The effects of problem solving applications on the development of science process skills, logical thinking skills and perception on problem solving ability in the science laboratory

Hatice Güngör SEYHAN

Cumhuriyet University, Sivas, TURKEY
E-mail: hgunsey@gmail.com

Received 28 Jul., 2015
Revised 14 Dec., 2015

Contents

Abstract

This study was conducted with 98 prospective science teachers, who were composed of 50 prospective teachers that had participated in problem-solving applications and 48 prospective teachers who were taught within a more researcher-oriented teaching method in science laboratories. The first aim of this study was to determine the levels of perception of problem-solving ability, science process skills and logical thinking skills of prospective teachers. The second aim was to compare the effects of problem-solving applications (PSASL) and a more researcher-oriented teaching method in the science laboratory on the perceptions of problem-solving ability, science process skills and logical thinking skills of prospective teachers. A pre-test–post-test control group design was used. In this study, data were obtained using the "Problem Solving Inventory (PSI)," "Science Process Skills Test (SPST)" and "Test of Logical Thinking (TOLT)." After the PSASL, five prospective teachers were selected among the experimental group and were interviewed using the fully structured interview form about the "PSASL" and the process it involves. Interviews were used to augment the quantitative data. According to the results obtained within the scope of the study, it can be said that the effect of PSASL on the perception levels of problem solving skills, scientific process skills and logical thinking skills of prospective teachers is more effective than the more researcher-oriented teaching method application. In addition, the results obtained from interviews with prospective teachers' ideas in the experimental group about PSASL were parallel with the past test results.

Keywords: Logical thinking skill, problem-solving ability, problem solving application, science laboratory, science process skill

Introduction

The fast changes in science and technology in recent times have affected education systems. Students of today need to be able to adapt to a rapidly changing technological world (Şaşan, 2002). As a result of these fast changes, the education systems need to be modified. The education systems can activate the students to learn ways to reach knowledge, to develop solutions for problems yet unknown and to enhance the skills of decision-making (Fisch & McLeod, 2007; İnce Aka, Güven & Aydoğdu, 2010). Science education reformers have supported the idea that learners should be engaged in the excitement of science, they should be helped to discover the value of evidence-based reasoning and higher-order cognitive skills and be taught to become innovative problem solvers (DeHaan, 2005; Perkins & Wieman, 2008). So, it is important for students to be prepared for the future by facing real problems in their learning environment and producing appropriate solutions to these problems (American Association for the Advancement of Science, 1993; Chin & Chia, 2004; Gallagher, 1997; Walker & Lofton, 2003).

Gagne (1980) suggested that the main objective of education is to teach individuals how to think and how to be good problem-solvers because in real life individuals who are able to think, question, research and produce solutions to the problems they meet may be successful. A great majority of the criticisms concerning the Turkish Education System relates to the fact that students who are raised as the passive recipients of knowledge may have difficulties in making critical choices, solving the complex problems they will face and achieving in their academic studies in the face of today's information explosion (Şahinel, 2007), and thus it is suggested that the new implications in the Turkish Education System should concentrate on students' intellectual development. The content and methods should be re-arranged in a way so as to instill in them such skills as critical thinking, creative thinking, relational thinking and reasoning (Özden, 2011). For this aim, student-centered learning may be a new implication. Student-centered learning is a broad approach that

"includes such techniques as substituting active learning experiences for lectures, holding students responsible for material that has not been explicitly discussed in class, assigning open-ended problems and problems requiring critical or creative thinking that cannot be solved by following text examples, involving students in simulations and role-plays, assigning a variety of unconventional writing exercises, and using self-paced and/or cooperative (team-based) learning". (Felder & Brent, 1996).

Therefore, appropriate methods must be chosen to realize this situation in the learning environment. Accordingly, the problem-solving method (PSM) may be implemented as one of the student-centered learning approaches.

As an instructional approach, PSM is a learning model which centers on the student, develops active learning, skills of problem-solving and field knowledge, and it is based on understanding and problem solving (Major, Baden & Mackinnon, 2000; Malinowski & Johnson, 2001). The problem solving method shows thought on an advanced level when this method is described as a scientific process in terms of finding, inquiry and critical thought (Kemertaş, 2001).

According to Chiappetta and Koballa (2002), various methods 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 method in the laboratory (Wilson, 1987). Laboratories are ideal and productive environments to implement technical concepts into real life content (Gallet, 1998). 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 better conditions by using the problem solving method in laboratories (Wilson, 1987). Although laboratory instruction has the potential to enhance the development of scientific concepts held by students through the encouragement of inquiry, intellectual development, problem solving and manipulative skills, research has shown it rarely obtains its full potential (Hofstein & Lunetta, 1982). Consequently, many educators have come to question the pedagogical value of traditional methods of laboratory instruction that give little consideration of how to plan an investigation or interpret experimental results (Merritt, Marilyn & Darlington, 1993). Laboratory activities in nontraditional styles of laboratory instruction such as the problem solving method in the laboratory are believed to promote the development of critical thinking skills (DeBoer, 1991; Gunstone & Champagne, 1990; Merrit et al., 1993; Raths, Wasserman, Jonas & Rothstein, 1986), reasoning skills (Merritt et al., 1993; Tamir, 1977), reading comprehension (Gunstone & Champagne, 1990) and teamwork (Merritt et al., 1993).

Problem solving is one of the primary tools for college and university science instruction (Gök, 2010). Problem solving ability sets one of the roles that individuals undertake in becoming individuals and coping with their environments. Problem-solving ability is often associated with decision-making and scientific rationale (Abdullah & Shariff, 2008). For improving problem solving abilities, 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 feedback and support them in acquiring these abilities (Jeon, Huffman & Noh, 2005).

