Effectiveness of Problem Based Learning on the Cognitive Development of Students at Secondary Level

Habiba Shaukat[1], Dr. Tehseen Tahir[2], Dr. Umbreen Ishfaq[3], Dr. Asaf Niwaz Satti[4], Dr. Muhammad Saeed[5]

Abstract

The study intended to investigate the effectiveness of problem based learning (PBL) on the cognitive development of class IX students' in the subject of chemistry. The objectives of the study were to; examine the effect of problem based learning on academic achievement of the students in chemistry, examine the effect of problem based learning on academic achievement of the students with different level of achievements, determine the effect of problem based learning on cognitive domain of secondary school chemistry students and to determine the effect of problem based learning on cognitive domain of secondary school chemistry students with different level of achievements. The sample consisted of class IX students of Working Folks Grammar Higher Secondary School No. 1, Haripur. Pre-test, post-test equivalent group design was used for this study. On the basis of pre-test results, students were divided into two groups and named randomly as experimental and controlled group having 45 students in each group. The same test was also given to experimental and controlled groups as a post-test to compare the effects of teaching chemistry through problem solving method and traditional method on students' achievements. Before the application of PBL, 5 groups were made in which there were 9 students in each group. The study recommended that the teacher should be encouraged to employ problem based learning in teaching chemistry and it should be incorporated as an essential part in training for science teacher by introducing different courses in order to implement it.

Keywords: *Problem Based Learning, Cognitive Domain, Chemistry, Academic achievement*

1. Introduction

Constructivist approaches to learning and teaching have become increasingly influential concepts over the past few decades as attention has increasingly

[1] M.Phil Scholar, Department of Education, University of Haripur
[2] Assistant Professor Department of Education, University of Haripur
Email: dr.tehseen78@gmail.com
[3] Assistant Professor Department of Education, University of Haripur
[4] Assistant Professor Department of Education, University of Haripur
[5] Assistant Professor Department of Education, University of Haripur

focused on how we learn, as well as what we learn. Problem Based Learning (PBL), additionally perceived as case-based learning, is an emerging approach which has improved teaching mode. In spite of the fact that there is no all-around acknowledged meaning of Problem Based Learning , the center of PBL can be abridged as the utilization of a "genuine" issue or circumstance as a setting for learning (Michel, Bischoff & Jakobs, 2002).

Problem-based learning (PBL) is an instructional method in which students learn through facilitated problem solving. In PBL, student learning centers on a complex problem. Students work in collaborative groups to identify what they need to learn in order to solve a problem. They engage in self-directed learning (SDL) and then apply their new knowledge to the problem and reflect on what they learned and the effectiveness of the strategies employed. The teacher acts to facilitate the learning process rather than to provide knowledge (Hmelo-Silver, 2004).

Students can actively learn in problem based learning by working on problems. Active learning strategies build learning accomplishment for pupils to assume a new dynamic part in the education procedure. Herreid (2003), indicated that problem based learning is broadly utilized almost as a part of all territories. In every dynamic education process, the pupils perceive as indicated by their particular requirements (Akınoğlu & Tandoğan, 2007).

Learning is a psychological strategy as indicated by constructivism and it happens by production of information in the cerebrum of learners (Bodner 1986). Bloom (1956) and his associates built up an arrangement of positioned learning results in which distinctive levels of intuition were composed. An alternative evaluation measure may include articles, creating tests, oral presentations, showcases, tests, and/or portfolios (Ewing, 1998). PBL at first applied in restorative institutional activities subsequently in science subjects (Barrows & Tamblyn, 1980).

Subsequent for making an invitational circumstance in which issue is exhibited (Torres, Preto & Vasconcelos, 2013), the educator needs to energize students amid the examination helping them to turned into a more self-administering learner (Barrel, 2007). In this technique, the end goal is to enhance information development and to create diverse capabilities of students through collaboration.

1.1 Research Objectives

1. To examine the effect of problem based learning on academic achievement of students in chemistry.
2. To examine the effect of problem based learning on academic achievement of students with different level of achievements.

3. To determine the effect of problem based learning on cognitive domain of secondary school chemistry students.
4. To determine the effect of problem based learning on cognitive domain of secondary school chemistry students with different level of achievements.

1.2 Research Hypotheses

The following hypotheses were tested in this study:

$H_{1:}$ There is significant effect of PBL on academic achievement of students in the subject of chemistry

H_2: There is significant effect of PBL on academic achievement of students with different level of achievements.

H_3: There is significant effect of PBL on academic achievement of students with higher level of achievements.

$H_{4:}$There is significant effect of PBL on academic achievement of students with low level of achievements.

H_5: There is significant effect of PBL on cognitive domain of secondary school chemistry students.

$H_{6:}$There is significant effect of PBL on the knowledge of secondary school chemistry students.

$H_{7:}$There is significant effect of PBL on the comprehension of secondary school chemistry students.

$H_{8:}$There is significant effect of PBL on the application of secondary school chemistry students.

$H_{9:}$There is significant effect of PBL on the synthesis of secondary school chemistry students.

$H_{10:}$There is significant effect of PBL on the analysis of secondary school chemistry students.

H_{11}:.There is significant effect of problem based learning on cognitive domain of secondary school chemistry students with different level of achievements.

H_{12}:.There is significant effect of problem based learning on cognitive domain of secondary school chemistry students with low level of achievements.

H_{13}:.There is significant effect of problem based learning on cognitive domain of secondary school chemistry students with high level of achievements.

1.3 Significance of Study

The study may be of more significant for curriculum developers in such a way that by considering the findings of the study revision will be made in the chemistry curriculum at secondary level. It may be significant for teachers of chemistry at secondary level to organize such instructional strategies which activate their scientific thinking and conceptual understanding. For this purpose,

teachers may assure the students to work collaboratively and generate enriched classroom environment and profit discoveries of the researches to upgrade the levels of scholastic accomplishment of the pupils. The study may be considerable for students in order to have a progress in their interest, self-reliance and abstract understanding.

1.4 Delimitation

The study was delimited to Working Folks Girls Grammar Higher Secondary School No.1 in District Haripur, Khyber Pakhtunkhwa. As the study was experimental in nature it was further delimited to only IX class students studying chemistry.

2. Review of Literature

Problem-based approaches to learning have a long history of advocating experience-based education. Psychological research and theory suggests that by having students learn through the experience of solving problems, they can learn both content and thinking strategies (Hmelo-Silver, 2004).

Researches proved that PBL is effectively used in chemistry. White (2001) described implications of problem based learning in a biochemistry course. Yuzhi (2003) adapted problem based learning in analytical chemistry courses. Students' expertise of critical thinking is enhanced though PBL (Elvan, Güven, & Aydoðdu, 2010). It is the dire need of time to adopt the new methods for the academic achievement of students in which every student perform task by thinking themselves and able to solve problems (Walker & Loften, 2003; Chin & Chia, 2004).

In the utilization of PBL one of the boundaries that surface is the absence of gifted educator to assume the part of facilitators and mediate the procedure (Hmelo-Silver, 2004). This technique empowers students to take care of the issue and learn new information rather than loaded information. The focus of PBL is to facilitate students to learn by setting off the issues that clarify the topic in finest way (Kılıç, 2006). It is the obligation of the educator in the PBL environment to help learning exercises by facilitating students (Greenwald, 2000; Posner & Rudnitsky, 2001; