

The Efficacy of Problem-Based Learning in an Instrumental Analyse Laboratory

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Abstract

In the context of the study, an instrumental analysis laboratory course offering Problem-Based Learning (PBL) was designed as an alternative to traditional laboratory practices. The study was conducted with a total of 36 volunteer, prospective chemistry teachers consisting of fourth year undergraduates and graduates. While PBL activities were conducted with 19 of the prospective teachers, instrumental analysis laboratory activities were conducted with 17 of them using the traditional approach. The first aim of this study was to determine the levels of perception of problem-solving ability and self-regulatory learning strategies of prospective teachers after and before all the applications. The second aim was to compare the effects of PBL instrumental analyze laboratory course and traditional instrumental analyze laboratory course on the perceptions of problem-solving ability and self-regulatory strategies 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)” and “Self-Regulatory Strategy Scale (SRSS)”. The pretest-posttest results of the SRRS test showed that the prospective teachers in the experimental group used self-regulatory learning strategies more often when compared to the ones in the control group. According to the results obtained within the scope of the study, it can be said that the effect of PBL on the perception levels of problem solving skills and self-regulatory learning skills of prospective teachers is more effective than the traditional laboratory teaching application.

Keywords: instrumental analyse laboratory, problem-based learning, problem solving abilitiy, prospective chemistry teachers, self-regulatory learning strategies

1. Introduction

1.1 Introduce the Problem

Nowadays, problem solving is accepted as a preferred and effective strategy in a socially important learning atmosphere. According to Borkowski (1992), particularly if a student is faced with a challenging task such as solving a problem that he encountered for the first time, his self-regulatory skills should induce motivation and give him energy. There shall also be progress in his processes like selecting the right strategy, implementation, and monitoring. While solving a problem, the students make efforts to make a plan, make an assessment, and decide which strategies to use. Thus, they all agree that during this process, they feel more successful, and more talented while carrying out certain tasks. The use of learning environments requiring more effort and participation, such as PBL activities, encourage students to ask more questions. In such environments, the fear of making mistakes is also reduced. Borkowski, Chan and Muthukrishna (2000) argue that the students should be given opportunities to make an attempt to carry out their tasks both independently and cooperatively. Although PBL processes are affected by the source of the problem, they require the use of goal-oriented and self-oriented strategies.

The PBL process is a student-centered method that is designed based on a poorly structured (real world or problems simulated in a complicated manner) realistic problem for which the students work cooperatively to develop appropriate solutions (Lambros, 2004). This learning strategy emphasizes the real world competencies including skills such as autonomous learning, cooperative learning, problem solving and decision making, and forms a strong basis (Tan, 2003, 2004). In the context of this learning strategy, a learning environment in which the students take an active role is established, and the students propose research questions, explore, conduct research on the related subjects, and offer solutions in this learning environment (Lambros, 2004). According to

Wheatley (1984, p. 1), “something is a problem when one doesn’t initially know how to do it, and problem-solving is what you do when you don’t know what to do”. Problem-solving skills, however, are shaped in accordance with the beliefs and expectations about one’s problem-solving skills (Heppner, Witty, & Dixon, 2004) because coping with environment and problems occur through one’s problem-solving capacity. The individual’s self-evaluation of the ability to cope with problems effectively is extremely important in this respect. Thus, individuals with positive perceptions of their problem-solving ability might also be much better at problem-solving than those with negative perceptions of their problem solving ability (Güçlü, 2003). Heppner and Krauskopf (1987) identified that perception of problem-solving ability plays a central role in the way an individual perceives and experiences different aspects of dealing with problem. According to Tan (2004), PBL focuses on the challenge of making students’ thinking visible. Like most pedagogical innovations, PBL was not developed on the basis of learning or psychological theories, although the PBL process embraces the use of metacognition and self-regulation. PBL embodies more student responsibility and activities when compared to conventional learning (Hmelo-Silver, 2004). Tan (2003) lists some of the features of PBL approaches that are put into practice in a course as below: (a) self-directed learning is primary. Thus, students assume major responsibility for the acquisition of information and knowledge, (b) development of inquiry and problem-solving skills is as important as content knowledge acquisition for the solution of the problem, and (c) learning is collaborative, communicative, and cooperative. Students work in small groups with a high level of interaction for peer learning, peer teaching, and group presentations. In PBL, comprehension occurs as a result of the interactions with the problem scenario and the learning environment. After dealing with the problem and the process of problem inquiry, cognitive contradictions occur and this happens through the stimulation of learning and improvement of knowledge as a result of cooperative processes following social discussions and individual’s self-evaluation of their own perspectives. PBL covers content learning, acquisition of process skills, problem solving skills, and lifelong learning. The term “lifelong learning” is quite important for PBL in regard to emphasizing the skills such as self-regulatory learning, autonomous knowledge collection, cooperative learning, and reflective thinking (Tan, 2004).

Another potential benefit of PBL is undoubtedly the improvement of self-oriented and self-regulatory learning skills of students (Hmelo-Silver, 2004; Zimmerman & Lebeau, 2000). That is why it can be noted that metacognitive strategies and self-regulation are indispensable for PBL processes (Tan, 2004). Pintrich (2000) defines self-regulatory learning as a process through which students deal with different strategies in order to regulate their cognition, motivation, and behaviors. Self-regulation is a characteristic commonly required for students to be successful in PBL contexts (Hmelo-Silver, 2004; Zimmerman & Lebeau, 2000). Self-regulatory learning occurs as a result of the controlling of learning process by the students, and their awareness about the process is among the objectives of PBL (Taşkın, 2008). Providing students the opportunity to select and control “what to study, how to study, and what products to produce”, PBL offers opportunities for self-regulatory learning (Hmelo-Silver, 2004; Paris & Paris, 2001). PBL also encumbers the students to find knowledge, coordinate actions and people, achieve targets, and evaluate different mentalities. According to Hmelo-Silver (2004), when the student is in a PBL environment, he tries to solve the problem through research and inquiry, and designs a plan including the steps required to find the most appropriate solution. In order to successfully complete these tasks, the students need to use their self-regulatory learning skills throughout the process. While examining a problem as a group, selecting the related knowledge, and compiling a list of knowledge to be used for finding other things later, the students make use of these self-regulatory learning skills. Although the knowledge is divided among different group members, the students use self-regulatory learning skills also in the research of different sources, transfer of this knowledge again to the group, and evaluation of the required additional knowledge and knowledge that should still be explored (Torp & Sage, 1998). All these activities happening in a PBL environment bring out self-regulatory learning skills. Since the students are required to use their reflective and critical thinking abilities on “what I learned” in PBL, they become responsible for their own learning (Hmelo-Silver, 2004). In PBL, the students participate in cooperative groups and determine their respective needs to solve the problems. Thus, PBL is a method that helps the students take an active part in solving real-world problems and be responsible from their own learning (Lee, Shen, & Tsai, 2010).

1.2 The Importance of the Study

In order to be able to keep up with and understand the era of knowledge and technology we are in, the skills of problem solving through scientific methods, inquiry, and research are quite important (Erbaş, Şimşek, & Çınar, 2005). Erbaş, Şimşek and Çınar emphasize that it is possible to raise individuals who can acquire knowledge through observation, ask meaningful questions, and look for answers to these questions in certain learning environments enabling permanent learning through the methods of learning by doing and experiencing. Adapting

to a new learning environment can be something difficult. Learners bring with them a range of learning strategies that may or may not be useful for the new context (Thomas, 2013). In order to ensure efficient participation, the students are required to develop and adapt strategies appropriate for these new environments. Laboratory practices are one of the factors making great contributions to this process. The importance of laboratory practices is examined very comprehensively in the related literature, however, it is observed that the main goal of laboratory practices is misinterpreted (Renner, 1986). It has been frequently observed that in laboratory practices, the teachers do not provide guidance on activities through which the students may ask questions, develop their hypotheses, make observations, design experiments, and predict the results. Besides the traditional laboratory practices, there have been various studies that involved PBL or problem solving laboratory 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 (Grigg, 2012; Güngör Seyhan, 2014; Güngör Seyhan, 2015; İnce Aka, Güven, & Aydoğdu, 2010; Taasobshirazi & Glynn, 2009; Yin, 2010). 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 (are likely to) be successful (Aydoğdu, 2012). A great majority of the criticisms concerning 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. For this aim, student centred learning may be a new implication. Student-centred 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, p. 43). Accordingly, Problem-Based Learning (PBL) may be implemented as one of the student-centred learning approaches.