Developing and enhancing the ability of problem solving and science-process skills of students have long been important objectives of science education (National Research Council, 1996). One of the widest purposes of science education reformation is to train up students who are interested in science actively (Lorsbach & Tobin, 1992). In addition, this system aims to increase students' academic achievement. This situation is possible for the upper-level mental skills and science process skills (Kaptan, 1999). According to the Ministry of National Education (2005), the new Turkish Elementary Science and Technology curriculum aims to enhance students' understanding of NOS and develop their scientific processing skills.

Scientific processing skills are the skills that facilitate learning in science, gain research tactics and methods and are essential for problem solving (Burns, Okey & Wise, 1985; Harlen, 1999; Tan & Temiz, 2003). According to Lind (1998), these are thinking skills used in forming information, thinking about problems and formulating results. 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 enable them to produce scientific knowledge as well as learn about the nature of science through experiences (Aydoğdu, 2006). Again, according to Chiappetta and Koballa (2002), one of the most important targets of laboratory studies is to arise an understanding in students about the nature of science. To improve this target, students are required to use some scientific processing skills during research in the laboratory. Individuals, who attain science process skills, possess problem solving abilities and know how to attribute meanings to the events happening by looking at them, and forming a different perspective. Furthermore, students with the said skills manage to think like scientists (Aydoğdu, 2006).

A problem solving strategy is a plan or method to achieve a goal. Analogical reasoning, deductive reasoning, inductive reasoning and deductive reasoning are examples of general strategies used in solving scientific problems (Sternberg & Williams, 2002). Problem solving capabilities are developed empirically or through inductive reasoning, in addition to the aforementioned scientific rationale. Together, these abilities enable science educators to expand upon probabilistic thinking in order to experiment with scientific theory (Stevens, Zollman, Christel, & Adrian, 2007). The ability of problem solving is generally viewed as the ability to reason analytically, to think critically and to create productively, which all involve quantitative, communicative, manual and critical-response skills (American Association for the Advancement of Science, 1993). According to Korkmaz (2002), logical thinking skill is an individual's solving a problem by realizing various mental processing or reaching principles and laws by abstractions and generalizations. According to Sonmaz (2002), it is one of the skills which is desired to be gained with science teaching. According to Aşkar (1988), logical thinking is one of the sub-stages of problem solving. Therefore, it is considered that logical thinking and reasoning skills of people who can solve complicated problems are sufficient (Bozdoğan, 2007). Problem solving training should be taken into consideration to improve logical thinking skills. When it is considered that the problem solving training improves the logical thinking skills of the students, the importance of teaching methods and techniques that develop problem solving skills is revealed (Aşkar, 1988). Abdullah and Shariff (2008) further defined deductive reasoning as "thinking patterns which include identifying and controlling of variables, proportional thinking, probabilistic thinking, combinational thinking, and correlational thinking" (p. 388). Logic is related with reasoning relations between thoughts, independently from the forming and content of thinking (Özlem, 2004) and logic is related with the validity of thinking (Çubukçu, 2004). It has been determined that there are various definitions of the "logic" concept. Logic defines a thinking form that is called "correct thinking" and "logical thinking" (Özlem, 2004); it is one of the most abstract and general among all thinking forms and an indispensable tool in explanation, prediction and verification processes consisting of the basic elements of the scientific method (Yıldırım, 2004). Logical thinking is a skill that can be obtained from cognitive development stages of Piaget in tangible and abstract processes. The logical thinking process is that an individual solves a problem through logical processes or reaches principles and laws through a series of abstractions or generalizations (Yaman & Karamustafaoğlu, 2006). Lawson, Banks and Logvin (2007) proved in their study that logical thinking skill is the primary factor affecting students' self-efficacy and achievement in science. There are also various studies mentioning the positive relationship between students' logical thinking skills and their abilities to comprehend science (Cavallo, 1996; Johnson & Lawson, 1998).

It is important to have the skills to research, inquire and solve problems through scientific methods in order to understand and comply with the age of information and technology (Erbaş, Şimşek & Çınar, 2005). According to Erbaş et al., to be able to cultivate individuals that are able to attain knowledge through observation, asking meaningful questions and seeking answers to these questions, certain learning environments, which enable permanent learning such as learning by doing and experiencing, should be provided. Laboratory practices are among the factors that have great contributions to this process (Erbaş et al., 2005). The importance of laboratory practices has been widely studied in the relevant literature; however, the main role of laboratories has been observed to be misinterpreted (Renner, 1986). In the laboratory practices, students were frequently observed not to be guided towards activities in which they could ask questions, create hypotheses, make observations, design experiments and estimate the results (Germann, Haskins & Auls, 1996). Besides the traditional laboratory practices, there have been various studies that involved problem solving applications and analyzed performances, critical thinking skills, problem solving skills, self-competence beliefs, self-regulations skills, metacognitive skills, scientific process skills, logical thinking skills and many other variables as a result of these applications (Ağdaş, 2013; Aurah, 2013; Delvecchio, 2011; Fanetti, 2011; Grigg, 2012; Grutsch, 2014; Gupta, 2012; Güngör Seyhan, 2014; Güngör Seyhan & Morgil, 2015; İnce Aka et al., 2010; Imai, 2014; Jenkins, 2013; Laird, 2014; Rader, 2010; Shoop, 2012; Taasoobshirazi & Glynn, 2009; Yin, 2010). Also, the results showing that PSASL has positive effects mainly on scientific process skills and on logical thinking makes this research remarkable in education, especially in chemistry education. Hence, it is believed that the research that is presented in this paper will contribute meaningfully to the existing related literature. The main purpose leading to this study was to cultivate individuals that aimed to make observations, ask meaningful questions and seek answers to these questions as the means to acquire knowledge within the age of technology and information today.

