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Chapter XI

ATTITUDES AND EXPERIENCES OF ELEMENTARY SCHOOL PUPILS AS GUIDELINES FOR IMPROVING PRE-SERVICE CHEMISTRY TEACHERS' COMPETENCIES FOR THE IMPLEMENTATION OF PROBLEM-BASED TEACHING[1]

Katarina B. Putica*
Innovation center of the Faculty of Chemistry, University of Belgrade, Belgrade, Serbia

Abstract: Modern society makes it a requirement of the educational systems to prepare pupils for successful adaptation to the changeable conditions of life and professional market, which also presupposes the preparedness to apply the knowledge of natural sciences, in order to overcome the numerous challenges caused by the fast scientific and technological development. Given that problem-based chemistry teaching can provide a significant contribution to this cause, five students of the study program Chemical Education at the Faculty of Chemistry University of Belgrade conducted a survey in which 93 pupils of the seventh grade and 74 pupils of the eight grade of elementary school took part, in order to learn about the pupils' attitudes and experiences with this way of teaching. Students, also, comprised age appropriate tests, which checked the pupils' preparedness to apply the knowledge of chemistry, in order to solve problems from everyday life. In this way, it was ascertained that the pupils from both grades had previous experiences with the problem-based chemistry teaching, and that they do not have negative attitude toward it. They find such a way of learning to be more difficult, but also more interesting, possible learning difficulties could be more easily overcome with more help form the teacher, or by learning within a group of pupils, and in order to prevent them, the teacher must check whether the pupils possess enough previously acquired knowledge in order to solve the given problems. The results of the tests show that the eighth grade pupils, having more experience with the problem-based teaching, as well as the wider span of the previously acquired knowledge, were significantly more successful, in comparison to the seventh grade pupils. In this way, pre-service chemistry teachers gained insight into the greatest challenges of the problem-based teaching and the ways in which they could be overcome, thus improving their competencies for the implementation of this way of teaching.

Keywords: *problem-based teaching, pre-service teachers, chemistry.*

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*E-mail: puticakatarina@gmail.com

Introduction

Life in the 21st century is shaped by fast scientific and technological development. New discoveries occur on daily basis and they quickly find their way into our homes and workplaces. Although these innovations have many benefits, incorporating them into our surroundings often causes great changes in our work and life routine. Given that the adaptation to such changes can be quite challenging, it is important for educational systems to ensure that pupils are enabled to apply the knowledge of natural sciences in all instances in which they have to overcome obstacles caused by the rapid scientific and technological progress (AAAS 1993; Elkind 2004; EURYDICE 2011; OECD 2009). However, the results of a questionnaire concerning the frequency of various pupils' activities during chemistry lessons, which was filled in by Serbian teachers within the framework of a TIMSS (Trends in International Mathematics and Science Study) survey, showed that pupils are rarely in a position to acquire new knowledge through solving problems from everyday life (Trivić et al. 2011). At the same time, the results of PISA (Programme for International Student Assessment) tests showed that most pupils in Serbia, having completed their elementary school education, are not able to apply the knowledge of natural sciences in solving real-life problems (Baucal, Pavlović Babić 2010, 2013). Considering these results, and the fact that the existing framework of professional competences envisaged by *The Standards of Competencies for the Teaching Profession and the Professional Development of Teachers* (ZUOV 2011) emphasizes the role of the teacher in the development of the key competences that enable pupils to live and work in the 21st century, it is clear that, within the study programs for the education of pre-service chemistry teachers, special attention must be paid to the development and advancement of their competencies for problem-based chemistry teaching.

Problem-based teaching

Within the framework of problem-based teaching, one proceeds from a problem-type situation for which there is no direct solution in the previously taught subject material. Instead, the pupils are expected to find the solution through their own efforts, by using and linking their previously acquired knowledge (Ivić et al. 2001; Mergendoller et al. 2006). In this way, the pupils first arrive at a potential solution to the given problem, that is, at a hypothesis. Following this, the pupils have to plan and carry out the procedure of its verification. Based on the results of the verification, the hypothesis is either accepted or rejected, and this represents new knowledge for the pupils. As can be seen, within problem-based teaching, new knowledge is acquired through a process of deduction (Bilgin *et al*., 2009; Cakir, 2008). Linking the existing and the newly acquired knowledge is essential for the acquisition of new knowledge with understanding (Aidoo 2016; Iqbal et al. 2017). Furthermore, by adding new knowledge to the already existing knowledge base, a new, broader system of knowledge is formed, and it is only knowledge which is a part of such a system that can be responsibly implemented in practice, for the pupils are able to review the consequences of its implementation from various perspectives (Minner et al. 2010; Tarhan, Acar-Sesen 2013). Problem-based teaching promotes the pupils' motivation for learning science (Akinoglu, Tandogan 2007; Hacieminoglu 2015; Oh, Yager 2004), has a positive impact on the development of self-regulation of the learning process (Sungur, Tekkaya 2006; Tosun, Senocak 2013) and it also represents the most efficient vehicle for promoting pupils' creative thinking (Inel, Balim 2010; Linn et al. 2003).

