Asian Journal of Chemistry Vol. 21, No. 5 (2009), 3671-3682

Enhancing Prospective Teachers' Development Through Problem-Based Learning in Chemistry Education

MUSTAFA ÖZDEN
Department of Science Education, Adiyaman University, Adiyaman, Turkey
Tel: (90)(416)2232210-1109; E-mail: mozden@adiyaman.edu.tr

The purpose of this study was to compare the attitudes towards chemistry and academic achievement of prospective elementary school teachers in a problem-based curriculum with those in a conventional elementary school teacher training program about 'solutions and properties' unit. The results of this study showed that there was a statistically significant difference between the control and experimental groups in terms of students' academic achievement and attitudes towards chemistry. In addition, it was seen that problem based learning model applied in experimental group had more positive effects about conceptual development than control group and students' evaluation of problem based learning showed that students were happy with the problem based learning and enjoyed the problem based learning model.

Key Words: Problem-based learning, Conventional teaching, Solutions, Attitudes, Chemistry.

INTRODUCTION

Problem based learning can be concluded "student centered learning, learning in small groups, presence of a tutor as a facilitator or guide, primarily encountering authentic problems in the learning sequence before any preparation or study has occurred, encountering the problems used as a tool to achieve the required knowledge and the problem-solving skills necessary to eventually solve the problem and information needs to be acquired through self-directed learning[1]. This present study has an important story addressing how the use of problem based learning as a student-centered teaching/learning strategy in content classes facilitates teacher candidates' conceptual understanding and increases their attitudes toward this student-centered teaching/learning approach.

The learning scenario is very important in problem based learning approach because it constitutes the basic education tool in problem based learning. So, introducing the students with interesting and challenging problems has a key role in effective teaching using problem based learning approach[2]. The characteristics of learning scenario in problem based learning were described by many researchers[3,4].

Science educators have started to use problem based learning approach in science education because of its appropriate structure to science education in a progressive rate[5-8]. Many researchers[9] showed the positive effects of problem based learning on academic achievement. Stattenfield and Evans[10] compared the students' academic achievement in conventional and problem based learning group and stated that the students in problem based learning group had higher academic achievement than the students in conventional group. Also, the results of the study carried out by McBroom and McBroom[11] showed that problem based learning increased students' level of knowledge, attitude and self-confidence. There are few studies about the application of problem based learning in chemistry education. For example, Yuzhi[6] found that students developed positive attitudes towards chemistry when they were taught through problem based learning. Similar studies in chemistry education conducted by Gürses *et al.*[4] and Senocak *et al.*[12]. The results of Gürses *et al.*[4] study showed that problem based learning approach promoted critical thinking and problem-solving skills; active participation in the learning process including self-direction, identification of own learning needs, teamwork, creative discussion and learning from peers; the integration and synthesis of a variety of knowledge. In the other study[12], it was found that there was a statistically significant difference between the experimental and control groups in terms of attitudes towards chemistry, academic achievement and development of students' skills such as self-directed learning, cooperative learning and critical thinking. In addition to these studies, Belt *et al.*[13] emphasized the development of problem solving case studies as an approach to problem based learning in analytical and applied chemistry. The main research questions were as follows: (1) Is there a statistically significant difference between students' academic achievement after learning about concepts of "Solutions" through problem based learning compared to a conventional teaching approach? (2) Is there a statistically significant difference between students' attitudes towards chemistry through problem based learning compared to a conventional teaching model? (3) Is there a statistically significant difference between students' conceptual development of "Solution Chemistry" through problem based learning compared to a conventional teaching approach?

EXPERIMENTAL

Sixty-three students were participated in this research. Thirty two of them were randomly selected to the control group and 31 were to the experimental group (all of them were all first year undergraduate students enrolled to general chemistry course (2 h per week and 14 weeks in a semester) in the Department of Elementary School Teacher Training Program in the spring semester of the 2005-2006 academic year in the Faculty of Education in Adiyaman University, Turkey. Non-equivalent groups pre-test and post-test control and comparison groups design was used as the research design[14]. The difference between pre-test to post-test for experimental-control group was investigated.

Data collection instruments: Three different assessment tools were used to evaluate the study. These are academic achievement test, "Solutions and Properties" conceptual open-ended questions, attitude scale towards chemistry and scales about students' views of problem based learning.