Aim of this Study

The aim of this study was two-fold. The first aim was to determine the levels of perception of problem solving ability, science process skills and logical thinking skills of prospective teachers. The second aim was to compare the effects of problem solving applications and a more researcher-oriented teaching method in the science laboratory on the perceptions of problem solving ability, science process skills and logical thinking skills of prospective teachers. The present study focused on the following research questions:

- What are the perception levels of problem solving ability of prospective science teachers?
- What are the levels of science process skills of prospective science teachers?
- What are the levels of logical thinking skills of prospective science teachers?

- Is there a significant difference between prospective science teachers' perception levels of problem solving ability according to the different teaching methods implemented?
- Is there a significant difference between prospective science teachers' science process skills according to the different teaching methods implemented?
- Is there a significant difference between prospective teachers' logical thinking skills according to the different teaching methods implemented?

Research Methodology

Method

The study used a pre-test–post-test control group design. It belongs to a true experimental design. The essential ingredient of the true experimental design is that subjects are randomly assigned to treatment groups. Random assignment is a powerful technique for controlling the subject characteristic's threat to internal validity, a major consideration in educational research (Fraenkel & Wallen, 2006). Descriptive statistics, independent *t*-tests and MANCOVA were employed in the data analysis. In order to determine the views of prospective teachers in the experimental group about PSASL, a fully structured interview form was used.

Participants

The study involved the participation of 98 prospective science teachers (20-21 years) studying at the Department of Science Education in Turkey, who participated in the spring term of the 2012-2013 academic year. They are third-year university students.

Instruments

Problem Solving Inventory (PSI)

PSI is utilized to assess an individual's perception about his/her own problem solving ability, and was developed by Heppner and Petersen (1982). According to Heppner, Witty and Dixon (2004), the inventory does not assess actual problem solving abilities but rather one's perception of one's problem solving beliefs and style. The scale was translated by Taylan (1990) and Savaşır and Şahin (1997). PSI is a Likert-type scale with 35 statements, which are scored between 1 and 6. The inventory has three sub-scales: “Problem solving Confidence”- assesses self-perceived confidence in solving problems, “Approach Avoidance Style”- assesses whether individuals tend to approach or avoid problems and “Personal Control”- assesses elements of self-control. The Cronbach’s alpha internal consistency coefficient was calculated for the inventory as 0.90 by Savaşır and Şahin (1997). Sample items on the PSI are: “When a solution to a problem was unsuccessful, I did not examine why it didn't work” (Approach Avoidance Style sub-scale), “I make snap judgments and later regret them” (Personal Control sub-scale). The range of scores attainable on the inventory is between 32 and 192. The results from this study indicate that the PSI means, standard deviations and estimates of internal consistency from the current study samples are comparable to those revealed in previous research studies. The results of this study also suggest that the PSI seems to be generalized to Turkish undergraduate students. Thus, findings suggest that the PSI may be a useful instrument to examine problem solving appraisal with Turkish undergraduate students. Compared to previous studies, the PSI demonstrated acceptable internal consistency with the alpha coefficients ranging from .81 to .89 for PSI total.

Science Process Skills Test (SPST)

The Scientific Process Skills Test (SPST) was developed by Okey, Wise and Burns (1982) and a Turkish adaptation was made by Geban, Aşkar and Özkan (1992). The test contains 36 multiple choice questions with four alternatives. The questions of the test aim to asses recognition of variables in a problem (12) as well as construct and define hypotheses (8), make operational explanations (6), design required analysis for solving the problem (3) and draw and interpret graphs (7). After the Turkish adaptation study, the Cronbach's alpha reliability coefficient was found to be 0.81 (Geban et al., 1992). Pre-service teachers’ correct answers were coded as "1" and wrong answers were coded as "0.” For this study, the alpha value of the test was found as 0.856.

The Test of Logical Thinking (TOLT)

The Test of Logical Thinking (TOLT) was used to determine students’ reasoning ability. It was originally developed by Tobin and Copie (1981) and translated and adapted into Turkish by Geban et al. (1992). The TOLT contains 10 items designed to measure controlling variables (items 1 and 2), proportional (items 3 and 4), probabilistic (items 5 and 6), correlational (items 7 and 8) and combinational (items 9 and 10) reasoning. The 10 items of the TOLT contain two responses each - an answer as well as a reason for having selected the answer. Individuals must respond correctly to both components for the response to be considered correct. Its reliability was found as .81. The TOLT has a reported internal consistency reliability coefficient of .82 and a value of .725 for this study.

Teaching Process

In this study, problem solving applications in the science laboratory progressed in five steps and lasted nine weeks (CoHE World Bank, 1997). In order to determine the effectiveness of PSASL, researchers randomly selected 50 prospective science teachers for the experimental group to implement PSASL and 48 prospective science teachers were selected by the researchers to form the control group, which was taught within a more researcher-oriented teaching method. Approximately two weeks before the start of PSI, SPST and TOLT were administered as pre-test treatments to determine whether both the experimental and control groups were equivalent with respect to their perceptions of problem solving ability and their skills of the science process and logical thinking. Secondly, the prospective teachers in the experimental group were informed of principles and application stages of PSASL and prospective teachers in the control group were informed of a more researcher-oriented teaching method.

PSASL consisting of five steps (CoHE World Bank, 1997) was realized within nine weeks with the participation of 50 prospective science teachers. The prospective teachers in the experimental groups were asked for their opinions on what problem solving means, the importance of the problem solving process and how it is realized through a small discussion. Next, they were informed about the PSASL, 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. Then the prospective teachers in the experimental group were randomly assigned to 10 groups. According to Johnson and Johnson (1975), problem solving was a collaborative process, in which individuals gathered for acquiring the goal. According to Zhang (1998), collaborative problem solving referred to the problem solving activities that included mutual interaction among the groups. The initial phase of the application (the problem case) also proceeded in the first week. In the first session, each of the five groups was given a problem case by the researcher. For ensuring meaningful problem solving, problem cases were chosen among daily life events. According to Çuhadaroğlu, Karaduman, Önderoğlu, Karademir and

Şekerel (2003), problems used in applications such as "problem-based learning," which support the development of problem solving abilities, must be chosen from among the problems which are the most fitting to the real world, they must be open-ended and, by making suitable personifications, students must be given the opportunity to treat the problem as if it were their problem and to be willing to solve it. All problem cases were presented to all student groups of the experimental group. The sample problem cases given to PSASL groups and the problem statements created by students groups were as follows:

<u>Problem Case</u>: If we assume that a fizzy drink is consumed from a glass bottle without any gas release, would the amount of bubbles swallowed be billions of bubbles?
<u>Problem Statement</u>: Quantitative determination of the amount of carbon dioxide in fizzy drinks.
<u>Problem Case</u>: It is believed that vitamin C support is good for sicknesses experienced, particularly in the winter, such as the flu and common cold. Therefore, we consume fruit such as lemons and oranges more. What if you were told that parsley, strawberries and green pepper are richer in vitamin C?
<u>Problem Statement</u>: How could we find out which fruit/vegetable has more vitamin C?
<u>Problem Case</u>: One of the most essential ingredients of various fizzy drinks is phosphoric acid. This component helps to protect the ingredients and enables the acidic solution.
<u>Problem Statement</u>: How could we identify the existence of phosphoric acid in fizzy drinks such as coke?

Prospective teachers were informed they would determine their problems by the second week. The second week, when the second phase started (identification of the problem), groups simplified their problems and differentiated events to analyze the events that did not require analysis. They divided the problems into steps or sub problems and expressed their problems in 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 solutions. Groups established their hypothesis for solving their problems and presented the solution way of their choice in the form of an experiment suggestion. In the fourth step of the application (trying the solutions), the prospective teachers were made the experiments in the science laboratory 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 that failed to obtain results according to the hypotheses they established revised their solution steps and the whole process was repeated starting from the step in which the failure occurred. During all PSASL processes, the researcher tried to make observations and provide each prospective teacher in the different groups an opportunity to participate in the process. When groups had a problem during the PSASL process, the researcher guided them with questions without giving any information. The researcher helped prospective teachers collaborate well and encouraged them to justify their thinking.

In the control group, the teaching of a variety of science topics related to everyday life followed the more researcher-oriented teaching method. For instance, with respect to problem (b), students in the control group of the PSASL process were taught within a more traditional approach through the "Determination of Vitamin C in Fruit and Vegetables" experiment directly by the researcher and the whole experiment process was conducted within a researcher-oriented teaching method. The teaching was conducted in such a way that the researcher was active and the students were passive listeners, the latter asking for explanations of the parts that they did not understand. In particular, the traditional teaching method consisted of a subject-based approach. The researcher employed such techniques as direct explanations and question-and-answer in the presentation of the topic.

Approximately two weeks after the finalization of the PSI, SPST and TOLT were administered as the post-test treatments to all groups for obtaining post-test measures after the implementation of the different teaching methods. After the PSASL, five prospective teachers were selected among the experimental group and were interviewed using the fully structured interview form about the "PSASL" and the process it involves.

Findings

Findings Related to Between PSI, SPST and TOLT Pre-test Scores

Independent *t*-tests were used to analyze the data obtained from pre-test treatments. The results are given in Table 1.

Table 1. The pre-test scores of prospective science teachers in both groups

Pre-test Scores	Groups	N	$\bar{X}$	SD	Df	t	*p*
PSI	Experimental	50	78.44	11.43	96	-.539	.591
	Control	48	79.60	9.86			
SPST	Experimental	50	72.05	11.85	96	.221	.826
	Control	48	71.52	11.76			
TOLT	Experimental	50	5.42	1.61	96	-.104	.918
	Control	48	5.45	2.03			

When Table 1 is examined, it can be seen that there is no significant difference between the perception levels of problem solving ability, between the science process skills and between the skills of logical thinking pre-test scores of prospective science teachers in both the experimental group and the control group ($p>\alpha$).

According to the scores in Table 1 it was observed that the experimental group and control group are equivalent with respect to their science process skills, skills of logical thinking and the perception levels of problem solving skills at the beginning of the study.

Findings to MANCOVA Analysis

MANCOVA analysis was performed in order to examine the effect of two different methods on the perception levels of problem solving ability, scientific process skills and logical thinking skills of prospective teachers. The perception levels of problem solving ability, scientific process skills and logical thinking skills of prospective teachers before the applications were considered as "common variables"; the perception levels of problem solving ability, scientific process skills and logical thinking skills of prospective teachers after applications were considered as "dependent variables"; and both methods which were used were considered as "independent variables." Within the realized analysis, first it was examined whether the regression lines calculated. The obtained results, that $p=.931>\alpha=.05$, indicated that the calculated regression lines were equal. After the hypothesis of equality of regression lines was tested, descriptive statistics regarding both realized method types and the perception level of problem solving ability, scientific process skills and logical thinking skills obtained after applications were determined and related results were shown in Table 2.