Research methodology

The aim of research and research questions

The aim of this research was to enable pre-service chemistry teachers to gain insight into elementary school pupils' attitudes and experiences concerning problem-based chemistry teaching and to check their preparedness to implement chemistry knowledge in solving problems that can be encountered in everyday life. In this way, pre-service chemistry teachers were given the opportunity to learn about the greatest challenges of problem-based teaching and the ways in which they could be overcome, which should help them to develop and improve their competencies for the implementation of this way of teaching. In accordance with this aim, the pre-service chemistry teachers sought answers to the following research questions:

1. Do seventh and eighth grade elementary school pupils have previous experiences with problem-based chemistry teaching and what are their attitudes towards it?
2. Are seventh and eighth grade elementary school pupils enabled to implement chemistry knowledge in order to solve problems that they can encounter in everyday life?

Research sample and research organization

In order to find the answers to the research questions, five students of the study program Chemical Education at the Faculty of Chemistry University of Belgrade conducted research in which 93 seventh grade pupils and 74 eighth-grade pupils from three primary schools in Serbia took part. The research was approved by the government of each school and all pupils who participated in it were volunteers. The research, featuring both seventh and eighth grade pupils, was conducted within the course of a single school lesson, during which the pupils filled in a questionnaire and completed a test aimed at their age group.

Research instruments

The data in this research were gathered by means of a questionnaire and two tests, compiled by pre-service chemistry teachers. The questionnaire was identical for both the seventh and eighth grade pupils, whereas the tests were adjusted to the level of knowledge of the two age groups.

The questionnaire consisted of four questions that referred to the pupils' attitudes and experiences with problem-based chemistry teaching. Of these, three questions were closed, whilst one was an open-ended question.

Both tests consisted of two problem-based tasks. The tasks in the test for the seventh grade pupils referred to the teaching topic *Solutions*, whereas the tasks in the test for the eighth grade pupils referred to the teaching topic *Salts*. The pupils had dealt with both teaching topics immediately before the research. The tasks in both tests referred to problem-type situations that the pupils could encounter in real life (e. g. preparing the solution of a hand disinfectant of a given mass percent composition during the flu season). Within the framework of each task, the pupils were expected to answer several open-type or multiple-choice items.

The full contents of all the questions in the questionnaire and tasks in the two tests will be presented within the Research results section.

Data analysis

Within the analysis of data gathered through closed question in the questionnaire, the number and percentage of the seventh- and eighth-grade pupils who opted for each answer that was offered were established. In the case of open-ended question, all the answers given by the pupils were coded and closely related coded data were classified within more narrowly defined categories. Within the analysis of data gathered through both tests, for each item within the problem-based tasks, the number and percentage of the pupils who gave a correct and incorrect answer, as well as the number and percentage of the pupils who provided no answer were established.

Results and discussion

The results of the questionnaire

Within the first question in the questionnaire the pupils were asked:

Whether, in the course of learning chemistry so far, you had an opportunity to acquire new knowledge through solving problem-based tasks?

The number (N) and percentage (%) of the pupils who chose each of the two proposed answers (Yes/No) are presented in Table 1.

Table 1: Distribution of the pupils' answers to question 1

	Grade 7				Grade 8			
Question	**N(Yes)**	**%(Yes)**	**N(No)**	**%(No)**	**N(Yes)**	**%(Yes)**	**N(No)**	**%(No)**
1	58	62.37	35	37.63	48	64.86	26	35.14

As can be seen in Table 1, more than 60% of the pupils in both grades have had an opportunity to acquire new knowledge through solving problem-based tasks.

The second question in the questionnaire was:

Do you agree with the claim that learning within the framework of problem-based teaching is harder, but also more interesting than learning within the framework of classical teacher's lecturing?

The number (N) and percentage (%) of the pupils who chose each of the three proposed answers (a-I completely agree; b-I partially agree; c-I disagree) are presented in Table 2.

