proof of the students' answers.

Application of Information Technologies (IT) in PBL is often utilized by 35% of teachers and sporadically by 55%. IT solutions (computer, the Internet) may serve only as a minor tool in the finding of new ideas or supplementary data for solving a problem task. In this case, what is more important is the training of self-abilities, skills, and procedures, together with cooperation. IT-information systems activity requires students to work collaboratively, exercise their critical thinking, and apply new concepts, students should be given ample opportunity to exercise and refine these skills (Solem 2000). An appropriate use of modern digital technology in education is one of the most important factors to increase its efficiency, but its implementation requires a teacher who knows these technologies (Čipera, Bílek, and Svoboda 2000).

Finally, we were interested in the approach of teachers for the cooperation of students in problem solving. More than half (63%), consider this ability as a typical representation of their teaching and 0% stated no support for this activity. Cooperation among students is very important, because the results of one person are supported by the whole group profiting from the work of all of its members.

The answers to question no. 7, summarized in Table 4, show that students experience minor difficulties with the discussion and presentation of the problem solutions (44%), however the concept of planning solution to the problem and its utilization for their own development create the major issues.

The respondents answers to question no. 8 (the need for students' ability to solve problems) displayed reasons according to abundance frequency: the connection of teaching with a real world, the concentration and attention of students is enhanced by communication with the students, it is positive for student's motivation, teaching is more fun and effective, the topics of study are better comprehended and the studying results are more satisfactory, the teacher's approach as a creator of innovations is coherent, the personal enrichment of the teacher, the development of the student's abilities, an impact on self-evaluation, a more independent approach to problem tasks, cooperation as well as presentation skills.

Teachers' problems related to the learning process

In the question no. 9, the teachers of natural science subjects stated, significant difficulties in the practical implementation of pedagogical innovations. The most problematic is the time expense for training, organization, and solution evaluation (72%), then a low number of teaching hours for natural science subjects (61%), a poor infrastructure (51%). Furthermore, poor discipline in the class (42%), students with low level of knowledge, requiring a special teaching approach and a lack of materials dealing with the novel teaching methods (26%) together with an administrative overloading of the teachers, were also mentioned.

Active innovative methods with a higher participation of students are more difficult from a class management point of view and involve self-control and self-discipline, together with communication skills. Good innovation does not work in the class without active listening (concentration, attention, eye contact, discussion of the rules) (Čtrnáctová and Zajíček 2010).

Table 4. Proficiencies the least problematic for students.

Student ability	(%)
Problem identification	19
Obtaining additional information needed to solve a problem	19
Solution planning	0
Problem solving	19
Evaluation of the manner of solving	10
Discussion about problems and a presentation of problem solution	44
Utilization of problems for one's own development	0

There is also a problem of suitable study materials applicable in PBL (flexible materials for teachers) and the motivation of students, a lack of interest in science and insufficient skills to solve problems. This also depends on the personality of the student.

Finally (question no.10), only 31% of teachers positively appreciate the possibilities of using PBL in the novel Slovak teaching standards (Hauser 2008). Some of the possibilities to implement the innovations are in a greater variability of teaching, adjusting topics according to their necessities and the potentialities of students. Teachers also see some advantages in implementing their own teaching methods, as well as in the selection of textbooks and teaching materials, as well as in group teaching. Teachers are negatively evaluating the National Educational Program (69%) considering the time allocation for natural science subjects as a main issue due to the quite large amounts of information.

Conclusion

There are a number of international natural science literacy tests, we can hardly say they are most credible, because the OECD is also completely aware of the different conditions for each test. There is no education model tailored to all countries. It is not possible simply to copy the education system of one country and use it in another country.

Teachers in highly developed countries (such as France, Norway, Sweden) who have well-funded education are unsatisfied with the test results due to their average rating results. Surveys of Norwegian teachers have shown that they consider the effects of the PISA project as a serious cause of trouble in their daily work (Baird et al. 2011).

It is impossible to construct a test that in a fair and objective way can be used across countries and cultures to assess the quality of learning in – real-life situations with – authentic texts. Problems also arise when the brave intentions of the PISA framework are translated to specific test items to be used in a great variety of languages, cultures, and countries (Sjøberg 2015).

One positive aspect of PISA is that it has brought schools and education to the forefront in the media and in political debates internationally, and even more so nationally in several countries. PISA is rather explicit that the tests do not measure quality according to the national school curricula, but measure based on the definitions and framework made by the OECD-appointed PISA experts. The PISA framework clearly states that the knowledge and skills tested by PISA 'are defined not primarily in terms of a common denominator of national school curricula but in terms of what skills are deemed to be essential for future life' (OECD 2015).

Natural science subjects (Physics, Chemistry, Biology) belong, according to National Educational Program of Slovakia, to the educational area 'People and Nature', which contains education connected with an investigation of nature. In this educational part, students are given the opportunity to know nature as a system of changes and relations. The natural science subjects, with their active and investigative character, allow the student to effectively understand the natural rules, the usefulness of knowledge from the sciences and their applicability in real life.

The role of this research was to find approaches on how to improve the learning process and thus scientific literacy in the future PISA evaluation.

Positive findings were: teachers focus their teaching on the real-world problems, they require rational responses of students and integrate problem-solving tasks particularly into the application phase of the lesson.

Negative findings were: students do not work well with the academic text and teachers do not lead students to the formulations of non-traditional solutions, they have some insufficiency, particularly in the planning of given problem solving and the usage of these conclusions for their own development.

Recommendations for improving the status of teachers are to focus not only on content knowledge, but on insufficient procedural and epistemic knowledge. They should also aim to remove the mentioned negative aspects and focus on science understanding and scientific explanation of phenomena with its proper interpretation. PISA results show in long term that Slovak students have sufficient content knowledge but often are not able to apply it in non-traditional tasks (NUCEM 2015; Palečková 2013). It is also a consequence of the above-mentioned fact that Slovak teaching standards (Hauser 2008) are highly demanding content-wise. Therefore the education should be realized with PBL elements to create better logical, critical and creative abilities of students, who are able to find relationships between the structure and features of species, which could lead to improvement of factors such as Solution planning and Evaluation of the manner of solving (Table 4) that were very weak according to our findings.

Our observations and experience prove that it is very important to start with PBL already in primary education to acquaint with and adopt group work habits because the main aim of teaching is to develop reading and science literacy, based on the work with scientific text. Students should understand the text and use the information for solving specific problems. Within the framework of independent work, they should be able to independently collect the necessary information on a given problem from various information sources (scientific literature, Internet) and use multimedia educational materials.

Problem presentation can be very motivating for students (motivation toward non-traditional problems solutions or creating problem situations) because they see the sense and usefulness of the things that they are going to study and it forces them to identify what they should know about problem solving.

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