Students who are successful in PBL display skills in self-regulated learning (Blumberg, 2000; Evensen, 2000; Sandars & Cleary, 2011; Zimmerman & Lebeau, 2000). Loyens, Magda and Rikers (2008) concluded that self-regulated learning is a developmental process. This suggests that self-regulated learning can be taught (Dignath, Buettner, & Langfeldt, 2008). Empirical studies investigating the value of PBL, characterize successful PBL students as life-long who display the ability to recognise gaps in their knowledge and aptly employ strategies to fill these gaps (Beachey, 2007; Carlisle & Ibbotson, 2005; Rideout et al., 2002). The essence of PBL is that students are required to make their own decisions in planning for, engagement in and evaluation of knowledge and skill acquisition, hence employ skills in SRL. Such studies serve as a reference for the instructors who would like to carry out this kind of learning processes and strategies more salient in order to better support learners moving into the PBL environment (Thomas, 2013). In line with the development of these new learning environments, the concept of PBL and its implementation have been reorganized in terms of context, and adapted and implemented in the learning environments across the world. Today, PBL has been being used in fields such as business, law, psychology, engineering, and education (Schmidt et al., 2007). Kalkan (2002) summarizes the possible reason why PBL shall be important in higher education as follows: (a) emphasizing the utmost student involvement in teaching, PBL contributes to the quality of task-oriented learning. Besides, encouraging self-regulation, the method contributes to the effective use of motivational, cognitive, and metacognitive strategies, (b) in addition to the academic knowledge, skill improving and enhancing activities are carried through PBL and all benefits of cooperative learning are reflected on the attitudes, (c) PBL makes the best use of all three basic methods lecture, small group teaching self-regulation, the most considerable contribution of PBL is seen on the life long learning.

PBL practices that were conducted in the laboratory in the context of the study were based on a guided cooperative strategy (Hmelo-Silver et al., 2007; Schmidt et al., 2007), which includes intensified facilitation efforts of the researcher, rather than the learning approach of "do it yourself", proposed by Kirschner, Sweller and Clark (2006). As an instructional approach, PBL was first applied in the Medical School of Case Western University, United States of America (USA), in the 1950s. It entered into the literature in the late 1960s following a research study undertaken at McMaster University in Canada (Rhem, 1998). "PBL is a student-centred learning approach that empowers students to conduct a research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2006, p. 12). PBL is consistent with the constructivist theory by challenging the student to take a responsibility for learning (Coombs

& Elden, 2004). Since, in the process of PBL, individuals try to make sense of newly encountered situations based upon their prior knowledge, this approach is based on the constructivist theory. As planning the learning activities necessitates students' active participation in a specific problem state, it is one of constructivist theory's most important applications (Saban, 2010). PBL is an approach of learning in which the process of constructing knowledge activates students' prior knowledge, and problem-solving strategies of ill-structured problems are developed and acquired through in-group discussions and through research (Koçakoğlu, 2010). The selection of ill-structured problems is critical to the success of the PBL (Savery, 2006). Ill-structured problems are routinely encountered in everyday and usually have divergent or alternative solutions (Shin, Jonassen, & McGee, 2003). When a problem is well-structured, students are less motivated and less invested in the development of the solution" (Savery, 2006, p. 13). The problems used in PBL should be designed in such a manner as to improve students' knowledge, personality, academic behaviour and attitudes (Barrett, 2012) and must allow for free inquiry (Savery, 2006). Problems should be presented to students through scenarios (Neville & Britt, 2007). Using problem scenarios in education differentiates PBL from other teaching approaches (Tan, 2010). Especially, PBL differs from a problem-solving approach "in that in the PBL problems are encountered before all the relevant knowledge has been acquired and, therefore, necessitates both the acquisition of knowledge and the application of problem-solving skills. In some cases, defining the problem itself forms part of the PBL. In a problem-solving approach, the knowledge acquisition has usually already taken place and the problems serve as a means to explore or enhance that knowledge" (Belt, Hywel Evans, McCreedy, Overton, & Summerfield, 2002, p. 65). In contrast to the traditional approach in which knowledge is transferred to students by the teacher, problem states are established by the teacher to match the concepts in PBL, and the students are required to find solutions to those problem states (Tan, 2010). Using complex and real-world problems to introduce a concept and motivating learning in an active and cooperative learning environment, PBL is a powerful alternative to the traditional teaching method in introductory courses in biology, physics and chemistry (Allen, Duch, & Groh, 1996).

A review of literature in the light of the above mentioned issues makes it clear that the PBL is considered important in the development of self-regulated learning and of problem-solving abilities. Yet, the need for research into the effects of PBL on the development of self-regulated learning especially in education is one of the reasons for performing this study.

1.3 The Aim of This Study

The aim of this study was two-fold. In the context of the study, firstly, a PBL activity was intended to be designed in order to be implemented as an alternative to a conventional laboratory course that is currently present at university level. In a typical laboratory course, scientific information about an experiment is generally shared with the students in advance and the students are expected to present the targeted results by following the laboratory process in the format of a recipe book. On the other hand, in a laboratory course designed in accordance with PBL, the students are asked to achieve a targeted result, first by defining a real life problem they are given and then carrying out experiments by making use of various sources of knowledge in order to solve this problem. PBL is a curriculum design and a teaching/learning strategy that was developed in the west over the last forty years (Yuzhi, 2003). In order to achieve acceptable performance during the process of the PBL activity, the students are expected to have sufficient skills to solve a problem they encounter, and take responsibility for their own learning. It is also a learning environment, that embodies most of the principles that we know to improve learning, i.e., being active and cooperative learners receiving prompt feedback, teaching which is tailored to students' learning preferences and promoting student empowerment and accountability (Yuzhi, 2003). For this reason, students' perception levels on problem-solving ability and self-regulatory strategies were determined as a result of participating in different teaching methods. The second aim was to compare the effects of PBL and traditional teaching application in the instrumental analyze laboratory on the perceptions of problem solving ability and self-regulatory learning strategies of prospective teachers. The present study focused on the following research questions:

- (1) What are the perception levels of problem solving ability and the levels of self-regulatory learning strategies all of the prospective teachers before and after the implementations?
- (2) Is there a significant difference between prospective teachers' perception levels of problem solving ability and the levels of self regulatory learning strategies according to the different teaching methods implemented?

2. Method

2.1 Research Design

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 one-way MANOVA were employed in the data analysis.

2.2 Participants

A total of 36 prospective chemistry teachers attending the Department of Chemistry (4th class and graduates) of a university in Turkey who have taken instrumental analyze and instrumental analyze laboratory courses in university level participated in this study. Instrumental analysis course, in which the applications are carried out, is a course taken by the students enrolled in the related program in the spring semester of 3rd grade. The students carrying out the applications participated in this study voluntarily. The number of students who are still attending to the last grade is 22 and the number of students graduating from this program is 14. While forming the groups, it was noted to make complete random sample selection and provide a homogeneous distribution of attending/graduated students. Mean age was 21.6 years (range 20-22 years). Of the prospective teachers participating in the study, 26 are females and 10 are males.

2.3 Instruments

2.3.1 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 to Turkish 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). 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. 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 .80 to .86 for PSI total.

2.3.2 Self-Regulatory Strategies Scale (SRSS)

Cronbach Alpha internal reliability coefficient of eight-factor scale developed by Kadioğlu, Uzuntiryaki and Çapa Aydın (2011) in order to measure the self-regulatory learning strategies used by high school students while studying for chemistry lesson varied in the interval of .68-.82. As the original target group of the scale was high school students, this scale was applied for 92 undergraduate students who took/were taking general chemistry course prior to this study. As a result of Confirmatory Factor Analysis (CFA), all relations of sub-scales with each other and with scale point were found to be meaningful. That the sub-scales of the scale indicated a high level relation in positive direction with scale point supported the structure validity of the scale in positive direction. Also, the fact that correlation values among the factors varied between .61 and .72 indicated that the factor structure of the scale was consistent. Cronbach Alpha value, which was estimated in order to examine the reliability of the scale, was in total .89 (29 items). The SRSS has a reported internal consistency reliability coefficient of .84 and a value of .70 for this study.

2.4 Data Analysis

Descriptive statistics, independent *t*-tests and one-way MANOVA were employed in the data analysis. *t*-test for independent groups is a statistical analysis method used for testing whether the averages belonging to two groups are different or not (Kalaycı, 2005). In this study, *t*-test for independent groups is was used to test whether there was an meaningful difference between PSI and SRSS pre-test results of the prospective teachers in experimental and control groups before starting applications.