Pre/Post solutions and properties achievement test (SPAT): This test consisted of 25 multiple choice questions and a sample of question can be seen in **Appendix 1**, to measure academic achievement regarding learning difficulties and misconceptions reviewed in the literature. The questions were related to the solutions and properties including definitions of solution, solubility and components of solutions, types of solutions, classification of solutions, factors affecting solubility and solubility rate, concentration and units of concentration and properties of solutions. The test was administered before and after treatment. The academic achievement test was prepared in conformity with the aims and acquisitions in the subject matters of "Solutions and Properties" unit taken part in general chemistry course for second grade university students. The pilot study of SPAT (40 questions total) was performed with a group of students who attended the General Chemistry I course in Elementary Mathematics Teaching Training Program. The reliability of internal consistency (Cronbach Alpha) of multiple choice test was found to be 0.72. The questions having low reliability and validity levels were omitted from the test and total question number was reduced to 25. The reliability of internal consistency (Cronbach Alpha) of multiple choice test was found to be 0.83 for 25 questions. This level of internal consistency data shows that the achievement test (SPAT) could be regarded adequately reliable[14]. The validity of SPAT was examined by a group of experts, chemistry teachers in the field of chemistry and chemical sciences.

Pre/Post solutions and properties conceptual open-ended questions (SPCOQ): In first instance, 15 open-ended questions were prepared considering the concepts and misconceptions with respect to general chemistry course content by the researcher. Then, numbers of the open-ended questions were reduced to eight in order to determine conceptual learning and misconceptions if there were. The eight subject matters for the eight open-ended questions are shown in Table-1.

TABLE-1
SUBJECT MATTERS RELATED TO OPEN-ENDED QUESTIONS

Question number	The subject matters related to questions
1	Definitions of solution
2	Solubility and components of solutions
3	Types of solutions
4	Classification of solutions
5	Factors affecting solubility
6	Factors affecting solubility rate
7	Concentration and units of concentration
8	Properties of solutions

Students were given 50 min (1 h class) to answer open-ended questions. These questions were encoded by means of open-encoding method in qualitative dimension. The answers of all individuals were evaluated by the researcher in open-encoding. The codes collected were categorized with the codes matched to them. The results of pre and post application were analyzed and discussed[15]. A sample from eight open-ended questions used in SPCOQ can be seen in **Appendix 2**.

Pre/Post attitude scale towards general chemistry course (ASGCC): Attitude scale with 20 items developed by Kara and Özden[16] was used in this research.

It was aimed that whether problem based active learning model affects students' attitudes towards general chemistry course or not. The scale contains 5-step Likert type items ranging from 1 (strongly disagree) to 5 (strongly agree) and reliability of the scale was found 0.79 by Kara and Özden[16]. The scale has 10 positive and 10 negative items and the time given for students was 20 min. ASGCC was applied pre-post intervention and a person could get score maximum 60 and minimum 20 from ASGCC.

Scales about students' views of problem based learning (PBL): The students' views of PBL were determined by four different scales as follows: (i) Peer evaluation scale (PES): The students evaluated their friends in his/her group in this scale. (ii) Self evaluation scale (SES): The students evaluated their performance during the PBL process by this scale. (iii) Instructor's performance evaluation scale (IPES): The students evaluated their instructor's performance during the PBL process with this scale. (iv) Students' evaluation of PBL scale (SEPBLS): The students evaluated the efficiency of the PBL model.

The scales above, contained 7 to 15 Likert type items on a 3 point scale (1-disagree, 2-neutral and 3-agree) and also each scale consisted of open-ended section in order to write their views. The experimental PBL group completed all scales at the end of trial.

Problem scenario and cases: The development of effective problem scenario and cases is very important to use principles of PBL. Problem based learning should have clear learning objectives and encourage independent learning. In this study, 6 problem scenario containing different views of the "solution chemistry" were developed by the author for this study. The case studies should present a "real" problem or scenario which students solve by application of prior knowledge, acquisition of new knowledge and by developing a problem solving strategy[12]. The case study should be flexible, allowing it to be tailored to a particular course. There are no unique correct solutions to the case study and the students should use judgement in order to come to an acceptable conclusion. The nature of the activities involved should ensure that in order to complete the case study, students should use a variety of scientific and transferable skills[13]. In this study, problem scenario were designed as a text describing the cases with a degree of difficulty that could be solved in an 8 week period of time. Problem scenario about solution chemistry can be seen in **Appendix 3**.

