

The Investigation of the Perception of Problem Solving Skills by Pre-Service Science Teachers in the Science Laboratory

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Abstract

This study was conducted with 100 pre service science teachers, who participated in problem solving applications at the science laboratory and the aim was to determine; i) their performances in problem solving applications, ii) their of perception levels for problem solving skills and iii) whether their performances in problem solving applications could be predicted by certain variables as their perception of problem solving skills and scientific process skills. Single group posttest model was made use of in the study. Perception of problem solving skills inventory, scientific process skill test, problem solving skill evaluation form and student report evaluation form were used as data collection tools. Following the activities, fully structured interviews were made with 10 pre service teachers for their opinions “problem solving approach in the science laboratory” and the processes it involves. Statistical analysis concluded that 45% of the change in performances of student teachers could collectively be predicted by certain variables as their perceptions of problem solving skills and scientific process skills.

Keywords: Problem-solving applications, Problem-solving skills, Perception of problem solving skills, Science education, Scientific process skills.

Introduction

One of the reasons why students receive science education is to bring them to a scientific literacy level. Scientific literacy is defined as knowing the nature of science, understanding how knowledge is attained, perceiving that scientific knowledge depends on known facts and could change according to the new evidence collected, identifying basic concepts, theories and hypotheses in science, and recognizing the difference between scientific proof and personal opinion (YK World Bank, 1997).

Problem solving process

Problem solving was first introduced as a case study at Harvard University in 1960s (Christensen, Garvin & Sweet, 1991). Later on, the method spread out to high schools, colleges and universities in various types. Teaching and utilization of problem solving in various ways provides a deeper learning experience for students along with student involvement in the conceptual process. In order to find solutions to problems, students have to collect and implement new knowledge as well as researching, taking decisions and work in cooperation with their group members. During this learning process, educators remain in the backstage while students play active roles. Within a problem solving process, the selected problem is never an exercise or implementation of a concept. Students have to obtain new

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concepts for solving the said problem; because, problems may not be easily solved through activating the previously learnt knowledge. Teaching of problem solving requires the creation of an active learning environment, where students have to take responsibilities in a group for collecting, exchanging and adopting new knowledge. Instead of being a passive receiver, students participate in the pedagogical process to be able to learn the knowledge (Whitehead, 1929; Gallet, 1998).

There are different definitions for problem solving in many literatures. Gagne (1970) differentiated problem solving as the highest level of learning from the problem solving skill as the unavoidable life skill. According to Wheatley (1984), problem solving is what you do when you do not know what to do. Gagne (1977) expressed problem solving as a thinking process, where students discover the composition of previously learnt principles to solve a problem. Ashmore, Frazer and Cassey (1979) defined problem solving as the result of the implementation of certain knowledge and principles to understand a problem. Perez and Torregrose (1983) considered problem solving as a scientific research task. Heppner (1982) used problem solving as a synonym for coping with problems. According to Cardellini (2006), problem solving is more than integrating numbers into well-known formulas. It is related to creativity, comprehensive thinking and formal knowledge.

Teaching of problem solving and its various ways of utilization enables students to learn faster and students perform within the conceptual process. In order to find solutions to the problems, students have to acquire and implement new knowledge, research, take decisions and cooperate with their peers. Such cooperative learning environments have also been shown to enhance students' problem solving skills in chemistry (Bilgin, 2005; Cooper, Cox, Nammouz, Case & Stevens, 2008; Mahalingam, Schaefer, & Morlino, 2008; Reid & Yang, 2002a; Wood, 2006). Collaboration during problem solving is particularly effective for students when they are working on open-ended problems (Cited by Delvecchio, 2011). During this learning process, teachers remain in the background while students play an active role. The problem dealt during the problem solving process is not an exercise or the implementation of a concept. Students have to attain new concepts to solve the given problem. Problems may not be solved easily through activation of students' previously learnt knowledge. Teaching problem solving creates an interactive environment, where students attain new knowledge, exchange their knowledge and take responsibilities for comprehending the knowledge. Instead of being a passive receiver, student participates in the pedagogical process (Whitehead, 1929; Gallet, 1998; Cited by: Temel, 2009).

Algorithmic and conceptual problem solving

Although the importance of educating children in such a way to implement scientific concepts and knowledge in their own lives has been emphasized in teacher training programs, it is observed that students learn science through memorizing. According to Gabel, Sherwood and Enochs (1984) studies have shown that students depend on algorithmic techniques rather than logical thinking skills (Lin, Hung & Hung, 2002) and that they have the tendency to utilize their algorithmic problem solving skills when solving conceptual problems (Nakhleh and Mitchell, 1993). On the other hand, science educators agree that the achievement in solving mathematical problems indicate mastery in a scientific concept (Nakhleh, 1993). As a result, the extreme emphasis on algorithmic problem solving results with a limited understanding of chemistry by students with mathematical problem solving skills (Lin et al., 2002). According to Niaz and Robinson (1993), studies have shown that mathematical problem solving skills (based on algorithmic solution strategies) are not measures for achievement in solving problems, which require conceptual understanding (Zoller, 2002). There is strong evidence against the opinion that the ability to solve algorithmic-based

mathematical problems enabled conceptual understanding (Niaz, 1995; Zoller et al., 1995; Dori & Hameiri, 1998; Cited by; Zoller, 2002).

Problem solving approach in the laboratory

According to Chiappetta and Koballa (2002), various approaches have been developed in recent years to increase the productivity of laboratories along with turning them into environments where meaningful learning occurs. One of these approaches is the problem solving approach in the laboratory. By using this approach, chemistry curriculum has been revised to allow for more purposeful utilization of laboratories (Wilson, 1987). Laboratories are ideal and productive environments to implement technical concepts into the real life contents (Gallet, 1998). However, traditional chemistry experiments are carried out in a way that does not require much thinking or preparation. Students participate in laboratory activities in the same way as following the instructions of a recipe (Neeland, 1999). With the aim of correcting this mistake, certain chemistry educators reached to better conditions by using the problem solving approach in the laboratories (Wilson, 1987).