Table 2: Distribution of the pupils' answers to question 2

	Grade 7						Grade 8					
Question	**N(a)**	**%(a)**	**N(b)**	**%**	**N(c)**	**%(c)**	**N(a)**	**%(a)**	**N(b)**	**%(b)**	**N(c)**	**%(c)**
2	61	65.59	4	4.30	28	30.11	50	67.57	7	9.46	17	22.97

As can be seen in Table 2, more than 65% of the pupils in both grades completely agreed with the given claim.

Within the third question in the questionnaire, the pupils were asked to provide the following recommendation:

Please recommend to your chemistry teacher at least one way in which he/she could facilitate your learning, within the framework of problem-based teaching.

The key recommendations provided by the pupils were as follows:

- *problem-based tasks should be solved through group work;*
- *the teacher should not give too many problem-based tasks at once, since the pupils find it easier to acquire new knowledge gradually;*
- *the problem-based tasks should be interesting;*
- *it is of key importance for the teacher to check and review with the pupils all the previously acquired knowledge required for solving the given problem-based task.*

Within the fourth question in the questionnaire the pupils were asked:

Do you retain longer the knowledge acquired through classical teacher's lecturing, or knowledge acquired through solving problem-based tasks?

The number (N) and percentage (%) of the pupils who chose each of the proposed answers (a – I longer retain knowledge acquired through classical teacher's lecturing; b – I longer retain knowledge acquired through solving problem-based tasks) are presented in Table 3.

Table 3: Distribution of the pupils' answers to question 4

	Grade 7				**Grade 8**			
Question	**N(a)**	**%(a)**	**N(b)**	**%(b)**	**N(a)**	**%(a)**	**N(b)**	**%(b)**
4	34	36.56	59	63.44	33	44.60	41	55.40

As can be seen in Table 3, more than 55% of pupils in both grades believe that they longer retain knowledge acquired through solving problem-based tasks.

Discussion of the results of the questionnaire

The results of the questionnaire show that both the seventh- and eighth-grade pupils who participated in this research had previous experience with problem-based chemistry teaching, and that they do not have negative attitude toward it. They find such an approach to be more interesting, knowledge acquired within it to be longer retained, and point out that learning could be further facilitated through group work and gradual introduction of problem-based tasks, the solving of which should be preceded with checking and revising of all the previously acquired knowledge that is necessary in order to find the required solutions.

The test results of the seventh-grade pupils

The concept of the first problem-based task that the seventh-grade pupils solved within the test was as follows:

Into a glass containing 100 cm^3 of water Marija, while constantly stirring, gradually began to add white powdery substance X. Initially, no precipitate was formed, but as Marija continued adding substance X, at one point the precipitate began to form, and with the further addition of the substance, its quantity increased.

Based on this concept, the pupils were expected to answer items 1a), 1b) and 1c). Distribution of the pupils' answers to these items is presented in Table 4.

Table 4: Distribution of the seventh grade pupils' answers to items 1a), 1b) and 1c)

Item	**N (correct answer)**	**% (correct answer)**	**N (wrong answer)**	**% (wrong answer)**	**N (did not answer)**	**% (did not answer)**
1a)	53	56.99	4	4.30	36	38.71
1b)	40	43.01	18	19.36	35	37.63
1c)	16	17.20	6	6.46	71	76.34

Within item 1a), the pupils were expected to provide the definitions of unsaturated, saturated and supersaturated solutions, which represent key previously acquired knowledge required for solving this task. As can be seen from Table 4, less than 60% of the pupils provided the correct definitions.

Within item 1b), the pupils were expected to determine what the solution above the precipitate of substance X was like, in terms of saturation. As can be seen from Table 4, less than 45% of the pupils correctly stated that the solution above the precipitate of substance X was saturated.

Within item 1c) it was stated that, after a certain period of time following the appearance of the precipitate, Marija stopped adding substance X. The pupils were required to suggest a method that would enable her to reduce the amount of the precipitate in the glass, without physically removing any of it. As can be seen from Table 4, more than 75% of the pupils did not attempt to answer this item, whereas less than 20% of them managed to answer it correctly, suggesting that the content of the glass should be heated. Given that this is a situation that they can often encounter in everyday life, it is worrying that such a small percentage of the pupils managed to answer this item correctly.

The concept of the second problem-based task that the seventh-grade pupils solved within the test was as follows:

During a flu epidemic, Andrija bought a hand disinfectant in a pharmacy. Handing him the disinfectant, the pharmacist explained: "You have here 100 grams of a 5% disinfectant solution. To disinfect your hands, use a 2% solution, which you are to prepare using the 5% solution you bought.