Treatment and phases of implementation: This study included 16 lecture hours over 8 weeks (2 lecture hours per week). The control and experimental group were taught by the same instructor (author of this article). Conventional instruction methods containing lecturing, discussion, didactic speech and problem solving strategies were used in the control group. The traditionally-designed "solution chemistry" was based upon lessons including lecture-questioning methods to teach concepts and knowledge. Teaching methods consisted of teacher speech, discussions and problem solving related to textbook. Control group students were required to prepare for the related unit from the textbook before the teacher's presentation. The teacher uses projector for slides and the blackboard to draw topics, concept mapping of the unit *etc*. The lesson based on teacher's explanations, discussions, asking questions, answering and the problem solving. The way of communication was generally from teacher to student in traditional instruction. In the experimental group, PBL and its strategies were explained to the students and they were trained to use PBL. Then, 5 heterogeneous groups of 6 students were formed. They had different academic skills and attitudes towards general chemistry and were of mixed gender composition. The PBL process had some successive phases.

Content coverage of each of the classes maps on to both the achievement post test (SPAT) and conceptual open-ended questions (SPCOQ) used in this study, because a week by week content covered in each course was almost the same.The items covered on the test did not disadvantage the conventional group, because the test covered the conventional lecture topics properly. In the same way, the treatment group had no advantage compared to conventional groups, because each problem scenario covered concepts and knowledge almost as the same as conventional lecture topics. Control and experimental group was instructed by the same author and tried to hold salient variables as constant as possible.

Data analysis: The data were analyzed using SPSS 11 Package program. Descriptive statistics containing mean and SD with 95 % Cl, independent samples t-test were used to analyze the effects of PBL on students' academic achievement, attitudes and concept learning. Power analysis was made with $\alpha = 0.05$ and $\beta = 0.12$ and it was found that 31 people were enough for sample size. So, sample size was justified by using power analysis.

Findings: The student teachers participated in the research were 63 students in total. 49.2 % was experimental and 50.8 % of student teachers was control group.

Findings with respect to the effect of problem based learning on academic achievement: Descriptive statistics are given in Table-2 in order to examine the effect of PBL on academic achievement for experimental and control group by using pre-post and t-test scores. Post test achievement results are based on both the multiple choice test (SPAT) and the open-ended questions (SPCOQ). Each of multiple choices item was 2.4 points and each of open-ended questions was 5 points.

As can be seen from Table-2, the arithmetic mean of pre-test scores for experimental and control group students was found 42.298 and 41.625, respectively. It can be seen that there is only 0.673 point difference between group means and p value is more than 0.05. This shows that there is no significant scores between the pre-test scores of the experimental and control group students. For this reason, it can be concluded that both groups have almost equal pre-knowledge level about the subject.

TABLE-2
RESULTS OF THE INDEPENDENT SAMPLES t-TEST PERFORMED WITH RESPECT TO THE DIFFERENCE BETWEEN PRE-POST TEST SCORES IN THE EXPERIMENTAL AND CONTROL GROUP

Academic achievement test	Groups	n	$\overline{X}$	Standard deviation	Standard error	Independent samples t-test		
						sd	t	p
Pre-test	Experiment	31	42.298	15.957	0.566	60	0.943	p > 0.05
	Control	32	41.625	16.267	0.201			
Post-test	Experiment	31	54.678	15.202	0.871	60	-2.137	p < 0.05
	Control	32	46.815	15.908	0.439			

After treatment for each group, the post-test scores for control and experimental group were 46.815 and 54.678, respectively. There is 7.863 point difference between group means and p value is less than 0.05. This means that there is a significant difference between the post-test scores of the experimental and control group at the 0.05 confidence interval. This result can be interpreted that PBL model plays a positive role in order to increase the academic achievement.

Findings with respect to the effect of PBL on attitudes towards chemistry: Descriptive statistics are given in Table-3 in order to examine the effect of PBL on attitudes towards chemistry for experimental and control group by using pre-post attitude and t-test scores.