Learning products of problem solving

Problem solving skill

Problem solving is one of the primary tools for college and university science instruction (Gök, 2010). A growing concern of chemistry educators is that students are not acquiring adequate problem solving skills during chemistry courses (Bodner, 2003; Hollingworth & McLoughlin, 2005; Taasooobshirazi & Glynn; Teichert & Stacy, 2002; Cited by Delvecchio, 2011). Problem solving skill sets one of the roles that individuals undertake in becoming individuals and coping with their environments. Individuals with positive senses of self achieve better in real problem solving skills (Güçlü, 2003). Middlecamp and Kean (1987) suggest that in order to improve students' problem solving skills, they should be taught about how to determine the type of a problem and choose strategies accordingly (Cited by Nakiboğlu & Kalın, 2009). For improving problem solving skills, it is important to guide students and provide them with feedback as well as introducing strategic methods and modeling students in utilization of these methods (Asieba & Egbugara, 1993; Collins, Brown, & Newman, 1989; Keith, 1993). Educators should be able to observe problem solving performances of students, provide their students with feedbacks and support them in acquiring these skills (Cited by Jeon, Huffman & Noh, 2005).

Scientific process skill

The main aim of science teaching is to enable students to develop their inquiry, critical thinking and problem solving skills, to become lifelong learners and to continue their senses of curiosity towards their environments. Therefore, it is very important for students to acquire scientific process skills, which enables them to produce scientific knowledge as well as learning about the nature of science through experiences (Aydoğdu, 2006). One of the essential aims of laboratory studies is to develop an understanding in students about the nature of science (Chiappetta & Koballa, 2002; Ayas et al., 1997). To achieve this aim, students have to use certain scientific process skills during their research at the science laboratory (Kanlı, 2007). Individuals, who attain scientific process skills, possess problem-solving skills and know how to attribute meanings to the events happening by looking at them, form a different perspective. Furthermore, students with the said skills manage to think like a scientist (Aydoğdu, 2006). Improving scientific process skills enable students to solve problems, think critically, take decisions, find answers and satisfy their curiosities. In the light of all these reasons, teaching scientific process skills should be essential. The importance to be attributed would enable students to improve their scientific process skills in time (Cited by Aydoğdu, 2006).

Purpose of the study

With 100 pre service science teachers, who participated in problem solving applications at the science laboratory (PSASL), the aim was to determine; i) their performances in problem solving applications, ii) their of perception levels for problem solving skills and iii) whether their performances in problem solving applications could be predicted by certain variables as their perception of problem solving skills (PSSP) and scientific process skills (SPS). In this respect, answers to the following problems were sought:

- How do science teachers perform after the problem solving applications in the science laboratory?
- How do science teachers' perception levels for problem solving skills change before and after the problem solving applications in the science laboratory?
- Are beliefs about PPSS with SPS variables, significant predictors for the performances of pre-service science teachers, who participated in the problem solving applications at the science laboratory?

Methodology

For this study, a mixed-method approach was employed. Quantitative model consisted of single group posttest implementation. A fully structured interview form was used for taking the opinions of student teachers after the problem solving applications in the science laboratory.

The Sample

The study was participated by 100 pre-service teachers (20-21 years) studying in their 3rd year at the Department of Science Education, Cumhuriyet University, Sivas/Turkey during the 2012 – 2013 academic year.

Instruments

Problem solving skill perception inventory (PSSPI)

PSSPI is utilized to assess an individual's perception about his/her own problem solving skills, was developed by Heppner and Petersen (1982). The inventory does not assess actual problem-solving skills but rather one's perception of one's problem-solving beliefs and style (Heppner et al., 2004; Cited by Temel, 2014). The scale was first translated into Turkish from English by Akkoyun and Öztan (1988) and later on it was translated again by Taylan (1990) and Savaşır and Şahin (1997). PSSPI is a Likert-type scale with 35 statements, which are scored between 1 and 6. The core range to be obtained from the inventory is between 32 and 192. The low scores obtained from PSSPI indicate effective problem solving skills, while the high scores indicate failure to find effective solutions to problems (Taylan, 1990). Savaşır and Şahin (1997) concluded in their study that the PSSPI was composed of three factors being "confidence in problem solving skill", "approaching- avoiding" and "self control". The Cronbach Alpha internal consistency coefficient was calculated for the inventory as 0,90 by Savaşır and Şahin (1997) (Cited by Temel, 2009).

Scientific process skills test (SPST)

Scientific process skills test (SPST) was originally developed by Okey, Wise and Burns (1982). It was translated into Turkish and adapted by Geban et al., (1992). SPST consists of 36 questions with four choices. The questions of the test aims to asses recognition of variables in a problem (12) as well as constructing and defining hypothesis (8), making operational explanations (6), designing required analysis for solving the problem (3), and drawing and

interpreting graphs (7). The validity of the test is rather high and its reliability is calculated as 0,82.

Problem solving skills evaluation form (PSSEF)

PSSEF is a form, where student teachers are assessed individually (Lynch, Wolcott & Huber, 2001). The problem solving skills of student teachers are evaluated according to the measures in the form (differentiating the nature of the problem and the relevant knowledge, organizing an open-ended problem, reorganizing an open-ended problem). All skills in the form were scored between 0 and 4 according to the quality of the skill. The set up and content validity of the form were obtained through taking expert opinion. For the reliability of the form both researchers filled this form for each student teacher and the consistencies between the two scores were looked at. The Pearson Correlation analysis concluded that the consistency between the scores of the two researchers was .89 (Temel, 2009).

Student reports evaluation form (SREF)

SREF (chem.ntci.on.ca/sch4u/InquiryRubric.pdf) is a form that is adapted by the researchers to evaluate the reports prepared by the groups as their products following their laboratory studies. The assessment measures in the form (purpose, materials and procedure, hypotheses, discussion) were scored from 1 to 4. For the reliability of the form, both researchers filled in this form according to the experiment reports of the groups and the consistency between the researchers' scores was evaluated. The Pearson Correlation analysis concluded that the consistency between the two researchers was .87 (Temel, 2009).

Teaching Process

Approximately three weeks before the start of PSASL, PSSPI and SPST were administered as pretests. Before the administration, students were informed by the researchers about the importance of scientific process skills and science teaching through scientific research along with their importance at the laboratory practices. These skills are important elements of the mental development and set the basis of the laboratory practices (Ayas et.al, 1997).

Problem solving applications at the science laboratory consisting of 5 steps was realized within 6 weeks with the participation of 100 science teachers (YÖK World Bank, 1997). After the pretest application, student teachers were asked for their opinions on what problem solving means, the importance of problem solving process and how it is realized through a small discussion. Next, they were informed about the problem solving applications at the chemistry laboratory, the steps of these applications, and how to proceed according to these steps to introduce the application to the student teachers during the first week of the study. Student teacher groups were asked to form groups of four and five. The initial phase of the application (the problem case) was also proceeded in this week. Each group was given a problem case. For ensuring meaningful problem solving, problem cases were chosen among daily life events. Student teachers were informed they would determine their problems by the second week. A total of 10 problem cases were presented to all student groups. Some of the problem cases given to student groups and some of the problem statements created by students groups were as follows:

- a) *Problem Case:* Because the silver is reacted with the hydrogen sulfide gas in the air, when the materials made from silver are exposed to air or in contact with matters such as egg yolks or rubber, the surface of silver materials get darker. The chemical name of the resulting silver sulfide is "darkening".