Manova technique was used in our study as the relationship was searched between a series of dependent variables and more than one independent variable. Manova is an extension of Anova including more than one dependant variable (Hair et al., 2009; Tabachnick & Fidel, 2001; Kalaycı, 2005). Multivariate analysis of variance like Manova is more powerful than variance analysis with single variable (ANOVA) and this technique protects the researcher against making 1st type mistake (Şencan, 2005). Multivariate analysis of variance is a powerful statistics frequently used in experimental and relational scanning researches. Multivariate analysis of variance should be used in applications including experimental studies in order to compare the subjects in different experimental conditions in terms of more than one dependant variable at the same time (Büyüköztürk, 2009).

3. Teaching Process

Approximately two weeks before the start of applications, PSI and SRSS were administered as pre-test treatments to determine whether all the prospective teachers were equivalent with respect to their perceptions of problem solving ability and self-regulatory strategies.

Before starting the implementations, the researcher informed the prospective teachers to participate in the PBL implementations about the context of PBL and the planned phases of a laboratory course. Following this, 19 randomly selected prospective teachers were asked to form groups of three-four people and the PBL implementations were conducted with a total of five groups. In this study, PBL in the instrumental analyze laboratory progressed in six steps (Yoon, Woo, Treagust, & Chandrasegaran, 2014) (as shown in Figure 1 below) and lasted 12 weeks.

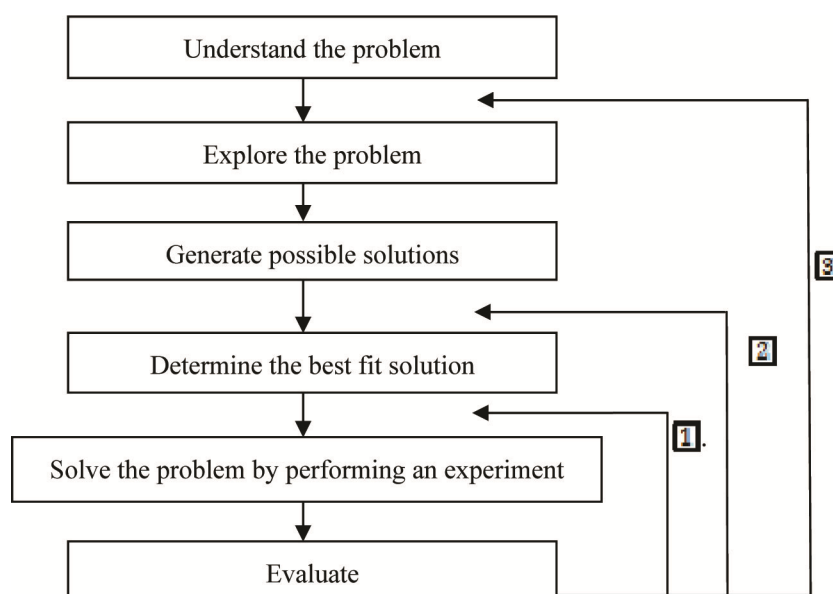


Figure 1. Stages of PBL instrumental analyze laboratory course (Yoon et al., 2014)

In the first phase of the PBL activity, which is “Understand the problem”, the prospective teachers were presented with a real life problem. In PBL activities, the real life problems presented to prospective teachers as real time scenarios which they may experience in their daily life at any moment. Learning in PBL is initiated with a problem that stimulates students to consider what they already know and what they will find out in an investigation (Yoon et al., 2014). Each group member that came together was expected to understand and define the “real life problem” she/he was given. PBL is an approach designed to encourage students to actively participate in the problem-solving of ill-structured real world problems (Yoon et al., 2014). PBL aims to help students develop higher order thinking skills and a substantial disciplinary knowledge base by placing students in the active role of practitioners (or problem solvers) confronted with a situation (illstructured problem) that reflects the real world (Yuzhi, 2003). In the second phase of the PBL activity, which is “Explore the problem”, the students were expected to reach the sources of problems and explore their problems. In an activity to be conducted for PBL, it was observed that there should be a need for only a part of the opinions and knowledge of prospective teachers when realizing the source of a problem. In order to identify in which phase of problem

exploration the prospective teachers felt greater need, they were asked to propose more than one question in the respective fields by designating the learning topics in at least three categories about “What do we know?”, “What do we need to know?” and “How do we find out?” (IMSA, 1996; Yoon et al., 2014). In this phase, in which the prospective teachers explored the problem, they felt a need to refer to various sources of knowledge, far beyond textbooks. It was observed that especially the faculty courses like instrumental food analyses taught at departments, such as Food Engineering at our university, are more in need of the notes from laboratory courses. Thus, at this point, the researcher provided considerable guidance to the prospective teachers about how to access which source of information. The third phase of the activity about PBL instrumental analysis course is “Generate possible solutions”. In this phase, the prospective teachers, who identified, explored, and defined the learning topics about the real life problem they were given, were asked to propose possible solutions to this problem. A laboratory course conducted through the PBL strategy does not only encourage the prospective teachers about how and where to use any experimental method, but also offers them the opportunity to explore the theoretical knowledge they need in order to select the experimental method and/or instrument and analytical methods that are appropriate for solving the real life problem. Thus, the prospective teachers explore the required knowledge and generate possible solutions as part of their groups (Yoon et al., 2014). The phase of “Determine the best fit solution” is the phase in which prospective teachers review the validity and applicability of the methods they propose and select the best way to solve the problem. In this phase, the instrumental method selected by the prospective teachers as the most appropriate solution might not have been a method they had previously learned and/or practiced in the context of the course, namely “instrumental analysis” or “instrumental analysis laboratory”. At this point, prospective teachers selected the most appropriate solution offer after having accessed various sources of knowledge in the previous phase. In the end, the prospective teachers made a comparison of the advantages and disadvantages of the method they proposed for the solution of the problem in the previous phase and become prepared to make their experiments in this phase. In the “Solve the problem by performing an experiment” phase of the PBL activity, the instrumental method determined to be the most appropriate one in the phase of problem solving was applied by the group members in the laboratory environment, the results were analyzed, and the analyses were reported. In the “Evaluate” phase, which is the last phase of the PBL activity, if and when the prospective teachers detected any deficiencies and/or insufficiencies in the experiments they made, they repeated the experiment phase. If and when any problems occurred regarding the most appropriate instrumental method selected by the prospective teachers from the solution offers in problem solving phase and/or about the selected instrumentation, they returned to the phase of selecting other solution offers. If and when the prospective teachers encountered a case like looking for a better solution, they went back to the previous phases in order to solve the problem through the most appropriate means (Yoon et al., 2014). In the whole process until the “evaluation” phase of the PBL activity, the group members participated together in the form of a group and attempted to fulfill their responsibilities about their own learning. After the final phase of the PBL activity, the group members were asked to individually report and verbally present all the results they achieved. Thus, each group member, who worked as a team in solving the problem they were given during the PBL activities, had the opportunity to verbally present the results they achieved, both to the teacher of the related course and in a discussion environment to be attended by other prospective teachers. In addition to the sufficiency of the written reports and the individual verbal presentations of prospective teachers, the researcher took into consideration their presence in the discussion environment where they exchanged their ideas with the other class members as well.

The content of a junior-year instrumental analysis class and the instrumental analysis laboratory in which the application of the theoretical information learned in this class is done are as follows: some instrumental methods of analysis applications of UV-Visible absorption: a single-component and two component chromophore systems analysis, UV-Visible Spectroscopy: quantitative analysis of two-component mixture of (Co(II)-Cr(III) mixture analysis), flame atomic absorption and emission, Mass Spectroscopy (MS), IR spectroscopy, polarography, Planar chromatography (TLC), conductivity and potentiometric titrations. Within the context of the study, researchers and/or executives who realized the applications in a traditionally-run instrumental analysis laboratory were more active and the prospective teachers were passive listeners, the latter asking for explanations of the parts that they did not understand. Control group students delivered the reports they prepared regarding the experiment after each one to the researcher. The researcher evaluated the performance of prospective teachers and related reports. Control group prospective teachers realized 8 different experiments during the applications and all applications lasted for 12 weeks as PBL applications. 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 applications, PSI and SRSS were administered as the post-test treatments to the prospective teachers.

3.1 The Sample Process Experienced by Prospective Teachers Participating in the PBL

This section presents a summary of what the prospective teachers who participated in the PBL activity did in each phase of the activity in the instrumental analysis laboratory and what kind of a process they followed. All group members who took part in the activity followed a similar process. Prospective teachers participating in PBL activities were presented with two real life problems in total within the scope of the application and each problem solving process was completed in 6 steps. In the “Understand the problem” phase of the PBL activity, the first of the real-life scenarios presented to all group members are as follow:

“In the central district of a province in Turkey’s Central Anatolia Region, where the main source of income is agriculture and most of the vegetables and fruits consumed at home are the families’ own products, symptom of bluish color started to be observed in the skin, mucous membrane (lining the inside of mouth), and nail beds of newborns in particular, in the last six months. In addition to the bluish color, the symptoms of tiredness, shortness of breath, and in advanced disease, fainting spells are also observed in the babies. The parents of children who showed all these symptoms applied to the nearest health clinic during the period when these symptoms occurred. It was concluded that these symptoms, observed especially in newborns, resulted from “Blue Baby Syndrome” and the related health personnel notified the Provincial Directorate of Public Health about these symptoms accordingly. You, as a “laboratory associate” working at the Public Health Laboratory operating under the Provincial Directorate of Public Health, are asked to carry out the related analyses and examinations to determine the possible causes of these symptoms. In your report, the objective of which shall be proposing the causes of the mentioned symptoms, please provide detailed information on which analytical/instrumental method and/or instrumentation you used and for what purpose, and how you analyzed the results after reaching the related data. Then please submit your report to the director of the laboratory responsible for this issue”.

In the second phase of PBL activity (Explore the problem), the group members first aimed to reach the source of the problem; in order to do that, together with the other group members in their respective groups, they determined the data about the answers of the three questions serving as a means of learning given in Table 1. The phase in which the prospective teachers needed more sources of knowledge was clarified as a result of the following three means of learning they presented: “What do we Know?”, “What do we Need to know?”, and “How Do we find out?”. Table 1 gives examples from the means of learning proposed by each of the group members.

Table 1. Sample “KND chart” for the real life problem

What do we Know?	What do we Need to know?	How Do we find out?
<ul style="list-style-type: none"> • Symptoms that occur as a result of blue baby syndrome [G (1-5)], • Especially at which age the symptoms of blue baby syndrome start to characterize the next phase of the disease [G (2, 3 and 5)], • Geographic structure of the region where these symptoms are observed [G (2 and 3)], • Main sources of income in the region [G (1, 2, 3 and 5)], • Characteristics and sources of the food and drinks consumed by the people living in the region where these symptoms are observed [G (1-5)], 	<ul style="list-style-type: none"> • Causes of symptoms that occur in blue baby syndrome [G (1-5)], • Whether or not chemical fertilizers are used in the cultivation of vegetables, especially the green leafy ones, consumed by the people living in the region of concern, the content of the chemical fertilizer, and its compliance with the standards of usage [G (2)], • Whether or not the source of drinking water consumed by the people living in the related region is underground water or not [G (3 and 5)], • The source of meat and meat products consumed by the people living in the related region [G (4)], • The reason why blue baby syndrome-related symptoms are observed, especially in newborns, 	<ul style="list-style-type: none"> • Determination of nitrates and nitrites in drinking water, • Mixing of nitrate-contaminated water with drinking water as a result of incorrect fertilization, and the consumption of this drinking water by the people in the region [G (3 and 5)], • Determination of nitrate and nitrite in green leafy vegetables [G (1 and 2)], • Increase in the nitrate and nitrite amounts in the breast milk of mothers who consume green leafy vegetables cultivated after incorrect fertilization based on this chemical fertilizer [G(1)], • Excessive consumption of green leafy vegetables cultivated after incorrect fertilization [G(2)], • Determination of nitrate and nitrite in

<ul style="list-style-type: none"> • Nutrition characteristics of children, especially newborns, showing blue baby syndrome symptoms and their mothers [G(1)]. 	meat [G(4)], <ul style="list-style-type: none"> • Mixing of nitrate-contaminated water with drinking water as a result of incorrect fertilization, and the consumption of this drinking water by animals in the region.
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Note. G (1-5): Group 1, Group 2, Group 3, Group 4 and Group 5.

In the third phase of PBL activity (Generate possible solution), the prospective teachers, who identified, explored, and defined the learning topics about the real life problem they were given, were asked to propose possible solutions to this problem. When proposing the solutions they considered to be the most appropriate, the prospective teachers made use of the results they determined in Table 1. The common conclusion reached by all the group members as a result of the studies they carried out through various sources is as follows:

When nitrate concentrations in drinking water exceed 4.5 mg/l value is emerging health problems. In high NO_3^- concentrations, infections in intestines, digestion, and urinary systems are observed in adults. High nitrate concentrations cause methemoglobinaemia in babies. This disease is also known as blue baby syndrome, which is caused by the fact that the digestion systems of babies lack the enzymes to eliminate nitrate. Nitrate causes stomach acids to occur in babies younger than six months (Erdem, 2006).

Consider following question: what can be the possible causes of high concentration in human body? When analyzing the answers given to this question, the group members had different approaches. In the fourth phase of PBL activity (Determine the best fit solution), all the group members attempted to select the most appropriate answers they could give to the abovementioned question. For example, the members of the third and fifth groups linked the presence of excessive nitrates in the body, which is the cause of symptoms, especially in babies, to the nitrate contamination in the drinking water of the people in the region. Thus, in the phases to follow, they focused more on the studies and analyses about the causes of “nitrate contamination in drinking water”. For example, the members of the third and fifth groups proposed the following methods and techniques for the chemical determination of nitrate ion in water.

For the Determination of Nitrate in Water:

- Cold Brucine Method
- 2,6-dimethylphenol spectrometric method
- Spectrophotometric Nitrate Determination with Indigo Carmine

For the Determination of Nitrite in Water:

All the methods used for the determination of nitrite in water are spectrophotometric and the determination can be carried out as mentioned below:

- Diazotization of aromatic amines and their combination with azo-dyes
- Oxidation of organic molecule with nitrites
- Formation of free-radical chromogens (chromogen: substance, itself without color, giving origin to a coloring matter)
- Formation of nitrous compounds

The presence of nitrite ions is a sign of active biological incident in the medium. Even if its concentration is very low, it indicates that contamination has started and biological incidents continue. Nitrite anion (NO_2^-) is determined based on the color of the reddish purple azo-dye that is caused by the sulfuric acid diazoniated with α -naphthylamine (aromatic amines) in the interval of pH 2-2.5. The tone of the color changes in line with the nitrite concentration and 0.001 mg/l nitrite nitrogen shall be determined through this method.

According to the members of the third and fifth groups:

Water quality can be determined by measuring various organic and inorganic nitrogen based compounds found in drinking water, tap water, surface water, and contaminated water bodies. Strong evidence of nitrate in surface waters means that the related water was previously contaminated with domestic and industrial waste waters containing ammonium and organic nitrogen or that nitrate was directly discharged to the related water very recently. Direct nitrate discharges result either from waste water coming from

industrial facilities where nitrate compounds are used or produced or from nitrate containing fertilizers used in agricultural lands carried by rain waters. The biggest cause of the presence of nitrate in underground waters is that nitrate fertilizers are carried by rain waters and irrigation waters to these waters. The nitrate compound, which is an extremely unstable form of nitrogen, shows that nitrification or denitrification reactions are happening in the medium (cevre.erciyes.edu.tr/dosyalar/.../2.../Nitrit%20ve%20Nitrat%20Tayini.pdf).