Table 2. Descriptive statistics of the past-test scores of PSI, SPST and TOLT

Past-test Scores	Group	N	Mean	Std. Deviation
SPST	Experimental	50	78.7786	7.95194
	Control	48	71.4325	9.75433
	Total	98	75.1805	9.57442
TOLT	Experimental	50	6.8400	1.83348
	Control	48	5.6458	1.87355
	Total	98	6.2551	1.93881
PSI	Experimental	50	69.4600	8.77196
	Control	48	77.2500	7.61717
	Total	98	73.2755	9.07220

That $p=.724>\alpha=.05$, according to the results obtained after the examination of the hypothesis of the equality of covariance matrixes within the scope of the study, indicated that this hypothesis was verified. Again within the scope of the study, for the perception levels of problem solving ability, scientific process skills and logical thinking skills and both performed methods, $p<\alpha$ involved in Wilks' Lambda lines provided preliminary information that these variables (pre-applications variables and application type) had an effect on dependent variables. The condition of $p>\alpha$ in the results obtained after the Levene test, made to test the hypothesis of the equality of error variables, demonstrated that this hypothesis was verified.

The perception levels of problem solving ability, scientific process skills and logical thinking skills of prospective science teachers were synchronized with MANCOVA before the applications and it has been demonstrated how the applied method types affected the prospective teachers after applications in Table 3.

Table 3. Tests of between-subjects effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	SPST_PastTest	5651.526(a)	4	1412.881	40.550	.000	.636
	TOLT_PastTest	228.537(b)	4	57.134	39.045	.000	.627
	PSI_PastTest	6978.713(c)	4	1744.678	161.472	.000	.874
Intercept	SPST_PastTest	860.935	1	860.935	24.709	.000	.210
	TOLT_PastTest	.203	1	.203	.139	.711	.001
	PSI_PastTest	13.482	1	13.482	1.248	.267	.013
SPST_PreTest	SPST_PastTest	3428.005	1	3428.005	98.384	.000	.514
	TOLT_PastTest	6.161	1	6.161	4.210	.043	.043
	PSI_PastTest	4.070	1	4.070	.377	.541	.004
TOLT_PreTest	SPST_PastTest	113.631	1	113.631	3.261	.074	.034
	TOLT_PastTest	148.331	1	148.331	101.368	.000	.522
	PSI_PastTest	9.387	1	9.387	.869	.354	.009
PSI_PreTest	SPST_PastTest	18.668	1	18.668	.536	.466	.006
	TOLT_PastTest	.001	1	.001	.000	.983	.000
	PSI_PastTest	5399.705	1	5399.705	499.750	.000	.843
Group	SPST_PastTest	990.553	1	990.553	28.429	.000	.234
	TOLT_PastTest	29.827	1	29.827	20.384	.000	.180
	PSI_PastTest	1122.880	1	1122.880	103.924	.000	.528
Error	SPST_PastTest	3240.411	93	34.843			
	TOLT_PastTest	136.086	93	1.463			
	PSI_PastTest	1004.848	93	10.805			
Total	SPST_PastTest	562798.630	98				
	TOLT_PastTest	4199.000	98				
	PSI_PastTest	534175.000	98				
Corrected Total	SPST_PastTest	8891.936	97				
	TOLT_PastTest	364.622	97				
	PSI_PastTest	7983.561	97				

a R Squared = .636 (Adjusted R Squared = .620)
b R Squared = .627 (Adjusted R Squared = .611)
c R Squared = .874 (Adjusted R Squared = .869)

It was demonstrated that both application types affected the perception levels of problem solving ability, scientific process skills and logical thinking skills of prospective teachers after the applications ($p<\alpha$). Also, when eta square values were examined, it was seen that 52% of the change in the perception level of problem solving ability, 23% of the change in the level of scientific process skill and 18% of the change in the level of logical thinking skill in prospective teachers resulted from the applied application type.

Finally, the averages of the perception levels of problem solving ability, the levels of scientific process skill and the levels of logical thinking skill of prospective teachers after the applications were demonstrated, as seen in Table 4.

Table 4. Estimated marginal means

Dependent Variable	Group	Mean	Std.Error	95% Confidence Interval	
				Lower Bound	Lower Bound
SPST_PastScores	Experimental	78.310(a)	.837	76.648	79.971
	Control	71.921(a)	.854	70.225	73.617
TOLT_PastScores	Experimental	6.798(a)	.171	6.458	7.139
	Control	5.689(a)	.175	5.342	6.037
PSI_PastScores	Experimental	69.944(a)	.466	69.019	70.869
	Control	76.746(a)	.476	75.802	77.690

a Covariates appearing in the model are evaluated at the following values: SPST_PreScore = 70.6635, TOLT_PreScore = 5.3878, PSI_PreScore = 78.3367.

The post-test results of the both applications displayed in Table 4 indicated that while the pre-test score of a prospective teacher regarding their perception level of problem solving ability was 78.33, it decreased down to 69.94 after the PSASL. The low scores obtained from PSI indicate effective problem solving abilities, while the high scores indicate failure to find effective solutions to problems (Taylan, 1990). Likewise, what the scientific process skill and logical thinking skill of a prospective teacher with a level of 70.66 and 5.38 before the applications may become after being subjected to both applications was given in Table 4. In this case it can be said that the PSASL application is more effective than the traditional laboratory application type, which is a more research-oriented application on the perception levels of problem solving ability, the levels of scientific process skill and of logical thinking skill of prospective teachers.