Problem Statement: Is it possible to reverse darkening process to its original?

- b) *Problem Case*: When we make house cakes, cookies or savory pastry in our house, we mostly use baking powder. When we use different brands of baking powder in the market, Problem Statement: Do the different baking powders have the same main ingredients? If we omit the small cooking errors, what are the reasons of difference in blistering levels?
- c) *Problem Case*: It is believed that Vitamin C support is good for sicknesses experienced particularly in winter such as flue and common cold. Therefore, we consume fruit such as lemon and orange more. What if you were told that parsley, strawberry and green pepper is richer in Vitamin C than others?

Problem Statement: How could we find out which fruit/vegetable has more Vitamin C than others?

The second week when the second phase starts (identification of the problem), groups simplify their problems and differentiate events to analyze from the events that do not require analysis. They divided the problems into steps or sub problems and expressed their problems in a clear language. The researchers controlled the problems determined by the groups. The third phase of the application in the third week (establishing hypothesis) involved the determination of all technical and theoretical questions they needed to solve their problems. Later, all groups shared responsibilities among their members and started to seek potential solutions to their problems. With this aim, groups made use of the library and various resources to collect information about their pre-problems. After the data collection week, the solutions suggested by the groups were collected and one among them was selected for each group to be tried. The researchers checked these solution ways. Groups established their hypothesis for solving their problems and presented the solution way of their choice in the form of an experiment suggestion. The fourth step was (trying the solution way) the experiments done by the students at the chemistry lab under the supervision of the researchers. During the experiment phase, the groups doing their experiments generalized the results they obtained and expressed them in their own words. In the fifth and final phase of the study (repeating), the groups, who failed to obtain results according to the hypothesis they established, revised their solution steps and the whole process was repeated starting from the step that the failure occurred.

During the PSASL, researchers evaluated each group member in terms of their application phases (identifying the nature of the problem and the relevant knowledge, generating an open-ended problem, solving an open-ended problem, regenerating an existing open-ended problem) using the PSSEF by scoring each skill with numbers between 0 and 4 according to the quality of the skill performed. Moreover, during this week, groups submitted to the researcher their individual reports, which include their purposes, observations, data analyses, hypotheses, work schedules and conclusions. SREF was used in the evaluation of all individual student reports submitted by group members. The evaluation measures indicated in the form (purpose, materials and procedure, hypothesis, conclusions, discussion) were scored between 1 and 4 by the researcher. In reflecting on the PSASL performances, the scores obtained from the PSSEF and SREF were added and converted into the scoring system over 100. Approximately two weeks after the finalization of PSASL, PSSPI and SPST were administered again this time as posttests.

After the PSASL, 10 pre service teachers were selected among the participating 100 pre service science teachers were interviewed using the fully structured interview form about the “Problem Solving Approach in the Science Laboratory” and the process it involves. Questions asked to the pre service teachers and their views obtained are presented in detail in the “findings” section of this study.

Findings of the research

Findings related to the student performances determined according to the problem solving applications in the science laboratory

With respect to the first sub problem of this study, performances of pre-service science teachers after the problem solving applications in the science laboratory were determined. The researchers observed all phases of the problem solving applications in the science laboratory and a PSSEF was filled in for each pre service teacher in the groups. The skills included in the PSSEF and were evaluated by the researchers consist of four major skills: (a) identifying the nature of the problem and the relevant knowledge, (b) generating an open-ended problem, (c) solving an open-ended problem and (d) regenerating an open-ended problem. Each skill has been divided into sub skills within themselves. Each group member was scored between 0 and 4 with respect to these sub skills. The total score obtained from the PSSEF was later included in the total scoring by the researchers for the scoring system over 100. Following the PSASL, individual experiment reports prepared by each group member were evaluated by the researchers via the SREF. Researchers calculated the total “PSASL Performance Score” for each pre service teacher using the scores obtained from PSSEF and the SREF. The lowest PSASL score for the pre service teachers was found to be 38, while the highest one was 97. Average performances of pre service teachers were calculated as $X_{avg}=68.05$. This average indicates that the pre service teachers performed well.

Findings related to the problem solving skill perception inventory

After the PSASL, in order to determine the perception levels of pre service teachers about problem solving skills, the PSASL data obtained from the posttest were taken into consideration. For all three factors included in the inventory, the average scorings of the factor items were calculated and the comparisons were made accordingly (Güçlü, 2003). The high scores obtained from the PSSPI indicates that the individual perceives him/herself as inadequate in terms of problem solving skills, while the low scores indicate the extent, to which the individual has improved problem solving skills (Taylan, 1990).

Descriptive data regarding the perceptions scores obtained by pre service teachers in the items of the “Confidence in Problem Solving Skill” factor are displayed on Table 1.

Table 1 shows that the general average score with respect to the perceptions of participating pre service teachers about the items of the “confidence in problem solving skill” factor is found to be 1,96.

Descriptive data regarding the perception scores of pre service teachers about the items in the “approaching – avoiding” factor are displayed on Table 2.

Table 2 shows that the general average score with respect to the perceptions of participating pre service teachers about the items of the “approaching - avoiding” factor is found to be 2,37.

Descriptive data regarding the perception scores of pre service teachers about the items in the “self control” factor are displayed on Table 3.