TABLE-3
RESULTS OF THE INDEPENDENT SAMPLES t-TEST PERFORMED WITH RESPECT TO THE DIFFERENCE BETWEEN PRE-POST ATTITUDE SCORES IN THE EXPERIMENTAL AND CONTROL GROUP

Academic achievement test	Groups	n	$\overline{X}$	Standard deviation	Standard error	Independent samples t-test		
						sd	t	p
Pre-attitude	Exp. group	31	45.678	17.787	2.5890	60	-2.313	p > 0.05
	Control group	32	45.815	16.564	2.6308			
Post-attitude	Exp. group	31	49.675	15.202	0.8710	60	-1.789	p < 0.05
	Control group	32	46.897	15.908	0.4390			

From Table-3, it is seen that the arithmetic mean of pre-attitude scale scores for experimental and control group students were 45.678 and 45.815, respectively. There is only 0.137 point difference between group means and p value is more than 0.05. This indicates that there is no significant scores between the pre-attitude scale scores of the experimental and control group students. So it can be concluded that both groups have almost equal pre-attitudes towards chemistry. After treatment for each group the arithmetic mean of post-attitude scores for experimental and control group were 49.675 and 46.897, respectively. There is 2.778 point difference between group means and p value is less than 0.05. This means that there is a significant difference between the post-attitude scale scores of the experimental and control group at the 0.05 confidence interval. This result can be concluded that PBL model causes a positive change in the attitudes of experimental group students towards chemistry.

Qualitative findings with respect to the effect of PBL on concept learning: Open-ended questions were used to measure conceptual development of experimental and control group students about "Solutions". The level of conceptual development for each group was quite poor and almost equal when the pre-SPCOQ was applied to both groups. After PBL model was applied to experimental group and conventional instruction (teacher centered instruction) was given to the control group students, it was seen that PBL model applied in experimental group had more positive effects about conceptual development than control group. Besides this, all groups have some common misconceptions about solutions before treatment. After applying each method to experimental and control group, it was observed that experimental group students had positive improvements more than control group students. Some of the open-ended questions (4, 6, 7, 8) asking about conceptual definitions to measure level of the concept learning were analyzed and the achievement of PBL group with respect to concept learning and eliminating alternative conceptions were observed. Student teachers do not receive knowledge from instructor in a passive form in PBL group. The problem case scenarios make student teachers constructing knowledge by themselves. So, the control group students' answers were in textual form related to concept definition, the PBL group defined the concepts with their own words. The experimental group was more successful in eliminating misconceptions than control group. Student teachers were communicated with each other, sharing and discussing their ideas in PBL group. For this reason, the transfer and sharing information among student teachers were performed. Since the problem scenarios were taken from daily life directly, it was attracted students' concern and attention in a long period of time. Problem scenarios were shown by pictures and caricatures etc aiming positive effect on student teachers' concept development by changing previously learned concepts in the well-done scenarios. In short, it can be stated that PBL model used in this research has positive effect on student teachers' conceptual development.

Students' evaluation of PBL: Four different scales were developed to determine PBL group students' evaluation of PBL. Table-4 indicates that the total mean scores of scales specific to students' self evaluation of PBL. All scores are close to the maximum point and this can be interpreted that the students were happy with the PBL and enjoyed the PBL model.

The open-ended section of the scales was used to collect the students' evaluation of PBL approach. These data supported qualitative findings of scales specific to students' self evaluation of PBL.

Question: What do you think about the disadvantages of PBL experience compared to conventional lecture experience in general? What do you value the best/ least about a PBL experience?

TABLE-4
TOTAL MEAN SCORES OF SCALES SPECIFIC TO STUDENTS' SELF EVALUATION OF PBL (n = 31)

Scales	Mean
PES (min 7 - max 21)	16.39
SES (min 7 - max 21)	18.82
IPES (min 10 - max 30)	27.12
SEPBLS (min 10 - max 30)	25.46

Response$_1$: PBL approach emphasizes the quality of content. It does not emphasize the quantity of content. For this reason, PBL approach may need much more time interval compared to conventional teaching and if there is no enough time in the curriculum, some subjects can be omitted from textbooks (23 %).