Conclusion and Discussion

According to the first research question of our study, perception levels about problem solving abilities of prospective science teachers were identified before and after the applications. According to the scores in Table 1 it was observed that the experimental group and control group are equivalent with respect to their science process skills, logical thinking skills and the perception levels of problem solving ability at the beginning of the study. The results displayed in Table 2 indicated that perception levels of problem solving ability of prospective science teachers decreased at the post-test following the applications. According to the results, it can be said that the prospective science teachers' perception levels of problem solving ability in both the experimental group and the control group were at low levels. Similarly, in the literature, research conducted by Güngör Seyhan and Eyceyurt Türk (2013), Güngör Seyhan (2014), Lin and Chiu (2004), Lee (2007), Saracaloğlu, Yenice and Karasakaloğlu (2009), Temel (2009; 2014) and Temel and Morgil (2012; 2013) with prospective teachers showed that prospective teachers were at a satisfactory level in terms of perceptions of problem solving abilities. That the mean post-test scores were lower than that of the pre-test scores indicated that the applications led to a statistically significant increase in the perception levels of prospective teachers about problem solving ability (Taylan, 1990). According to Taylan (1990, p. 41), high scores show that the respondent perceives oneself as insufficient in terms of problem solving skills, while low scores show the respondents' problem solving skills as being at a satisfactory level. Prospective teachers in both groups were able to improve their perception levels of problem solving abilities with the help of the applications. The results in Table 2 showed that there is a decrease in the perception levels about problem solving ability of the prospective teachers in both the experimental group and the control group. A significant difference was found between the PSI pre-test and post-test scores of the prospective science teachers in both the experimental group and the control group according to the different teaching methods implemented. Accordingly, the result may be interpreted as PSASL and the more researcher-oriented teaching method having different effects on prospective science teachers' perception levels of problem solving ability. It is reasonable to argue that the difference observed in the prospective science teachers' perception levels of problem solving ability arises from the use of the PSASL approach. It was also found that the PSASL approach, in which a greater decrease was observed in the scores of perception levels of problem solving ability, was more influential than the more-researcher-oriented teaching method in raising prospective teachers' perception levels of problem solving ability. When prospective science teachers experienced problem solving in the science laboratory approach, they were provided with a learning environment where they sought solutions to the given problem situations through doing and experiencing, and they actively participated in the research process. They had the opportunity to perform experiments in the laboratory independently. They were creative and productive during the problem solving process; they took the responsibility of their own learning and expressed diverse opinions when proposing solution ways. Literature was observed to involve studies on the positive aspects of problem solving activities performed in the science laboratory (Gallet, 1998; Neeland, 1999; Wilson, 1987).

The second research question of the study was investigating the changes in the science process skills of prospective teachers during the science laboratory applications. Science process skills are the skills that are used both in creating scientific knowledge and in performing laboratory activities (Temel & Morgil, 2013). Prospective teachers participated in a laboratory activity that was different from the laboratory activities (PSASL and a more research-oriented laboratory), where they were given a laboratory portfolio and asked to perform their experiments by following the instructions included in the portfolio. They sought solutions to the given problem situations by using these skills. When the SPST pre-test and post-test scores of prospective science teachers in both the experimental group and control group were examined, it was determined that there is an improvement in the science process skills of prospective science teachers in both the experimental group and control group. Another research topic analyzed in the study was the changes in the logical thinking skills of the prospective science teachers who participated in the study. Prospective teachers, who participated in PSASL applications, performed the experiments they had proposed at the finding solutions to given problem situations phases in the laboratory, tested their hypotheses in line with the results they obtained from the experiments and created solutions to their problem situations by establishing cause and effect relationships. The significant relationship found between the logical thinking skills of prospective teachers and their perceptions about problem solving skills indicated that problem solving improved logical thinking skills and problem solving was essential in improving logical thinking skills.