In the fifth phase of PBL activity (Solve the problem by performing experiment), the prospective teachers implemented the solution that they considered to be the most appropriate. Each group member developed a work plan for the smooth implementation of the phases to be put into practice on the way to the solution they proposed. In this phase, it was observed that the prospective teachers needed more sources about how they would carry out which analyses at the laboratory environment, in addition to the lecture notes of the theoretical/practical courses they had previously taken. At this point, it was observed that the group members were mostly in need of the lecture notes of the “instrumental food analyses” course—both theory and practice—conducted as a laboratory course, especially in the Departments of Food Engineering at universities. This course aims to educate university students the working principle and areas of use of frequently used devices in food analyses. In this context, the learning outputs of (1) learning the objective and scope of Instrumental Food Analyses, (2) learning chromatographic techniques, and (3) learning spectroscopic techniques come into prominence in the content of this course. In the end, all group members had access to all samples and technical instruments, and were ready in the laboratory under control of the researcher. For example, the members of the third group, who in the previous phase linked the presence of excessive nitrates in the body, which is the cause of symptoms especially in babies, to the nitrate contamination in the drinking water of the people in the region, decided to carry out “nitrate analysis in drinking waters” as a solution. Thus in this phase they accessed all theoretical and practical information about “nitrate analyses in drinking waters” and utilized the “Cold brucine method” for the analysis of nitrates and nitrite in drinking water in the laboratory under control of the researcher. The members of the second group linked the source of problem to “nitrate contamination in green leafy vegetables” and carried out related analyses to “determine nitrate in green leafy vegetables”. The members of the fourth group, on the other hand, linked the source of problem to “nitrate contamination in meat and meat products” and carried out related analyses to “determine nitrate in meat and meat products”. In the last phase of the PBL activity, all group members reported the results they obtained through the analyses they conducted. In the evaluation phase, all group members had the opportunity to evaluate the results of the analytical/instrumental methods they conducted for their respective analyses. If the causes of excessive nitrate concentration and thus the causes of symptoms overlapped with the findings they obtained after conducting the most instrumental method they proposed as a solution, their comments supporting these findings were required to be included in their reports and verbal presentations to be made afterwards as a group. If the assumptions of group members in regard to the solution of the problem did not overlap with the findings obtained after conducting the most instrumental method, they returned to the phase of “determining the best fit solution”. For example, members of the third group argued that the cause of all these symptoms observed in the people in the region, mostly in the newborns, was the excessive nitrate concentration in babies and they claimed that the reason for this excessiveness was the nitrate contamination in drinking water.

As a result of various studies they conducted about nitrate and nitrite contamination in drinking water, the members of the third group reached the assumption that since the main source of income of the people in the region is agriculture, the reason was most probably the fact that they carried out improper fertilization in agricultural production. They used the “Cold brucine method” in order to test their assumption claiming that the people of the region were exposed to excessive nitrate concentration, since they carried out improper chemical fertilization and nitrate was accordingly mixed to underground waters and then to drinking waters through rain and/or other causes. In the study that was carried out to determine nitrate and nitrite amounts in drinking water samples, qualitative analyses of nitrite in water samples were carried out. In the case of qualitative determination of nitrite, a sample of 50 ml drinking water and a sample of 50 ml pure water without nitrites were separately taken for control. One ml sulfanilic acid was added on top of both and they are mixed thoroughly. Then, 1 ml α -naphthylamine hydrochloride reagent was added. After waiting for approximately 10-15 minutes, the colors of the sample and control sample were compared to each other. If the sample turns pink, there is nitrite [in the mixture]. If nitrite is qualitatively determined in drinking water, the amount of nitrite should be quantitatively determined as well, in order to clean the water or prevent the source of nitrites. The quantitative determination of nitrites is based on the reading of nitrite amount contained in the sample on spectrophotometer and the comparison of readings with the readings of standard solutions. Members of the third group used the cold Brucine method, which is a commonly used method, for the chemical determination of nitrate ions in drinking

water. The method is based on readings of the yellow color [ed solution] resulting from the reaction between Brucine and nitrates on a spectrophotometer and a comparison of the readings with the readings of standard solutions. When nitrate and nitrite contents of the samples were examined, the nitrate and nitrite amounts in the drinking water sample were higher than the acceptable daily intake amount recommended by the World Health Organization (WHO) for children. The results were at a sufficient level to explain the excessive nitrate and nitrite concentration, especially in newborns. Members of the third group prepared their related reports accordingly and made verbal presentations during which they opened their assumptions and findings to discussion.

4. Findings of the Research

4.1 Findings Related to between PSI and SRSS Pre-Test Scores

Independent *t*-tests were used to analyze the data obtained from pre-test treatments. The results are given in Table 2.

Table 2. The pre-test scores of prospective chemistry teachers in both groups

	Groups	N	X (Pre-test scores)	X (Post-test scores)	SD	df	t	p
SRSS	Experimental	19	4.3506	4.5095	.61193	33.715	1.775	.085
	Control	17	4.0183	4.0185	.49733			
PSI	Experimental	19	3.4699	3.1352	.33063	32.852	-1.277	.210
	Control	17	3.6160	3.5580	.35564			

When Table 2 is examined, it can be seen that there is no significant difference between the perception levels of problem solving ability and between the self-regulatory learning strategies pre-test scores of prospective teachers in both the experimental group and the control group ($p > \alpha$).

According to the scores in Table 2 it was observed that the experimental group and control group are equivalent with respect to the perception levels of problem solving skills and the self-regulatory learning strategies at the beginning of the applications.

4.2 Findings to MANOVA Analysis

One-way MANOVA analysis was performed in order to examine the effect of two different methods on the perception levels of problem solving ability and self-regulatory learning strategies of prospective teachers. Before moving on to MANOVA analysis, it is necessary to test the assumptions. First of all, it is expected that *p* values for each group, which is one of the Kolomogrove-Smirnov values obtained for the normalcy of scores related to dependent variables (post scores of SRSS and PSI), should be bigger than .05 (Kalaycı, 2008). According to obtained data, because the values of both method types in the PSI and SRSS dependent variables are $p < .05$, it can be said that there is a normal distribution. Another assumption of MANOVA is the homogenous distribution of variances. For the homogeneity of variances, *p* value in Levene's Test of Equality of Error Variances is checked. The value is expected to be bigger than .05 (Kalaycı, 2008). According to the data concerning the homogeneity of variances, *p* values for both SRSS and PSI variables are $p = .068$ and $p = .478$, respectively, therefore it can be claimed that variances are evenly distributed according to independent variable groups for both dependent variables. Likewise, in order to test the MANOVA assumption that the correlation among variables is equal across groups, BOX's M test results were taken into consideration. According to the results, because $p = .162 > p = .05$, the assumption that the correlation among variables across groups is valid. After ensuring that MANOVA assumptions are valid, analysis was done.

In order to understand the effect of independent variables on dependent ones in the one-way MANOVA test results, one should check Wilks' Lambda value. The most frequently used value is the Wilks' Lambda value (Kalaycı, 2008). If $p < .05$, then it means that there is a meaningful difference. In this case, according to Table 3 formed at the end of the analyses conducted within the context of this study, it can be said that both method types create a meaningful difference in prospective teachers' comprehension levels, problem solving skills and their self-regulatory learning strategy levels ($p = .00 < p = .05$).

Table 3. Multivariate tests (b)

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.994	2954.522(a)	2.000	33.000	.000	.994
	Wilks' Lambda	.006	2954.522(a)	2.000	33.000	.000	.994
	Hotelling's Trace	179.062	2954.522(a)	2.000	33.000	.000	.994
	Roy's Largest Root	179.062	2954.522(a)	2.000	33.000	.000	.994
Groups	Pillai's Trace	.417	11.800(a)	2.000	33.000	.000	.417
	Wilks' Lambda	.583	11.800(a)	2.000	33.000	.000	.417
	Hotelling's Trace	.715	11.800(a)	2.000	33.000	.000	.417
	Roy's Largest Root	.715	11.800(a)	2.000	33.000	.000	.417

^a Exact statistic^b Design: Intercept+groups

When examining Table 4 in order to determine in which dependent variables both methods showed significant differences, it can be interpreted that since $p=.01 < p=.05$ for the sub-dimension of self-regulatory learning strategies of prospective teachers and since $p=.00 < p=.05$ for the sub-dimension of perception levels about problem solving skills, both methods showed significant differences in both dimensions. Eta squared values given in Table 4 show the ratios of change for the dependent variables in regard to the different types of methods used. According to the results obtained, the type of method causes a change of 18% in the prospective teachers' self-regulatory learning strategies and a change of 32% in their perception levels of problem solving skills.

Table 4. Tests of between-subjects effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	SRSS	2.163(a)	1	2.163	7.448	.010	.180
	PSI	1.604(b)	1	1.604	16.105	.000	.321
Intercept	SRSS	652.534	1	652.534	2246.917	.000	.985
	PSI	401.942	1	401.942	4036.115	.000	.992
Groups	SRSS	2.163	1	2.163	7.448	.010	.180
	PSI	1.604	1	1.604	16.105	.000	.321
Error	SRSS	9.874	34	.290			
	PSI	3.386	34	.100			
Total	SRSS	670.785	36				
	PSI	405.352	36				
Corrected Total	SRSS	12.037	35				
	PSI	4.990	35				

^a R Squared=.180 (Adjusted R Squared=.156)^b R Squared=.321 (Adjusted R Squared=.301)

Table 5 shall be examined in order to identify among which groups (experimental group and control group) there are significant differences in favor of PSI and SRSS final test following both implementations.

Table 5. Estimated marginal means

Dependent Variable	Groups	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
SRSS_PostScores	Experimental	4.510	.124	4.258	4.761
	Control	4.019	.131	3.753	4.284
PSI_PostScores	Experimental	3.135	.072	2.988	3.282
	Control	3.558	.077	3.402	3.714

According to the data given in Table 5, a significant difference was observed between the levels of self-regulatory learning strategies of prospective teachers and the levels of self-regulatory learning strategies of the control group because when examining the SRSS averages and the confidence intervals for both groups included in the table, the SRSS confidence interval of the prospective teachers in the experimental group range between 4.258 and 4.761, while the confidence interval of the control group ranged between 3.753 and 4.284. These two intervals do not totally overlap with each other. Thus, one can claim there is a significant difference between the two groups in favor of the average results of the experimental group. Again, according to the PSI final test results given in Table 5, the PSI averages of the prospective teachers in the experimental group was lower than those of the prospective teachers in the control group. 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). According to the confidence intervals of both groups for the PSI values given in Table 5, the improvement in the problem solving skills of the prospective teachers is in favor of the prospective teachers in the experimental group.

5. Discussion

In the context of the study, a problem-based learning activity was intended to be designed in order to be implemented as an alternative to a conventional laboratory course that is currently present at the university level. According to the first and third research questions of our study, perception levels of problem solving abilities of all prospective teachers were identified before and after the applications. According to the scores in Table 2 it was observed that the experimental group and control group are equivalent with respect to their 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 teachers decreased at the post-test following the all applications. According to the results, it can be said that the prospective teachers' perception levels of problem solving ability in both the experimental group and the control group were at low levels. 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. Accordingly, the result may be interpreted as PBL and traditional laboratory course methods having different effects on prospective teachers' perception levels of problem solving ability. It is reasonable to argue that the difference observed in the prospective teachers' perception levels of problem solving ability arises from the use of the PBL instrumental laboratory course approach. It was also found that the PBL laboratory approach, in which a greater decrease was observed in the scores of perception levels of problem solving ability, was more influential than the traditional laboratory course method in raising prospective teachers' perception levels of problem solving ability. When prospective teachers experienced problem solving in the instrumental analyze 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 course 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. PBL, which represents one of the most important implementations of the constructive learning approach, can be defined as a teaching/learning approach characterized with using problems as a means of improving the students' problem solving skills and helping them gain the related basic information (Torp & Sag, 1998). Literature was observed to involve studies on the positive aspects of problem solving activities performed in the science or chemistry laboratory (Gallet, 1998; Neeland, 1999; Wilson, 1987). Similarly, in the literature, research

conducted by Güngör Seyhan and Eyceyurt Türk (2013), Güngör Seyhan (2014), Güngör Seyhan (2015), 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.

The second and four research questions of the study was investigating the changes in the self-regulatory learning strategies of prospective teachers during the PBL and traditional instrumental analyze laboratory applications. According to the scores in Table 2 it was observed that the experimental group and control group are equivalent with respect to their self-regulatory learning strategies at the beginning of the study. The study examined how the self-regulatory learning strategies of prospective teachers varied after both PBL activities and conventional instrumental analysis laboratory practices. According to the data given in Table 2, while an increase was observed in the SRSS results of prospective teachers who participated in PBL activities, no significant changes in the SRSS results of prospective teachers who participated in conventional laboratory practices were observed. When the reactions of prospective teachers, who participated in PBL activities, against SRSS substances are examined in detail, the clearest observation is that there was a significant decrease especially in the fourth and eighth items of the “participation” dimension of the SRSS scale in favor of the final test. The fourth item is “I only keep the sources to help me study (books, notebooks, etc.) on my desk” and the eighth item is “I study in a silent environment in order to concentrate”. Throughout the PBL instrumental analysis laboratory activities, all group members actively participated in all phases of the activity in order to solve the real life problem they were given. Thus, especially in the first phase of PBL activity, which is “understand the problem”, they felt the need for various information sources rather than only books and/or lecture notes. The dimensions in which the prospective teachers who attended PBL activities improved themselves the most were especially “Participation”, “Motivation”, “Self-Structuring”, “Summarizing” and “Planning”. The common items on which most of the prospective teachers agreed were as follows, with respect to various dimensions: the dimension of “participation”: “I try to get rid of the things that distract my attention while studying”; the dimension of “motivation”: “I remind myself that I will need the information about the related subject in my future life”; the dimension of “summarizing”: “I make a list of the terms that I don’t understand”; the dimension of “self-structuring”: “I tell myself the methodology I followed while solving the questions”, and the dimension of “planning”: “I determine the method I will use before I start studying”. It is thought that especially the “KND” chart they developed in the first phase played an important role in establishing the phases of PBL activity to enable the prospective teachers to show a high level of participation in SRSS items after the implementations.

Self-regulation concept is the process for which individuals sequence problem-solving and come to a solution by reviewing information, evaluating information, and modifying solutions (Mithaug, 1993). According to Mithaug (1993), self-regulation occurs when there is a divergence between what an individual has and what the individual wants or needs. Self-regulation consists of three phases: a) obtaining information about a problem, b) choosing options for solving a problem, c) and responding to a problem. When an individual works to solve a problem and achieve a solution, they engage in the following series of behaviors: a) determining the state from the desired, b) identifying a solution, c) implementing a solution, d) evaluating if the solution reduced or eliminated any discrepancy between states, and e) repeating steps two to four if a solution did not reduce or eliminate an existing discrepancy.

The analysis on whether the decrease in the perception levels of prospective teachers of both groups was significant within and between the groups was performed through one-way MANOVA. It was demonstrated that both application types affected the perception levels of problem solving ability and self-regulatory learning strategies of prospective teachers after the applications ($p < \alpha$). Also, when eta square values (Table 4) were examined, it was seen that 32% of the change in the perception level of problem solving ability, 18% of the change in the levels of self-regulatory learning strategies in prospective teachers resulted from the applied application type. According to Table 5, it was observed that PBL, which is applied as an alternative to a traditional laboratory application in the instrumental analyze laboratory, may contribute to the development of the perception levels of problem solving ability and self-regulatory learning strategies. According to the results, prospective teachers who participated in PBL were able to improve perception levels of problem solving ability and self-regulatory learning strategies better than those who followed a traditional application in the laboratory. These results support the findings of S. G. Paris and A. H. Paris (2001) who claim positive effects of PBL on self-regulated learning. As mentioned, “self-regulated learning is also more likely when teachers create classroom environments in which students have opportunities to seek challenges, to reflect on their progress, and to take responsibility and pride in their accomplishment” (p. 99). Sungur and Tekkaya (2006) found positive effects of PBL on “goal orientation”, “use of elaboration learning strategies”, and “metacognitive

self-regulation”, which are similar to our findings that PBL students were different in using “organising and transforming” and “goal-setting and planning” strategies. The research by Yoon et al. (2014) showed that students in the treatment group used self-regulated learning strategies more frequently than students in the comparison group. According to the results of the self-evaluation, students became more positive and confident in problem-solving and group work as the semester progressed. Overall, PBL was shown to be an effective pedagogical instructional strategy for enhancing chemistry students’ creative thinking ability, self-regulated learning skills and self-evaluation. According to Perry, Vandekamp, Mercer and Nordby (2002), students engage in self-regulated learning in classrooms where they (a) receive opportunities to participate in complex, open-ended activities, (b) make choices that influence their learning, and (c) evaluate themselves and others. Perry and colleagues proposed that one of the characteristics of PBL classes contributing to self-regulated learning is cooperation among students working in small groups. King (2002) claimed that some peer-learning tasks, such as (a) working together to solve ill-structured problems, (b) working on problems with several possible solutions, (c) analyzing and integrating ideas that reach beyond presented material to build new knowledge, (d) making decisions within groups, and (e) assessing learning demand a highly complex level of cognitive processing.