PBL approach has many steps and it takes long time compared to traditional lecturing. Although, PBL approach was very effective learning method, it can cover some of the units in the curriculum because of time problem.

Response$_2$: PBL approach is difficult and time consuming to correct students' reasoning (17 %).

This approach was not easy as conventional teaching as and it is plausible for hardworking students. For example, I am a lasy student preferring traditional lecture, because, I am able to learn something that was given out by the tutor in a faster way.

Response$_3$: PBL forces large number of students need access to the same library, computer resources and internet facilities simultaneously (14 %).

This approach was very interesting and enjoyable. It chanalizes us to make research in the library, internet etc. but the books, magazines and journals avaliable in the library was insufficient and I don't know how to scan related literature in the internet exactly.I've tried to learn from other people and tutor.

Response$_4$: PBL model causes uncertainity about what constitutes a good learning need or appropriate literature selection and uncertainty about the depth of knowledge acquired (12 %).

Some problem scenarios about "solutions and properties" were presented and we worked on these real life problem scenarios. I think, some of these problem scenarios can not reflect the depth of knowledge acquired because these scenarios sometimes present only a narrow view of subject. There is no rule about appropriate literature selection and learning needs are not defined properly in PBL approach.

Based on these statements, the PBL approach seemed to increase the motivation of the students.

Conclusion and educational implications

The effects of PBL model in the unit of "Solutions and Properties" in university level on student teachers' attitudes towards chemistry, academic achievement and concept learning were examined in this study. The following results were collected.

The experimental group and the control group were almost equal level of achievement. After treatment, it was observed that there was a rise in success with both groups but the experimental group was more successful than control group. This result may be verified that PBL model can be more successful than conventional teaching methods if it applied properly supported by Jones-Wilson[7]. The findings showed that PBL approach can be more effective than traditional teaching approach in terms of academic chemistry achievement with regard to Research Question 1. The reason of this achievement can be stated that the students in the experimental group has been integrated the concepts in the unit of "Solutions" with daily life examples and solved the problems with respect to the PBL approach and so they have been assimilated the subject more than control group.

The experimental and control group students' attitudes towards chemistry were in low level and almost equal before treatment, since chemistry lessons can be taught theoretically and disconnected from daily life problems generally. The conventional teacher-centered instruction could be monotonous and based on memorization of concepts. This position may have been affected students' attitudes towards chemistry in a negative way. After treatment, there was a rise about the attitudes towards chemistry for both group of students, but, the experimental group had significant change about the attitudes towards chemistry in a positive way more than control group with respect to Research Question 2. Walker and Lofton[17] concluded that PBL approach caused to have positive attitudes towards learning a subject supporting this study.

PES ($\overline{X}$ = 16.39) and SES ($\overline{X}$ = 18.82) mean scores in the students' evaluation of PBL approach were relatively high. This indicates that students in the PBL group may have found that the PBL strategies encouraged them to take control of their self-directed learning experiment by promoting their involvement in the group. The Turkish culture is especially well suited to PBL approaches, because PBL is based on group working, communication and sharing information with each other like the characteristics of the Turkish culture. Turkish culture encourages collaboration and cooperation in the society. Since the role of teacher was different in the PBL process in this study, students' evaluation of instructor's performance would be significant. The IPES mean scores were relatively high ($\overline{X}$ = 27.12). This result showed that students found the teacher's role as more interactive and responsive to their needs in a high level of performance. Moreover, learners described PBL approach as exciting, enjoyable, flexible and motivating with respect to the result of high SEPBLS mean score ($\overline{X}$ = 25.46). This result also suggests that effectiveness of PBL approach was perceived positively in a high level by the participants. Students' evaluation of PBL scores supported the positive attitudes toward chemistry in PBL group. The students had developed independent, self-directed learning skills, critical thinking and problem solving strategies through PBL process.

It can be stated that conceptual development of both groups was in low level and all groups have some common misconceptions about "Solutions". Regarding the Research Question 3, control group students have less improvement with conceptual development with respect to the experimental group. The reason of this positive development with experimental group can be described as connecting chemical concepts with daily life problems and eliminating the misconceptions by solving daily life problems related to chemistry based on the strategies and steps in PBL approach. These results can be analyzed easily by examining open-ended questions, evaluating the definitions of concepts and some common misconceptions about solutions.

This study can contribute evidence to support PBL approach lead to the development of student teachers' in terms of attitudes towards chemistry, academic achievement and concept learning. For that reason, it is suggested that instructional methods like PBL should be integrated in to the instruction program in universities in a proper way. This approach is very important and effective in training qualified student teachers because if they believe the efficiency of PBL they may apply this approach in their classroom in future. Since the teacher's role is very important in PBL approach, they should be trained extensively by faculty instructors in different time intervals of profession.

The implementation of PBL approach is also very important for everyone in the school. The implementation of PBL in the classroom should be meaningful through having an aim based on curriculum and supported by adequate data-collection tools. Student teachers should be informed about the stages of implementation and the aims and objectives clearly.

PBL approach should provide to learn for all students having different learning styles in chemistry education if it is applied properly, because this approach contains various types of activities. Besides this, all academic staffs of universities should be informed about PBL in detail and original problem scenarios should be developed from daily life problems about chemistry by the experts of subject. The most plausible PBL settings should be formed by considering teachers and students' views about PBL. PBL approach should be integrated with the laboratory activities in chemistry lesson. As a result, it can be concluded that PBL model can be used in chemistry education instead of conventional teacher centered education. The further studies about the application of PBL in chemistry education should be encouraged for this purpose.

Appendix 1. Sample of questions used in SPAT

Question 2) Which of the following is not a solution?

A) air B) vodka C) household ammonia D) brass E) milk

Question 20) What is the boiling point of a water solution that contains 1.5 moles of an electrolyte, potassium iodide, dissolved in 1000 grams of water?

A) 100 ºC B) 100.78 ºC C) 101. 56 ºC D) 105.58 ºC E) 107.66 ºC

Appendix 2. Sample of questions used in SPCOQ

Question 1) How does the solubility rate change when the temperature increases for the substances whose solubility are inversely proportional with the temperature? Explain in brief.

Question 3) Explain why it takes shorter times to cook an egg in Malatya, a city of Turkey in the east (atmospheric pressure = 720 mm Hg) than in Mugla, a city of Turkey in the west (atmospheric pressure = 755 mm Hg)?

Appendix 3. Problem Scenario Cases

(i) The naughty child of the home has mixed the salt and sugar together in the kitchen during the game. When you came back home, you wanted to drink a coffee after a perfect dinner. You prefer your coffee with sugar, but there is no pure sugar for coffee and there is no possibility to obtain pure sugar from outside (*e.g.* neighbourhood, grocer *etc.*). How do you obtain pure sugar from salt-sugar mixture by using the materials in the kitchen?

(ii) You have a different kind of fish gifted by your friends in the aquarium. This kind of fish lives only in soft water. Hard water is dangerous for this type of fish. We have hard water in the house but we can not use it for aquarium. How is hard water made soft water in the house conditions for this fish living in the aquarium?

(iii) You have some coffee beans from the motherland of coffee. You want to drink coffee but you have an allergy to the caffeine. For this reason, you should decaffeinate the coffee beans. How can you remove at least 97 % of the caffeine from the coffee beans?

(iv) You want to boil the water for drinking tea, coffee etc. in the kettle, but the bottom of the kettle was covered with a thick layer of lime. How can you remove this layer of lime from the bottom of the kettle?

(v) Your boy-friend likes to eat haricot bean and chickpea meals in the dinner. You invited him to eat haricot bean and chickpea meals in the dinner. You have a little time and you want to cook this meal in a perfect way. You have only one ordinary saucepan and you know that it takes a long time to cook and the meals will not cook enough. The haricot bean and chickpea should be cooked exactly. What can you make for easy, perfect and rapid cooking in the kitchen?

(vi) Your mother likes to prepare jam and fruit juice in the house by herself. She is very careful during making jam and fruit juice but her jam and fruit juice can be sugared and the sugar crystal precipitates in the jam or fruit juice. Your mother worries about this because she spends a lot of time for this preparation. How can you help to her for this sugar precipitation problem?

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(*Received*: 12 June 2008; *Accepted*: 17 February 2009) AJC-7240