Based on this concept, the pupils were expected to answer items 2a), 2b) and 2c). The distribution of the pupils' answers to these items is presented in Table 5.

Table 5: Distribution of the seventh grade pupils' answers to items 2a), 2b and 2c)

Item	N (correct answer)	% (correct answer)	N (wrong answer)	% (wrong answer)	N (did not answer)	% (did not answer)
2a)	37	39.79	2	2.15	54	58.06
2b)	21	22.58	2	2.15	70	75.27
2c)	8	8.60	1	1.07	84	90.33

Within item 2a), the pupils were expected to provide a definition of the mass percent composition of a solution, which is the key previously acquired knowledge required for solving this task. As can be seen from Table 5, only 40% of the pupils successfully provided the required definition.

Within item 2b), the pupils were expected to answer what should be done in order to turn a 5% solution of a substance into a 2% solution, that is, whether a certain amount of water should be added to, or removed from it. As can be seen in Table 5, only 25% of the pupils attempted to answer this item, and those who did were relatively successful at it.

Within item 2c), the pupils were expected to recommend to Andrija the exact procedure for the preparation of the 2% solution of the hand disinfectant, starting from its 5% solution. As can be seen in Table 5, less than 10% of the pupils managed to give a correct answer to this item. Such a result indicates that most of the pupils are still not enabled to prepare a solution of a given mass percent composition, which is a cause for concern, considering that this is a requirement which they may encounter relatively frequently in everyday life.

The test results of the eighth-grade pupils

The concept of the first problem-based task that the eighth-grade pupils solved within the test was as follows:

In a glass in front of you there is transparent lime water (a water solution of calcium hydroxide). When, using a plastic tube, you blow the air that you exhale into lime water, a white precipitate starts to form in the glass.

Based on this concept, the pupils were expected to answer items 1a), 1b) and 1c). Distribution of the pupils' answers to these items is shown in Table 6.

Table 6: Distribution of the eight grade pupils' answers to items 1a), 1b) and 1c)

Item	N (correct answer)	% (correct answer)	N (wrong answer)	% (wrong answer)	N (did not answer)	% (did not answer)
1a)	58	78.38	0	0.00	16	21.62
1b)	56	75.68	2	2.70	16	21.62
1c)	44	59.46	0	0.00	30	40.54

Within item 1a), the pupils were expected to answer which substance present in exhaled air, reacted with calcium hydroxide. As can be seen in Table 6, almost 80% of the pupils stated correctly that it was carbon dioxide.

Within item 1b), the pupils were expected to state which substance formed the white precipitate. As can be seen from Table 6, the percentage of the pupils who gave the correct answer to this item is similar to the percentage of the pupils who gave the correct answer to the preceding item, which indicates that more than 75% of the eighth-grade pupils correctly understood the reaction of calcium carbonate synthesis.

Within item 1c), in view of the fact that the substance that formed white precipitate also forms layers of lime scale on kitchen dishes, the pupils were expected to conclude whether water is an efficient means of lime scale removal. As can be seen in Table 6, almost 60% of the eighth-grade pupils correctly stated that water cannot be used to remove lime scale.

The concept of the second problem-based task that the eight-grade pupils solved within the test was as follows:

One drop of a water solution of substance A is transferred onto a piece of blue litmus paper. A red circle appears on the blue litmus paper. Following this, a drop of a water solution of substance B is transferred onto the red circle. The circle turns blue.

The pupils were then presented with two rows of substances, the ones in Row 1 representing the potential substance A, whereas those in Row 2 represented the potential substance B.

Row 1: K_2SO_4, KOH, H_2O, H_2SO_4

Row 2: $MgCl_2$, $Mg(OH)_2$, H_2O, HCl

Based on this concept, the pupils were expected to answer three items. The distribution of the pupils' answers to items 2a) and 2b) is shown in Table 7.

Table 7: Distribution of the eight grade pupils' answers to items 2a) and 2b)

Item	N (correct answer)	% (correct answer)	N (wrong answer)	% (wrong answer)	N (did not answer)	% (did not answer)
2a)	57	77.03	0	0.00	17	22.97
2b)	52	70.27	7	9.46	15	20.27

Within item 2a), the pupils were expected to state under which conditions red litmus paper changes colour to blue. As can be seen from Table 7, around 77% of the pupils correctly stated that red litmus paper changes colour to blue under alkaline conditions.