Table 1. The arithmetical average and standard deviation values regarding the items of the “confidence in problem solving skill” factor

Items	N	X_{avg}	s
5. I am usually able to produce creative and effective solutions for solving my problems.	100	2.14	1.054
10. Although I fail to notice the problem at the very beginning, I have the ability to solve most of my problems.	100	2.01	.822
12. I usually take my own decisions regarding myself and I am usually pleased with these decisions.	100	1.85	.857
19. In developing a plan to solve one of my problems, I believe that I could proceed according to the plan.	100	1.83	.932
23. I believe that I could solve most of the problems if I have adequate time and try hard enough.	100	1.84	.950
24. I believe that I could solve the problems that may emerge when I face with a new situation.	100	1.67	.876
27. I trust my ability to solve new and challenging problems.	100	1.94	.896
33. The outcome of a decision made is usually in line with the result I expect.	100	2.39	.919
34. I am usually unsure that I may cope with the situation when I experience a problem.	100	1.93	.879
35. One of the first things I do when I experience a problem is to understand what the problem is actually about.	100	1.97	1.086
Total	100	1.96	.927

Table 2. The arithmetical average and standard deviation values regarding the items of the “approaching – avoiding” factor

Items	N	X_{avg}	s
1. When the solution ways I choose fail to solve my problem, I do not try to find out why they were unsuccessful.	100	1.75	1.131
2. When I face a challenging problem, I do not think in detail on how I should collect data to find out what actually is happening.	100	1.81	.825
4. After solving a problem, I do not think about which method worked and which method did not in detail.	100	1.65	.833
6. After trying a certain method to solve a problem, I stop for a while and compare the outcome to the one I expected.	100	2.05	.845
13. When I come across a problem, I usually choose the first solution method that comes to my mind.	100	3.60	1.517
15. In deciding upon a potential solution way regarding a problem, I evaluate the succeeding possibilities for each of my choices.	100	3.86	1.550
16. When I face a problem, I stop and think about the problem before I move on to another topic.	100	2.09	.964
17. I usually act according to the first idea that I think of.	100	3.35	1.465
18. In trying to take a decision, I assess, compare and contrast the potential outcomes of each option and decide accordingly.	100	2.03	.989
20. Before implementing a certain solution plan, I try to estimate its potential outcome.	100	2.07	.956
21. I do not produce too many options when thinking about potential solution ways of a problem.	100	2.46	1.158
30. When I face a problem, I usually do not take into consideration the effective factors other than myself.	100	2.19	1.284
31. When I face a problem, one of the first things I do is to review the situation and consider all relevant information.	100	2.01	.969
Total	100	2.37	1.11

Table 3. The arithmetical average and standard deviation values regarding the items of the “self control” factor

Items	N	X_{avg}	S
3. If my initial attempts to solve a problem fail, I doubt about being able to solve that problem.	100	2.17	.921
14. Sometimes, instead of stopping and thinking over my problems, I let it slide.	100	2.21	1.103
25. I sometimes feel that although I try hard to solve a problem, I fail to focus on the real topic and lose time with unnecessary details.	100	2.61	1.171
26. I take instant decisions and I feel sorry about them later on.	100	2.14	1.054
32. Sometimes, I get too emotional that I do not consider most of the ways to cope with my problem.	100	4.04	1.510
Total	100	2.63	1.151

Table 3 shows that the general average score with respect to the perceptions of pre service teachers about the items of the “self control” factor is found to be 2,63.

In order to determine whether the PSASL were effective on perceptions of pre service teachers about problem solving skills, t-test for dependent groups was administered for the comparison of PSSPI pre and posttest results. Findings are displayed on Table 4.

Table 4. Findings of the t-test for dependent groups with respect to the PSSPI pre and posttest result comparisons

	N	X_{avg}	correlation	s	t	p
Pretest	100	2.53	.592	.418	6.075	.000
Posttest	100	2.28				

Table 4 shows that the pretest average score of pre service teachers regarding the perception of problem solving skills before the PSASL was 2,53; however, it this average was observed to decrease down to 2,28 following the applications. The highness of the total scores obtained from PSSPI indicates that the individual perceives herself inadequate in problem solving skills, while the low scores indicated that the individual had improved problem solving skills at the obtained level (Taylan, 1990). Therefore, the result that the posttest average is lower than that of the pretest indicates a statistically significant increase in the perception levels of pre service teachers about problem solving skills ($t_{(100)} = 6.075$, $p < 0,05$).

Statistical analysis of the results obtained from PSSPI and SPST

Multi linear regression analysis was conducted with the aim of analyzing the extent, to which the posttest results obtained from PSSPI and SPST predicted the student performance. The results are displayed on Table5.

Table 5 shows that 45% of the change in the student performance as a result of the PSASL could be predicted together by the PSSP and SPS variables of the pre service teachers, to whom the model was applied. The remaining part of 55% is predicted through the other variables that were not included in the model. The $F=39,701$ value indicates that our model is significant at all levels as a whole ($R = .671$, $R^2 = .045$, $F=39.701$, $p = .000$).

Table 5. The results of multiple linear regression analysis between PSSPI and SPST and the performances of students

Model	R	R Square	Adjusted R Square
1	,671 ^a	,450	,439

^aPredictors: (Constant) PSSP and SPS^bDependent Variable: PerformanceAnova^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10096,015	2	5048,007		
	Residual	12333,733	97	127,152	39,701	,000 ^a
	Total	22429,747	99			

^aPredictors: (Constant)) PSSP and SPS^bDependent variable: PerformanceCoefficients^a

Model		Unstandardized coefficients		Standardized coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	82,283	9,543		8,622	,000
	PSSPI	-15,182	1,981	-,584	-7,662	,000
	SPST	,321	,098	,249	3,266	,002

^aDependent variable: Performance

Correlations

		Performance	PSSPI	SPST
Pearson Correlation	Performance	1.000	-,624	,342
	PSSPI	-,624	1.000	-,160
	SPST	,342	-,160	1.000
Sig. (1-tailed)	Performance	.	,000	,000
	PSSPI	,000	.	,046
	SPST	,000	,046	.

According to the standardized regression coefficient (Beta), the respective sequence of the variables according to their levels of importance in terms of student performance is as follows: PSSP and SPS. The t-test on the significance of the regression coefficients showed that the PSSP and SPTS variables were significant predictor of the performance. According to the results of the regression analysis, the regression equation (mathematical model) about the prediction of the student performance is as follows:

$$\text{Student Performance} = 82.283 - 15,182 \text{ PSSP} + ,321 \text{ SPS}$$

While the 45% of the performances of student teachers who participated in the PSASL could be predicted by the variables included in the model, the correlation coefficient was calculated with the aim of determining the relationship between the independent variables as well as its direction. The correlations in Table 5 are analyzed for the correlation analysis results of the study and a negative and significant relationship ($p=,000$) at the high level ($r=-,624$) was found between the PSSP scores and PSASL performances of pre service teachers. In other words, performance levels of pre service teachers decreased as the scores of perceptions about problem solving skills increased. According to Taylan (1990), high scores obtained from PSSPI indicated the inability to find effective solutions for problems and a low

level of problem solving skill. This result shows that pre service teachers who perceive their problem solving skills well had good performances, while pre service teachers who perceived their problem solving skills to be low had bad performances. A positive and significant relationship ($p=,000$) at the weak level ($r= ,342$) was found between the SPS scores and PSASL performances; a negative and significant relationship ($p= ,046$) at the weak level ($r= - ,160$) was found between the PSSP and SPS scores of pre service teachers.