The analysis on whether the decrease in the perception levels of prospective science teachers of both groups was significant within and between the groups was performed through MANCOVA. It was demonstrated that both application types affected the perception levels of problem solving ability, scientific process skills and logical thinking skills of prospective teachers after the applications ($p<\alpha$). Also, when eta square values were examined, it was seen that 52% of the change in the perception level of problem solving ability, 23% of the change in the levels of scientific process skills and 18% of the change in the level of logical thinking skills in prospective teachers resulted from the applied application type. In this case it can be said that the PSASL application is more effective than the traditional laboratory application type, which is a more research-oriented application on the perception levels of problem solving ability, the levels of scientific process skills and the levels of logical thinking skills of prospective teachers. Data obtained from Table 4 provides opportunity to make predictions about how the perception levels of problem solving skills, scientific processing skills and logical thinking skills of a prospective teacher, whose mentioned levels were determined before both applications, would change after both applications. According to Table 4, it was observed that PSASL, which is applied as an alternative to a more research-oriented laboratory application in the science laboratory, may contribute to the development of the perception levels of problem solving ability, scientific processing skills and logical thinking skills. According to the results, prospective teachers who participated in PSASL were able to improve their science process skills better than those who followed a researcher-oriented application in the laboratory (Table 3). Changes in the logical thinking skills of the prospective teachers in both groups following the application were displayed in Table 3. The results indicated that logical thinking skills of prospective teachers who participated in PSASL activities improved better than those who belonged to the other group. The literature was observed to involve studies, where the relationship between problem solving abilities, science process skills and logical thinking skills were analyzed through laboratory methods that led to improvement in science process skills and the logical thinking skills (Cracolice, Deming & Ehlert, 2008; Geban et al., 1992; Güngör Seyhan, 2008; 2014; Güngör Seyhan & Morgil, 2015; İnce Aka et al., 2010; Koray, Köksal, Özdemir & Presley, 2007; Temel, 2009; Temel & Morgil, 2013). The results of the study by İnce Aka et al. (2010) reveal that there is no significant difference between experimental and control groups' students' pre-science process skills and pre-achievement test scores. Another result of this study displays that experimental group students have higher mean scores than control group students in post science process skills and the post achievement test. At the end of the study by Temel (2009), it has been seen that realized applications have a statistical effect on pre-service chemistry teachers' perceptions of problem solving skills, science process skills and logical thinking ability. Also, multiple regression analysis has displayed that 42% of the changes in pre-service chemistry teachers' performances were predicted by their perceptions of problem solving skill, science process skill and logical thinking ability together. In another study by Temel and Morgil (2013), it was determined that pre-service teachers perceive their problem solving skills as good after realized applications and these applications are significant effects on their perceptions of problem solving skills. Also a correlation was determined between pre-service teachers' perceptions of problem solving skills, science process skills and logical thinking abilities. As a result of the investigation by Koray et al. (2007), it was determined that the experimental group was more successful than the control group in terms of the science process skills and academic achievement. Statistical analysis of the study by Güngör Seyhan (2014) concluded that 45% of the change in performances of pre-service teachers could collectively be predicted by certain variables such as their perceptions of problem solving skills and scientific process skills. Changes in the logical thinking skills of the prospective teachers in both groups following the application were displayed in Table 3. The results indicated that logical thinking skills of prospective teachers, who participated in PSASL activities, improved better than those who belonged to the other group.

Following the PSASL, five prospective teachers of the experimental group 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 in the science laboratory and its process. The aims of the interviews were to reveal the points where prospective teachers experienced difficulties during the process and were used to augment the quantitative data. Some of the questions asked and responses given by the prospective teachers are given as examples hereby below:

- During the PSASL, which of the following science process skills were challenging for you to use? Would you please explain your 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 36: The problem case we were given reflected ill-structured real world situations. Therefore, we had difficulties in forming a "problem statement with certain limits" as the researchers requested. According to my point of view, in order this phase to succeed, sub problems with certain limits should be formed in analyzing a problem case. However, when posing an appropriate problem statement following the sub-problems, we had difficulties due to our failure in establishing the relevant connections.
>
> Student 28: Actually, we did not have any difficulties with analyzing the given problem case. Our problem statement was a relevant one with certain limits. Maybe, the difficulty we had was in designing an experiment for the most appropriate solution after presenting the solution options. We had more help from the researcher about this issue.

- In order for 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 42: When the researchers explained the applications before they started, it did not seem meaningful to me at the beginning. However, as we looked at the process and the experimental reports we submitted after the applications, we understood how important it was to reach conclusions using a real world problem case we were given. In fact, if the limits were related to a real world problem instead of being related to the laboratory, I believe that we could solve all problems we encounter maybe not through the same process but through implementing a similar method.
>
> Student 22: The previous experiments we performed at the science laboratory were too artificial. I think this was not because of us. I felt like "what am I going to do in the future with what I have learnt here?" However, all problem cases we were given here were all related to the real life situations.

- 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 44: During PSASL, when asking questions about the problem, group members may come up with things that we do not even think of. The only disadvantage of working with a group could

be the fact that some group members did not participate in the group actively.

Student 36: According to me, the greatest advantage of cooperative learning is its ability to develop a student's sense of responsibility. For instance, I was able to understand the importance of constructive criticism when proposing a solution for each opinion presented by a group member.

- 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 42: I believe that the success of this application depends on the success of the initial phase. That is, in order to create a successful targeted problem statement, firstly, you must understand the problem case very well. In fact, we required a lot of support from the researcher at this initial phase.

Student 28: We designed an experiment, which fit the most appropriate solution option for our problem statement. However, we got help for the researcher with respect to the content and performance of our experiment. I believe we had a successful experience as a group.

The only common point indicated by the prospective teachers during the interviews was that they had never participated in such an application before. In other words, prospective teachers mentioned that, during all the years of their education, they had used close-ended laboratory techniques and had not undertaken too many responsibilities. Fully structured interviews made after the PSASL concluded that prospective teachers moved beyond a laboratory application, which emerged from a typical cooking book model, towards developing an understanding that student-centered teaching was supported through improving skills related to asking relevant questions, trying to seek answers to all questions asked, suggesting solution options and designing an experiment in line with the most appropriate solution option as well as improving the willingness in students towards "self-learning." According to the prospective teachers, the PSASL environment required them to be active both individually and within groups. Therefore, they emphasized the predominance of creativity and inquiry skills. Interviews revealed that prospective teachers with low PSASL performances had difficulties, particularly in determining the problem statement and dividing the problem into sub problems. Prospective teachers, who experienced difficulties in this phase, were observed to fail in other phases of problem solving strategies. According to Lin and Chiu (2004), by seeing educators demonstrating or conducting experiments themselves, learners supplement what is in textbooks and as a result learning is enhanced. An advantage of laboratory usage is that it helps improve learners' higher order learning skills such as analysis, problem solving and evaluating.