The results of the study by Loyens, Magda and Rikers (2008) suggested that conceptual clarity of what self-directed learning entails and guidance for both teachers and students can help PBL to bring forth self-directed learners. In another research by Demirel and Arslan Turan (2010) asserted that PBL provides students with a positive environment to collaborate and gives them opportunity to study topics in which they have interest. However, due to the small sample size, generalizability of the study was low and researchers pointed out the need for investigating the effectiveness of PBL with larger samples. The study by Temel (2013) was found that the PBL and the traditional teaching method did not have significant effects on prospective teachers’ self-regulated learning skills. It was also found that the prospective teachers’ attitudes towards and their self-efficacy perceptions of PBL were at the middle level, and that the two variables accounted for 49% of the total variance in self-regulated learning skills. This study’s findings by Thomas (2013) suggest that learners can demonstrate increases to cognitive and metacognitive functioning, as well as self-efficacy through engagement with a program to support self-regulated learning in PBL. To summarize, PBL improves the effective problem solving skills of students, the transfer of knowledge to new problem situations, self-directed, and self-regulatory learning skills, efficient cooperation skills, and self-motivation (Hmelo-Silver, 2004).

This study obtained findings demonstrating that PBL can be utilized in teaching science. However, the findings are limited to the numbers of students in the experimental and control groups. This study should be conducted on larger groups and the efficiency of PBL approach should be questioned. In conclusion, it is thought that when the teaching program of the chemistry course is put into practice through PBL activities, it will have positive impacts on the quality of cognitive and affective learning products and it is recommended that similar studies are conducted at different educational levels and in different courses.

References

- Allen, D. E., Duch, B. J., & Groh, S. E. (1996). The power of problem-based learning in teaching introductory science courses. In L. Wilkerson, & W. H. Gijssels (Eds.), *Bringing Problem-Based Learning to Higher Education: Theory and Practice*. San Francisco, CA: Jossey-Bass. <https://dx.doi.org/10.1002/tl.37219966808>
- Barrett, T. (2012). Learning about the problem in problem-based Learning (PBL) by listening to students’ talk in tutorials: A critical discourse analysis study. *Journal of Further and Higher Education*, 37(4), 519-535. <https://dx.doi.org/10.1080/0309877X.2011.645464>
- Beachey, W. D. (2007). A comparison of problem-based and traditional curricula in baccalaureate respiratory therapy education. *Respiratory Care*, 52(11), 1497-1506.
- Blumberg, P. (2000). Evaluating the evidence that problem-based learners are self-directed learners: A review of the literature. In D. Evensen, & C. E. Hmelo (Eds.), *Problem-based learning: A research perspective on learning interactions* (pp. 199-226). Mahwah: Erlbaum.
- Bories, P. N., & Bories, C. (1995). Nitrate determination in biological fluids by an enzymatic one-step assay with nitrate reductase. *Clinical Chemistry*, 41, 904-907.
- Borkowski, J. G. (1992). Metacognitive theory: A framework for teaching literacy, writing, and math skills. *Journal of Learning Disabilities*, 25, 253-257. <https://dx.doi.org/10.1177/002221949202500406>

- Borkowski, J. G., Chan, L. K. S., & Muthukrishna, N. (2000). A process-oriented model of metacognition: Links between motivation and executive functioning. In J. C. Impara, & L. L. Murphy (Eds.), *Buros-Nebraska series on measurement and testing: Issues in the measurement of metacognition* (pp. 1-41). Lincoln, NE: Buros Institute of Mental Measurement.
- Borneff, J. (1971). *Hygiene, leitfaden für studenten und ärzte*. Georg Thieme Verlag, Stuttgart.
- Brâthen, G. (1975). Nitrat und nitrit in kâse: Toxicologie, wirkung und analyse. *Meieriposten*, 64(8), 243-248.
- Carlisle, C., & Ibbotson, T. (2005). Introducing problem-based learning into research methods teaching: Student and facilitator evaluation. *Nurse Education Today*, 25(7), 527-541. <https://doi.org/10.1016/j.nedt.2005.05.005>
- Cemek, M., Akkaya, L., Birdane, Y. O., Seyrek, K., Bulut, S., & Konuk, M. (2007). Nitrate and nitrite levels in fruity and natural mineral waters marketed in western Turkey. *Journal of Food Composition and Analysis*, 20, 236-240. <https://doi.org/10.1016/j.jfca.2006.12.003>
- Demirel, M., & Arslan, T. B. (2010). The effects of problem based learning on achievement, attitude, metacognitive awareness and motivation. *Hacettepe University Journal of Education*, 38, 55-66.
- Dignath, C., Buettner, G., & Langfeldt, H. P. (2008). How can primary school students learn self-regulated learning strategies most effectively? A meta-analysis on self-regulation training programmes. *Educational Research Review*, 3(2), 101-129. <https://dx.doi.org/10.1016/j.edurev.2008.02.003>
- Diraman, H. (1993). A study on the various types of cheese produced nitrate sought in Thrace region. *Food*, 18(5), 293-295.
- Erbaş, S., Şimşek, N., & Çınar, Y. (2005). *Science laboratary and applications*. Ankara: Nobel Publishing.
- Erdem, E. (2006). *Mersin-Tarsus arasında Aliivyon akiferde yeraltı suyu kirliliğinin fotometrik ölçümler ile araştırılması* (Unpublished Master's thesis). Mersin University, Mersin.
- Ertmer, P. A., Newby, T. J., & MacDougall, M. (1996). Students' approaches to learning from case-based instruction: The role of reflective self-regulation. *American Educational Research Journal*, 33(3), 719-752. <https://dx.doi.org/10.3102/00028312033003719>
- Evensen, D. H. (2000). Observing self directed learners in a problem-based learning context: Two case studies. In D. H. Evensen, & C. E. Hmelo (Eds.), *Problem-based learning: A research perspective on learning interactions* (pp. 263-298). Mahwah: Lawrence Erlbaum Associates, Inc.
- Felder, R. M., & Brent, R. (1996). Navigating the bumpy road to student-centered instruction. *College Teaching*, 44(2), 43-47. <https://dx.doi.org/10.1080/87567555.1996.9933425>
- Fraenkel, R. J., & Wallen, E. N. (2006). *How to design and evaluate research in education*. New York: McGraw Hill.
- Gagne, R. M. (1980). Is educational technology in phase? *Educational Technology*, 20, 7-14.
- Gallet, C. (1998). Problem-solving teaching in the chemistry laboratory: Leaving the cooks. *Journal of Chemical Education*, 75(1), 72-77. <https://dx.doi.org/10.1021/ed075p72>
- Gordon, P., Rogers, A., & Comfort, M. (2001). A taste of problem-based learning increases achievement of urban minority middle-school students. *Educational Horizons*, 79(4), 171-175.
- Grigg, S. J. (2012). *A process analysis of engineering problem solving and assessment of problem solving skills* (Unpublished PhD thesis). Clemson University.
- Güngör, S. H., & Eyceyurt, T. G. (2013). An investigation of the relationship between performance in the problem-solving laboratory applications and views about nature of science of pre-service science teachers. 4th International Conference on New Horizons in Education. *Procedia-Social and Behavioral Sciences*, 106, 401-410.
- Güngör, S. H. (2014). The investigation of the perception of problem solving skills by prospective science teachers in the science laboratory. *Eurasian Journal of Physics and Chemistry Education (EJPCE)*, 6(2), 142-161.
- Güngör, S. H. (2015). 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. *Asia Pacific Forum on Science Learning and Teaching*, 16(2).

- Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis* (6th ed.). Upper Saddle River, NJ: Pearson.
- Heppner, P. P., & Krauskopf, C. J. (1987). An information processing approach to personal problem solving. *The Counseling Psychologist*, 15(3), 371-447. <https://dx.doi.org/10.1177/0011000087153001>
- Heppner, P. P., & Petersen, C. H. (1982). The development and implications of a personal problem solving inventory. *Journal of Counseling Psychology*, 29, 66-75. <https://dx.doi.org/10.1037/0022-0167.29.1.66>
- Heppner, P. P., Witty, T. E., & Dixon, W. A. (2004). Problem-Solving appraisal: Helping normal people lead better lives. *The Counseling Psychologist*, 32(3), 466-472. <https://doi.org/10.1177/0011000003262794>
- Hmelo-Silver, C. E. (2004). Problem-Based learning: What and how do students learn? *Educational Psychology Review*, 16, 235-266. <https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, 42(2), 99-107. <https://doi.org/10.1080/00461520701263368>
- IMSA. (1996). *PBL network, collaborative inquiry in action*. Retrieved August 1, 2009, from <http://pbln.imsa.edu/>
- İnce Aka, E., Güven, E., & Aydoğdu, M. (2010). Effect of problem solving method on science process skills and academic achievement. *Journal of Turkish Science Education*, 7(4), 13-25.
- Kadioğlu, C., Uzuntiryaki, E., & Çapa Aydın, Y. (2011). Development of Self-Regulatory Strategies Scale (SRSS). *Education and Science*, 36(160), 11-23.
- Kalaycı, Ş. (2008). *SPSS Applied Multivariate Statistical Techniques*. Ankara: Asil Publishing.
- Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41(2), 75-86. https://doi.org/10.1207/s15326985ep4102_1
- Lambros, A. (2004). *Problem-based learning in middle and high school classrooms: A teacher's guide to implementation*. Corwin Press: Thousand Oaks, CA.
- Lee, T. H., Shen, P. D., & Tsai, C. W. (2010). Enhance low-achieving students' learning involvement in Taiwan's higher education: An approach via E-Learning with Problem-Based learning and Self-Regulated learning. *Teaching in Higher Education*, 15(5), 553-565. <https://dx.doi.org/10.1080/13562517.2010.506999>
- Lee, Y. C. (2007). Teaching the nature of science through practical problem solving in daily-life contexts. *School Science Review*, 88(324), 97-105.
- Lin, H. S., & Chiu, H. L. (2004). Student understanding of the nature of science and their problem-solving strategies. *International Journal of Science Education*, 26(1), 101-112. <https://dx.doi.org/10.1080/0950069032000070289>
- Loyens, S., Magda, J., & Rikers, R. (2008). Self-directed learning in problem-based learning and its relationships with self-regulated learning. *Educational Psychology Review*, 20(4), 411-427. <https://dx.doi.org/10.1007/s10648-008-9082-7>
- Mikuska, P., & Vecera, Z. (2003). Simultaneous determination of nitrite and nitrate in water by chemiluminescent flow-injection analysis. *Analytica Chimica Acta*, 495, 225-232. <https://dx.doi.org/10.1016/j.aca.2003.08.013>
- Mithaug, D. E. (1993). *Self-Regulation theory. How optimal adjustment maximizes gain*. Westport, CT: Praeger.
- Neeland, E. G. (1999). An introductory organic lab for the problem-solving laboratory approach. *Journal of Chemical Education*, 76(2), 230-231. <https://dx.doi.org/10.1021/ed076p230>
- Paris, S. G., & Paris, A. H. (2001). Classroom applications of research on self-regulated learning. *Educational Psychologist*, 36, 89-91. https://doi.org/10.1207/S15326985EP3602_4
- Perry, N. E., Vandekamp, K. O., Mercer, L. K., & Nordby, C. J. (2002). Investigating teacher-student interactions that foster self-regulated learning. *Educational Psychologist*, 37, 5-15. https://dx.doi.org/10.1207/S15326985EP3701_2

- Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 451-502). San Diego, CA: Academic Press. <https://dx.doi.org/10.1016/B978-012109890-2/50043-3>
- Pirinçci, İ., & Acet, A. (1984). Studies on nitrate and nitrite levels in feed. *Ankara University Journal of Veterinary Faculty*, 31(1), 41-52.
- Renner, J. W. (1986). Rediscovering the Lab. *The Science Teacher (January)*, 44-45.
- Rhem, J. (1998). Problem-based learning: An introduction. *The National Teaching & Learning Forum*, 8(1), 1-7.
- Rideout, E., England-Oxford, V., Brown, B., Fothergill-Bourbonnairs, F., Ingram, C., Benson, G., ... Coates, A. (2002). A comparison of problem-based and conventional curricula in nursing education. *Advances in Health Sciences Education*, 7(1), 3-17. <https://dx.doi.org/10.1023/A:1014534712178>
- Sanders, J., & Clearly, T. (2011). Self-regulation theory: Applications to medical education: AMEE Guide No. 58. *Medical Teacher*, 33(11), 875-886. <https://dx.doi.org/10.3109/0142159X.2011.595434>
- Saracaloğlu, A. S., Yenice, N., & Karasakaloğlu, N. (2009). The relationship between communication and problem solving skills and reading interest and habits of candidate teachers. *YüzüncüYıl University Journal of Education Faculty*, 6(2), 186-206.
- Savaşır, İ., & Şahin, N. H. (1997). *Assessment in the cognitive-behavioral therapy: Frequently used scales*. Ankara: Turkish Psychologists Association.
- Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *The Interdisciplinary Journal of Problem-based Learning*, 1(1), 9-20. <https://dx.doi.org/10.7771/1541-5015.1002>
- Schmidt, H. G., Loyens, S. M. M., Van Gog, T., & Paas, F. (2007). Problem-Based Learning is Compatible with Human Cognitive Architecture: Commentary on Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, 42(2), 91-97. <https://dx.doi.org/10.1080/00461520701263350>
- Selenka, F. (1980). Sanitary evaluation of nitrate in drinking water. *Zentrald. Bacteria Microbiol. Hyg., Abst.I, Orig. B*, 172(1-3), 44-58.
- Sungur, S., & Tekkaya, C. (2006). Effects of problem-based learning and traditional instruction on selfregulated learning. *The Journal of Educational Research*, 99, 307-317. <https://dx.doi.org/10.3200/JOER.99.5.307-320>
- Taasooobshirazi, G., & Glynn, S. M. (2009). College students solving chemistry problems: A theoretical model of expertise. *Journal of Research in Science Teaching*, 46(10), 1070-1089. <https://doi.org/10.1002/tea.20301>
- Tan, O. S. (2004). Cognition, metacognition, and problem-based learning. In O. S. Tan (Ed.), *Enhancing thinking through problem-based learning approaches: International perspectives* (pp. 1-16). Singapore: Thomson Learning.
- Tan, O. S. (2003). *Problem-based learning innovation: Using problems to power learning in the 21st century*. Singapore: Thomson Learning.
- Taşkın. (2008). *New approaches in science and technology teaching*. Ankara: Pegem Academy.
- Taylan, S. (1990). *Adaptation, reliability and validity studies of Heppner's problem solving inventory* (Unpublished Master's thesis). Ankara University, Institute of Social Sciences, Ankara.
- Temel, S., & Morgil, İ. (2012). Problem solving applications in chemistry laboratory. *Ankara University Journal of Faculty of Educational Sciences*, 45(2), 55-76.
- Temel, S., & Morgil, İ. (2013). Problem-solving applications in chemistry laboratory. *Pamukkale University Journal of Education Faculty*, 33(1), 39-52. <https://dx.doi.org/10.9779/puje421>
- Temel, S. (2009). *Problem solving applications in chemistry laboratory* [Unpublished PhD thesis]. Hacettepe University, Institute of Science, Ankara.
- Temel, S. (2013). The effects of problem-based learning on self-regulated learning skills and the variables predictive of these skills. *Mediterranean Journal of Social Sciences, MCSER Publishing*, 4(14), 297-302. <https://dx.doi.org/10.5901/mjss.2013.v4n14p297>
- Temel, S. (2014). The effects of Problem-Based learning on prospective teachers' critical thinking dispositions and perceptions of Problem-Solving ability. *South African Journal of Education*, 34(1), 769-789. <https://dx.doi.org/10.15700/201412120936>

- Thomas, L. K. (2013). *Investigating self-regulated learning strategies to support the transition to problem-based learning*. Doctor of philosophy thesis, Faculty of Education, University of Wollongong.
- Torp, L., & Sage, S. (1998). *Problems as possibilities: Problem-based learning for K-16 education*. Alexandria, WA: Association for Supervision and Curriculum Development.
- Wheatley, G. H. (1984). *Problem solving in school mathematics*. MEPS Technical Report 84.01, West Lafayette, IN: Purdue University School Mathematics and Science Center.
- Wilson, H. J. (1987). Problem-solving laboratory exercises. *Journal of Chemical Education*, 64(10), 895. <https://dx.doi.org/10.1021/ed064p895>
- Yin, C. L. (2010). *Analyses of attribute patterns of creative problem solving ability among upper elementary students in Taiwan* (Unpublished PhD thesis). St. John's University, New York.
- Yoon, H., Woo, A. J., Treagust, D., & Chandrasegaran, A. L. (2014). The efficacy of problem-based learning in an analytical laboratory course for pre-service chemistry teachers. *International Journal of Science Education*, 36(1), 79-102. <https://dx.doi.org/10.1080/09500693.2012.727041>
- Yuzhi, W. (2003). Using problem-based learning in teaching Analytical Chemistry. *The China Papers*, 28-33.
- Zimmerman, B. J., & Lebeau, R. B. (2000). A commentary of self-directed learning. In D. H. Evensen, & C. E. Hmelo (Eds.), *Problem-based learning: A research perspective on learning interactions* (pp. 299-313). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

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