Findings related to students' fully-structured interviews

Following the PSASL, 10 pre-service teachers were selected among the participants with very good and very poor performances and they were interviewed using a fully-structured interview form about the “Problem Solving Approach at the Science Laboratory” and its process. Some of the questions asked to and responses given by the pre service teachers are given as examples hereby below:

- During the PSASL, which of the following scientific process skills were challenging for you to use? Would you please explain you response together with the reasons? (a) creative and critical thinking, (b) taking the responsibility for self-learning, (c) asking questions in line with the given problem case, (d) determining a problem statement, (e) Making research about the problem statement, (f) proposing solutions in line with the problem statement determined, (g) establishing hypothesis and questioning, (h) collecting and evaluating data, (i) designing an experiment as a solution proposal, (j) performing the experiment, (k) reaching conclusions and interpretation.

Student 44: *Yes, the “taking the responsibility for self-learning” was challenging for us. Because, we had difficulty in analyzing the information obtained as a result of the research on the problem case we were given, that is we had difficulty in connecting relevant information and eliminating irrelevant information or making them meaningful. Thus, as we were unable to make the relevant information meaningful, we had difficulty asking questions related to the given problem case.*

Student 45: *It was not difficult for us to analyze the given problem case, I mean, establishing sub problems. However, as we were unable to establish the relevant links, we had difficulty in creating an appropriate problem statement. We had to request assistance from the researcher. I don't think we had a problem in the creative and critical thinking phase. Because, none of the laboratory applications I participated during my education required creative or critical thinking. For instance, it was the first time that we were expected to propose and design an experiment in a laboratory application. That part was challenging.*

Student 42: *We had difficulty in asking questions appropriate to the given problem. Because, it was the first time that we were expected to ask a question and answer it at the same time. Yes, I researched the topic quite well but I noticed that I don't have a good questioning skill.*

Student 47: *Determining the problem statement was quite challenging for us. Because, I believe that, in determining a problem statement, the given problem case should be well understood and analyzed. By taking logical decisions within cause and effect relationships, I think, reasoning is more effective in creating a relevant problem statement from a given problem case than imagination.*

Student 31: *Since I had never come across with such an application before, I had difficulty in doing the analysis on the “problem case”. In particular, I had difficulty in producing questions about the problem case. Cooperating with the*

group members decreased the level of difficulty to a certain extent. I noticed that more creative ideas came out while working with a group. I think this application should never be executed individually.

Student 75: When we saw the problem case we were given, we had difficulty in finding out what it was about or what we should research. We also had difficulty in determining the problem statement. Because, we had problems with figuring out a statement in appropriate to the problem case, and what caused the problems we had about the results. I also think that performance of the experiment was also challenging. Because we didn't know what to do to overcome the problems we had during the performance of the experiment. Also, I don't think that we were successful in the implementation phase of the experiment.

Student 76: First of all, I don't think I am competent in creative thinking. Because I had a perception problem about the problem case, we were given. I also had problems with collecting and recording data after designing and performing the experiment. I don't think I was good at interpreting the outcomes. If I were expected to perform this application individually, I don't think I would be able to do it with all phases. At the end of the whole process, I understood the case when I looked back at all the things we had done but I think it was too late.

Student 22: We had a lot of difficulty in figuring out the topic related to the problem case. Since we were unable to figure out the relevant topic, we couldn't create a problem statement. I also think that proposing an experiment was also challenging. I believe that the contribution of the group members was more dominant.

Student 25: This is the first time I am experiencing such a laboratory practice. That's why the initial step is very important for such a practice to succeed. I mean, it requires mastering the given "problem case". I believe that if the relevant topic is figured out, then the following phases would be performed more easily. We had a lot of difficulties in this practice, as we were unable to figure out the topic in the problem case phase, I mean, at the very first step.

Student 28: Finding solution suggestions phase was very challenging for us. After the problem case was given to us, we thought a lot about what the problem was related to. We did a lot of research using a variety of resources.

- In order the problem solving method to be executed in a meaningful way, particular importance was given to choosing problem cases from daily life events. Do you think the problem cases given to you during laboratory applications should reflect real life problems? Would you explain your opinion along with the reasons?

Student 45: It is very important for the given problem cases to reflect the real life problems since people can establish connections between the problem cases and the real event in this way. This would enable the individual to have a better understanding of the events and the world as well.

Student 76: Problem cases given in this application should definitely be selected from the daily life. Because, staying in close connection with life would help us in suggesting solutions to problems in an experimental environment, doing research, exchanging ideas within groups, coming to logical conclusions, attributing a meaning to life and getting to know the world we live within a better understanding.

Student 75: *Yes, problem cases should reflect the real world. Because, this would allow us to make better observations on what is happening around us. Furthermore, it helps us in finding solutions using scientific process skills for all problems we face. Selecting problem cases from the real world also enables the learnt knowledge to be more meaningful and permanent.*

Student 25: *Yes, they should. Because, selecting problem cases from real world would increase attention to the topic and various solutions may be suggested due to their relevance with daily life.*

Student 22: *They definitely should. Because; this application requires hands-on activities. We performed and experienced, and therefore we connected real life phenomena with the daily life in a laboratory environment. Learning became both meaningful and permanent.*

-PSASL involves a process to be executed in groups. What are your positive and negative opinions during your performance of this application within your group? Should the cooperative learning model in groups be used in PSASL? Would you please explain your opinions with reasons?

Student 25: *I consider working with a group as an advantage within this process. Since there are individual differences in knowledge and skills, the points I lacked could be compensated by the other group members. When I was stuck in terms of creativity, the process was still successful with the help of my friends.*

Student 75: *Suggesting different ideas in proposing solution ways to our problem statement during PSASL was very nice. As well, while asking questions relevant to the problem case, certain things we can't remember could be suggested by our friends. The only disadvantage of working with a group may be the lack of active participation in the group work by some of our friends.*

Student 76: *Since there was an exchange of ideas in this application, I believe that a more permanent learning occurs. It improves the sense of responsibility. Ideas and thoughts of the group members should be respected.*

Student 44: *For a study to be successful with such a group, the group members should definitely be selected carefully. It makes the both the application and the process successful when the group members undertake equal amount of responsibilities and cooperate during the tasks.*

-While trying to find solutions to the given problem cases, for which of the following problem solving strategies did you most require the guidance of the researcher; (a) rereading the problem, (b) trying to understand the problem, (c) thinking about concepts related to the problem, (d) expressing the problem in one's own words, (e) finding possible solutions to the problems, (f) dividing the problem into sub problems, (g) focusing on the solution of the problem? Would you please explain the strategy for which you required assistance from the researcher including its reasons?

Student 47: *We requested guidance particularly in the "trying to understand the problem" section. Because, I think that other phases are more relevant to understanding the problem well. Another phase we requested guidance was "dividing the problem into sub problems". Because, when you divide a problem into its sub problems, the real problem becomes clearer and a better analysis could be done.*

Student 44: *I believe that the “expressing the problem with one’s own words” phase was quite challenging. Because; we had problems with analyzing the problem case effectively and creating the problem statement. We requested the guidance of the researcher in this phase.*

Student 75: *“Trying to understand the problem” phase was quite challenging. We were unable to understand how to create a problem statement from a real-life problem. Therefore, we were unable to divide the problem into sub problems. I think, dividing the problem into sub problems is the most important phase in creating the problem statement.*

Student 76: *“Focusing on the solution of the problem” phase was very challenging. Because; we were not creative enough in experimental suggestions.*

Student 45: *We requested the assistance of the researcher in “dividing the problem into sub problems”. In order the problem statement to be created, relevant sub problems are required. All group members created different sub problems in this respect; however, most they were irrelevant.*

Conclusions and discussion

This section includes the results obtained from the PSASL and the discussions about these results. In this study, where it was aimed to enable pre service teachers to find solutions to various problems related to science topics through PSASL, students performed the PSASL in 5 phases (Ayas et al., 1997).

With respect to the first sub problem of the study, the PSASL performance of pre service teachers was determined to be 38 at the minimum and 97 at the maximum level. Performance averages of the pre service teachers was found to be $X_{avg} = 68.05$. This average indicates that the pre service teachers performed well.

Determination of the participating pre service teachers’ perceptions about problem solving skills as the second sub problem of the study was made through calculation of average scores and standard deviation values regarding the three factors of the PSSPI. Looking at the average scores belonging to the items of the “confidence in problem solving skill” factor displayed in Table 1, it could be stated that the pre service teachers were confident about their problem solving skills in general. Pre service teachers mentioned this confidence in statements such as “I generally am able to take decisions regarding myself and I am pleased with these decisions”, “when planning to solve one of my problems, I believe that I am able to execute the plan”, “I believe that I am able to solve problems that may occur when I face a new situation” and “I believe that I can solve most the problems I experience if I have enough time and try hard enough”. The average scores displayed in Table 2 with respect to the “approaching- avoiding” factor indicated that pre service teachers “did not think much about how they could collect data to determine what really is happening when they face a difficult problem”, “did not think in detail about what was useful and what was not in solving this problem” and “did not investigate the reasons if the solution method they used in solving a problem failed”. Average scores given in Table 3 at the “self-control” factor lead to the observation that the pre service teachers “doubted about their abilities to cope with a problem in case they fail at the beginning” and “they regretted about the immediate decisions they had taken”. Therefore, pre service teachers were not found to be competent in terms of preserving their self-control over the problematic situations.

The posttest results of the PSSPI with respect to the second sub problem of the study displayed in Table 4 indicated that while the pretest averages of pre service teachers regarding

their perceptions about their problem solving skills was 2,53, it decreased down to 2,28 after the applications. The high scores obtained from the PSSPI indicated that the pre service teachers considered themselves incompetent in terms of problem solving skills whereas the low scores indicated a high level of problem solving skill (Taylan, 1990). That the posttest average was lower than the pretest average highlights a statistically significant increase in pre service teachers' perceptions about their problem solving skills ($t(100)= 6.075, p<0,05$). The applications performed enabled pre service teachers to improve their perceptions about the problem solving skills. They participated actively in the application to find solutions to the real life problem cases they were given. To find solutions for their problems in the laboratory environment, they proposed solution methods and supported these with experiments they designed. Their creativity was predominant throughout the problem solving process. They undertook the responsibility of their own learning and suggested various ideas during the solution process, in particular when suggesting solutions. The literature involves studies about the positive aspects of problem solving applications in the laboratory environment.

The third sub problem of the study focused on whether PSSP and SPS variables were significant predictors for the performances of pre-service science teachers, who participated in the problem solving applications at the science laboratory. Table 5 showed that 45% of the change in the performances of pre service teachers were collectively predicted by the PSSP and SPS variables included in the model ($R= ,671; R^2= ,450; F=39,701; p= ,000$).

The correlations in Table 5 are analyzed for the correlation analysis results of the study and a negative and significant relationship ($p=,000$) at the weak level ($r= -,624$) was found between the PSSP scores and PSASL performances of pre service teachers. In other words, performance levels of pre service teachers decreased as the scores of perceptions about problem solving skills increased. According to Taylan (1990), high scores obtained from PSSPI indicated the inability to find effective solutions for problems and a low level of problem solving skill. This result shows that pre service teachers who perceive their problem solving skills well had good performances, while pre service teachers who perceived their problem solving skills to be low had bad performances. There are studies on the relationship between the problem solving skill and the performance. Geban, Aşkar and Özkan (1992), a concluded in their study that the students in the treatment group, who were administered computer simulation experiment and problem solving approaches performed better in chemistry than the students in the control group, who were administered the traditional approach. In the study by Su (2008), performances of students in the treatment group who experienced a process to develop their problem solving skills were higher in terms of conceptual problem solving skills, while that of the students in the control group remained the same. Jeon, Huffman and Noh (2005) concluded in their study that students who belonged to the problem solving-based group performed better in terms of conceptual knowledge than the students in the traditional group. Temel (2009) expressed observations similar to our study with respect to the conclusions of his study on problem solving skills and performances of students participating in problem solving activities at the chemistry laboratory.