Considering the benefits of this approach for students, teachers should involve student-centered approaches more often in their teaching. Educators play essential roles in providing effective learning environments. Educators should comprehend the importance of student-centered teaching methods where student-educator and student-student interactions are possible; students take the responsibility of their own learning and acquire knowledge through research. In order to do that, they should know about the pros and cons of all methods. With the help of the in-service training activities, educators should be allowed to improve themselves in this field. In this study, prospective teachers participated in the laboratory activities during the process, in which they sought answers to the given problem situations. Open-ended laboratories such as problem solving applications enable students to recognize the fields where theoretical knowledge could be used, and to make generalizations according to the evidence obtained. Students mostly perform scientific research and inquiry in the laboratories. Laboratories are ideal environments for students to overcome their misconceptions as well as their lack of knowledge. Therefore, in order to ensure permanent and productive learning, students should be provided with learning environments where they could learn by doing and experiencing (Dkeidek, Mamlok-Naaman & Hofstein, 2012).

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Appendix I

The application process experienced by Student 13 in Group 3 by prospective science teachers participating in the PSASL:

Group 3: Student 13
1. Problem statement One of the most essential ingredients of various fizzy drinks is phosphoric acid. This component helps to protect the ingredients and enables an acidic solution.
2. Identifying the problem **2.1. Sub problems** • What are other ingredients than phosphoric acid in the fizzy drinks such as coke? • Are there any components other than phosphoric acid which provide acidic solutions in fizzy drinks?

- Are there any other components that help fizzy drinks to be preserved for a long time?
- What is the structure of phosphoric acid?
- How is phosphoric acid found in fizzy drinks such as coke?
- How does phosphoric acid affect the acidic structure of fizzy drinks such as coke?
- How does phosphoric acid help preserve acidic fizzy drinks?
- What is the reason for the bubbles that appear when fizzy drinks are opened? Is it the phosphoric acid that causes these bubbles?
- What other fields make use of phosphoric acid other than the acidic nutrition industry?

2.2. Problem Statement: How could we detect the existence of phosphoric acid in fizzy drinks such as coke?

3. Establishing Hypothesis

Technical and theoretical questions required for solving the problem;

- What is the structure and formula of phosphoric acid?
- How and why is phosphoric acid used in the nutrition industry and other industries?
- How is phosphoric acid found in coke?
- Is the proportion of phosphoric acid the same in all fizzy drinks?
- What products other than fizzy drinks like coke contain phosphoric acid?

Proposed Ways of Solution

- Determination of phosphoric acid through ascorbic acid method?
- Ion Chromatography used in determination of the phosphates found in fruit juice, milk and dairy products, fruit nectars etc.
- Phosphate determination method used for determining the existence of phosphoric acid, which is one of the primary components of detergents and is found in coke.

Experiment proposal: Phosphate determination method for determining the existence of phosphates in coke (3rd proposed solution way)

Hypothesis: Existence of phosphoric acid, which helps fizzy drinks like coke to be preserved, adds sweet taste to them and enables them to become acidic solutions, could be determined through the phosphate.

4. Trying the solution way:

<u>The name of the experiment</u>: Discovering Phosphates in Cola

<u>The aim of the experiment</u>: One of the main ingredients in many cola beverages is phosphoric acid. This compound helps to preserve the beverage, gives it part of its sweet taste, and provides an acidic solution. Phosphoric acid ionizes to a hydrogen ion, H+, and a phosphate ion, PO43-, in cola. In this activity, we will test for the presence of phosphates in cola and in common materials such as laundry detergent.

<u>Solution and Materials</u>:

- Cola soft drink
- Laundry detergent
- Sodium phosphate (Na3PO4) (or other phosphate salt)
- Magnesia mix
- Hydrochloric acid, 1.0M
- Test tubes, pH paper and droppers

<u>Procedure</u>:

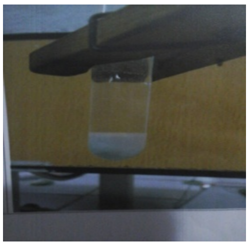
- Establish a positive test for phosphate using sodium phosphate (Na3PO4).
- 0.5g of sodium phosphate is placed in a test tube. The tube is filled half full with distilled water and the tube is shaken until the solid dissolves.
- A piece of pH paper (or red litmus paper) is wetted with the solution. It should be basic.
- Hydrochloric acid is added, one drop at a time, until the solution is neutral.
- A dropper full of magnesia mix is added to the tube.
- The tube is set aside and it is observed carefully. A white precipitate that slowly forms and settles to the bottom of the tube confirms the presence of phosphate.
- Test cola for phosphate.
- The previous test is repeated, but it has been a test tube half-filled with cola instead of distilled water.
- The cola may already be acidic, so it may not be necessary to add hydrochloric acid.
- Test detergent for phosphate.
- The previous test is repeated, but a small amount of granular detergent

(enough to cover a dime) is dissolved in a test tube half-filled with water.

- Be sure to test the solution with pH paper. It may be necessary to add acid to make the solution neutral.

The results of the experiment:

Phosphorus is one of the major minerals in the body. It is necessary for proper bone development, and a deficiency can cause serious defects. One of the primary sources of phosphorus is phosphates, and phosphates are in high concentration in cola beverages because of the phosphoric acid added during the bottling process. In this activity, prospective teachers will have an opportunity to first establish a qualitative test for the presence of phosphates and then use this test to show the presence of phosphates in cola and in some laundry detergents.



Sodium phosphate (Na3PO4) Cola Laundry detergent

The questions related to the experiment:

- How did you show the presence of phosphate ions in the samples?
- Show the formula for phosphate.
- How did the amount of phosphate in the cola and the laundry detergent compare?
- Which mineral is provided by the phosphate ion?

5. Feedback: We have obtained results that verified the hypothesis I had established at the 3rd phase of the application following the experiment we had performed.