Within item 2b), the pupils were expected to state whether, in the presence of a water solution of $MgCl_2$, the litmus paper could change colour. As can be seen in Table 7, around 70% of the pupils correctly stated that, in the presence of this substance, no change in the colour of litmus paper would occur.

Finally, the distribution of the pupils' answers to item 2c), requiring of them to state which substances from Rows 1 and 2 represent substance A and substance B respectively, is shown in Tables 8 and 9. In the case of substance A the correct answer was H_2SO_4, whereas in the case of substance B the correct answer was $Mg(OH)_2$.

Table 8: Distribution of the eight grade pupils' answers concerning the choice of substance A

	N(K_2SO_4)	%(K_2SO_4)	N(KOH)	%(KOH)	N(H_2O)	%(H_2O)	N(H_2SO_4)	%(H_2SO_4)
1	3	4.06	0	0.00	0	0.00	71	95.94

Table 9: Distribution of the eight grade pupils' answers concerning the choice of substance B

	N($MgCl_2$)	%($MgCl_2$)	N($Mg(OH)_2$)	%($Mg(OH)_2$)	N(H_2O)	%(H_2O)	N(HCl)	%(HCl)
2	0	0.00	72	97.30	0	0.00	2	2.70

As can be seen from Tables 8 and 9, the overwhelming majority of the pupils correctly chose substances A and B. The high percentage of correct answers given by the eighth-grade pupils to all the items within the second task indicates that they have been adequately enabled to assess the acidity/alkalinity of substances that they encounter, which is of great importance for them in everyday life.

Discussion of the test results

The test results show that the eighth-grade pupils are better equipped to apply chemistry knowledge in various problem-type situations that they may encounter in everyday life, compared to the seventh-grade pupils. One of the reasons for this lies in the fact that the eighth-grade pupils have better mastered the knowledge required for solving the given tasks. Namely, although the pupils in both grades solved tasks related to teaching topics that they had dealt with immediately prior to doing the tests, the eighth-grade pupils, through dealing with previously taught teaching topics, both in the eighth and seventh grade, had already acquired certain knowledge about salts (e. g., they learned about acids and bases, the formation of the ionic bond and certain characteristics of ionic compounds). Consequently, it was easier for them to add the new knowledge about salts, such as reactions, solubility and acidity/alkalinity, to this already existing base of knowledge. On the other hand, the seventh-grade pupils, who had just begun learning chemistry, did not possess any significant previously acquired knowledge related to the teaching topic *Solutions*. This particularly refers to the teaching unit *The mass percent composition of solutions*, where in order to master the definition of this term, the mathematics knowledge (percentage calculus and proportions) which was new to the students, was also required. That is why it is, perhaps, not unexpected that less than 10% of the seventh-grade pupils were able to devise a procedure for preparing a solution of a particular mass percent composition. The better results of the eighth-grade pupils can probably, also, be linked to their greater experience with solving problem-based tasks in chemistry, as well as other subjects, which certainly facilitated devising the procedure for finding the correct solutions.

Conclusion

The results of this research indicate that:

- The seventh and eighth-grade elementary school pupils had previous experiences with problem-based chemistry teaching and they do not hold a negative attitude toward it;
- The seventh and eighth-grade elementary school pupils find learning through solving problem-based tasks to be harder, but also more interesting in comparison to learning through classical teacher's lecturing;
- The seventh and eighth-grade elementary school pupils find that knowledge acquired through problem-based teaching is retained longer, in comparison to knowledge acquired through classical teacher' s lecturing;
- The seventh and eighth-grade elementary school pupils believe that in order to facilitate the acquisition of new knowledge through solving problem-based tasks the new knowledge should be acquired gradually, preferably through group work, and before commencing the solving of a given problem-based task, all the previously acquired knowledge that will be required to find the solution should be checked and revised.
- The eighth grade pupils are better equipped for the implementation of chemistry knowledge in solving problems from everyday life, in comparison to the seventh grade pupils, which can be attributed to the broader scope of previously acquired chemistry knowledge, more time to consolidate and verify that knowledge, and greater experience with solving problem-based tasks.

The results of this research represent significant guidelines for the development and advancement of the competences of pre-service chemistry teachers, when it comes to problem-based teaching. In view of the fact that they gained insight into the greatest challenges of problem-based teaching, and pupils' recommendations on how to overcome them, the pre-service chemistry teachers will be able to implement problem-based teaching in the most effective way, and thus successfully prepare their pupils for the scientific and technological challenges of life in the 21st century.

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