The relationship between pre service teachers' performances in the PSASL and their scientific process skills ($r= ,342$) was observed to be positive and significant ($p=,000$) at the weak level with a 1% level of significance. The literature includes various studies on the relationship between problem solving skills and scientific process skills, laboratory methods, which lead to improvement in scientific process skills. Geban, Aşkar and Özkan (1992) studied the effects of computer simulation experiment approach and the problem solving approach on high school students' performances in chemistry in terms of scientific process skills. The study concluded that the students in the treatment group performed better in chemistry than those in the control group, who were taught according to the traditional

approach. Suits (2004) administered a practical laboratory test with the aim of comparing scientific process skills of students attending two different general chemistry laboratory classes. The results showed that students of the treatment group received statistically higher scores than those of the control group. Goh, Toh and Chia (1989) used a laboratory approach adapted for the development of scientific process skills. Data obtained from the tests administered in the study resulted that students in the treatment group performed better than those in the control group at all tests. This evidences that the approach, which emphasizes the learning of scientific process skills, increased practical performances of students. Koray et al., (2007) analyzed the effects of creative and critical thinking-based science laboratory applications on scientific process skills of pre service elementary teachers as well as their academic performances. The study concluded that the pre service teachers in the treatment group performed better in terms of both achievement and scientific process skills than those of the control group, who received traditional laboratory education. This difference was interpreted according to the active participation of students in the treatment group using the scientific process skills that he experiments required.

Among the pre service teachers who participated in the PSASL, 10 pre service teachers with very good and very poor performances in terms of problem solving activities at the science laboratory were selected and interviewed. The aim of the interviews was to reveal the points where pre service teachers experienced difficulties during the process. The only common point indicated by the pre service teachers during the interviews was that they had never participated in such an application before. In other words, pre service teachers mentioned that, during all the years of their education, they had used close-ended laboratory technique and had not undertaken to many responsibilities. According to the pre service teachers, problem-solving application in the laboratory environment required them to be active both individually and within groups. Therefore, they emphasized the predominance of creativity and inquiry skills. Interviews revealed that pre service teachers with low PSASL performances had difficulties particularly in determining the problem statement and dividing the problem into sub problems. Pre service teachers, who experienced difficulties in this phase, were observed to fail in other phases of problem solving strategies. Real world problems are complex and often have ill-defined solution methods (Overton & Potter, 2008; Reid & Yang, 2002b). Students are more engaged in problem solving tasks of this nature (Reid, 2000; Renkl, Mandl, & Gruber, 1996). Learners who are challenged by complex problems demonstrate higher motivation and persistence (Deci & Ryan, 2000; Cited by Delvecchio, 2011). Pre service teachers with high performances mentioned that although it was the first time they experienced such an application, it enabled them to improve their problem solving skills.

As a conclusion, the common point indicated is as follows: Such methods as the problem solving at the laboratory method, which place students in the center of learning, encourage asking more questions, inquiring and researching, promoting suggestion of solution methods and enabling them to take the responsibility of their own learning through designing an experiment, are favorable.

References

- Ashmore, A.D., Frazer, M.J. & Cassey, R.J. (1979). Problem-solving and problem-solving networks in chemistry. *Journal of Chemical Education*, 56(6), 77–379.
- Asieba F. O. & Egbugara O.U. (1993). Evaluation of secondary pupils' chemical problem solving skills using a problem-solving model. *Journal of Chemical Education*, 70(1), 38-39.

- Ayas, A., Çepni, S., Johnson, D., & Turgut, M.F. (1997). *Chemistry Teaching*. YÖK World Bank. EGP Pre-Service Teacher Education Publications. Bilkent, Ankara.
- Aydoğdu, B. (2006). *Identification of variables effecting science process skills in primary science and technology course*. Master's thesis, Dokuz Eylül University, İzmir, Turkey.
- Bilgin, I. (2005). The effect of problem-solving strategies on university students "problem-solving achievements of quantitative problems in chemistry. *Educational Sciences: Theory & Practice*, 5, 628-635.
- Bodner, G. (2003). Problem solving: The difference between what we do and what we tell students to do. *University Chemistry Education*, 7, 37-45.
- Cardellini, L. (2006). Fostering creative problem solving in chemistry through group work. *Chemistry Education Research and Practice*, 7(2), 131-140.
- Cavallo, A.M.L. (1996) Meaningful learning, reasoning ability, and students' understanding and problem solving of topics in genetics. *Journal of Research in Science Teaching*, 33(6), 625-656.
- Chiappetta, E.L. & Koballa, T. R. (2002). *Science instruction in the middle and secondary schools* (5th edition). Upper Saddle River, NJ: Merrill/Prentice Hall.
- Christensen, C., Garvin, D. & Sweet, A. (1991). *Education for Judgment: The Artistry of Discussion Leadership*. Boston MA, Harvard Business School Press.
- Collins, A., Brown, J.S., & Newman, S.E. (1989). *Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics*. In L.B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser*. Hillsdale, NJ: Erlbaum.
- Cooper, M., Cox, C. J., Nammouz, M., & Case, E. (2008). An assessment of the effect of collaborative groups on students' problem-solving strategies and abilities. *Journal of Chemical Education*, 86, 866-872.
- Delvecchio, F., (2011). *Students' use of metacognitive skills while problem solving in high school chemistry*. Unpublished Masters' Thesis. Queen's University Kingston, Ontario, Canada.
- Dori, Y. J. & Hameiri, M. (1998). The 'Mole Environment' study ware applying multi-dimensional analysis to quantitative chemistry problems. *International Journal of Science Education*, 20, 317-303.
- Gabel, D.L., Sherwood, R.D. & Enochs, L. (1984). Problem-solving skills of high school chemistry students. *Journal of Research in Science Teaching*, 21(2), 221-233.
- Gagne, R.M. (1970). *The conditions of learning*, New York, Holt, Rinehart & Winston.
- Gagne, R.M. (1977). *The conditions of learning*, (3rd.Ed.), New York, Holt, Rinehart and Winston.
- Gallet, C. (1998). Problem-solving teaching in the chemistry laboratory: Leaving the cooks. *Journal of Chemical Education*, 75(1), 72-77.
- Geban, Ö., Aşkar, P., & Özkan, İ. (1992). Effects of computer simulations and problem-solving approaches on high school students, *Journal of Educational Research*, 86(1), 5-10.
- Goh, N.K., Toh, K.A., & Chia, L.S. (1989). Use of modified laboratory instruction for improving science process skills acquisition. *Journal of Chemical Education*, 66(5), 430-432.

- Gök, T. (2010). The general assessment of problem solving processes and metacognition in physics education, *Eurasian J. Phys. Chem. Educ.* 2(2), 110-122.
- Güçlü, N. (2003). *The problem solving skills of high school principals. Journal of National Education*, 160.
- Heppner, P.P. (1982). Personal problem solving: A descriptive study of individual differences. *Journal of Counseling Psychology*, 29(6), 580-590.
- Heppner, P.P., & Petersen, C.H. (1982). The development and implications of a personal problem solving inventor. *Journal of Counseling Psychology*, 29(1), 66-75.
- Heppner, P.P, Witty, T.E. & Dixon, W.A. (2004). Problem-solving appraisal: helping normal people lead better lives. *Counseling Psychologist*, 32(3), 466-472.
- Hollingworth, R., & McLoughlin, C. (2005). *Developing the metacognitive and problem solving skills of science students in higher education*. In C. McLoughlin, & A. Taji (Eds.), *Teaching in the sciences: Learner-centered approaches* (pp. 63-83). New York, NY: The Haworth Press Inc.
- Middlecamp, C., & Kean, E. (1987). Generic and harder problems: Teaching problem solving. *Journal of Chemical Education*, 64(6), 516-517.
- Jeon, K., Huffman, D., & Noh, T. (2005). The effects of thinking aloud pair problem solving on high school students' chemistry problem-solving performance and verbal interaction. *Journal of Chemical Education*, 85(10), 1558-1564.
- Kanlı, U. (2007). *The effects of a laboratory based on the 7e model with verification laboratory approach on students? Development of science process skills and conceptual achievement*, PhD dissertation, Gazi University, Institute of Education Science, Ankara, Turkey.
- Keith, R.L. (1993). *Correlation between the consistent use of a general problem-solving strategy and the organization of physics knowledge*. PhD dissertation, University of Minnesota.
- Koray, Ö., Köksal, M.S., Özdemir, M. & Presley, A.İ. (2007). The effect of creative and critical thinking based laboratory applications on academic achievement and science process skills. *Elementary Education Online*, 6(3), 377-389.
- Lin, H.S., Hung, J.Y. & Hung, S.C. (2002). Using the history of science to promote students' problem-solving ability. *International Journal of Science Education*, 24(5), 453-464.
- Lynch, C. L., Wolcott, S. K., & Huber, G. E. (2001). Tutorial for optimizing and documenting open-ended problem solving skills [On-line]. Available on 23 July 2014, <http://www.WolcottLynch.com>.
- Mahalingam, M., Schaefer, F., & Morline, E. (2008). Promoting student learning through group problem solving in general chemistry recitations. *Journal of Chemical Education*, 85, 1577-1581.
- Nakhleh, M.B. (1993). Are our students conceptual thinkers or algorithmic problem solvers? *Journal of Chemical Education*, 70(1), 52-55.
- Nakhleh, M.B. & Mitchell, R.C. (1993). Concept learning versus problem solving: there is a difference. *Journal of Chemical Education*, 70(3), 190-192.
- Nakiboğlu, C., & Kalın, Ş. (2009). The thoughts of secondary students about the use of problem-solving steps. *Journal of Kastamonu Educational Faculty*, 17(2), 715-725.

- Neeland, E.G. (1999). An introductory organic lab for the problem-solving laboratory approach. *Journal of Chemical Education*, 76(2), 230-231.
- Niaz, M. & Robinson, W.R. (1993). Teaching algorithmic problem solving or conceptual understanding: role of development level, mental capacity and cognitive style. *Journal of Science Education and Technology*, 2(2), 407-416.
- Niaz, M. (1995). Relationship between student performance on conceptual and computational problems of chemical equilibrium. *International Journal of Science Education*, 17, 343-355.
- Okey J.R, Wise K.C. & Burns, J.C. (1982). *Integrated process skill test-2*, (Available from Dr. James R. Okey, Department of Science Education, University of Georgia, Athens, GA 30362).
- Overton, T., & Potter, N. (2008). The role of goal orientation in self-regulated learning. *Chemistry Education Research and Practice*, 9, 65-69.
- Perez, D.G. & Torregrose, J.M. (1983). A model for problem-solving in accordance with scientific methodology. *European Journal of Science Education*, 5(4), 447-455.
- Reid, N., & Yang, M. (2002a). Open-ended problem solving in school chemistry: A preliminary investigation. *International Journal of Science Education*, 20, 1313-1332.
- Savaşır, İ. & Şahin, N.H. (1997). *The evaluation in cognitive and behavioral therapies: Frequently used scales*. Ankara: Turkish Psychologists Association Publications.
- Su, K.D. (2008). An informative study of integrating multimedia technology into problem-solving for promoting students' abilities in general chemistry. *International Journal of Instructional Media*, 35(3), 339-353.
- Suits, J.P. (2004). Assessing investigative skill development in inquiry-based and traditional college science laboratory courses. *School Science and Mathematics*, 104(6), 248-257.
- Taasoobshirazi, k. G., & Glynn, M. (2009). College students solving chemistry problems: A theoretical model of expertise. *Journal of Research in Science Teaching*, 46, 1070-1089.
- Taylan, S. (1990). *The adaptation, reliability and validity studies of Heppner's problem-solving inventory*. Unpublished Masters' Thesis, Ankara University, Institute of Social Sciences, Ankara, Turkey.
- Teichert, M., & Stacy, A. (2002). Promoting understanding of chemical bonding and spontaneity through explanation and integration of ideas. *Journal of Research in Science Teaching*, 39, 464-496.
- Temel, S. (2009). *Problem solving applications in chemistry laboratory*. Unpublished doctoral dissertation, Hacettepe University, Institute of Science, Ankara, Turkey.
- Temel, S. (2014). The effects of problem-based learning on pre-service teachers' critical thinking dispositions and perceptions of problem-solving ability. *South African Journal of Education*, 34(1), 769-789.
- Wheatley, G.H. (1984). *MEPS technical report*, (Tech. Rep. No. 84.01.) School Mathematics and Science Centre, Purdue University, West Lafayette, IN.
- Whitehead, A. N. (1929). *The aims of education*, Macmillan, New York.
- Wilson, H.J. (1987). Problem-solving laboratory exercises. *Journal of Chemical Education*, 64(10), 895.

- Wood, C. (2006). The development of creative problem solving in chemistry. *Chemistry Education Research and Practice*, 7, 96-113.
- YÖK World Bank. (1997). *National education development project*. Pre-Service Teacher Education, Ankara, Turkey.
- Zoller, U., Lubezky, A., Nakhleh, M.B., Tessier, B. & Dori, J. (1995). Success on algorithmic and LOCS vs. conceptual chemistry exam questions. *Journal of Chemical Education*, 72(11), 987–989.
- Zoller, U. (2002). Algorithmic, LOCS and HOCS (Chemistry) exam questions: performance and attitudes of college students. *International Journal of Science Education*, 24(2), 185–203.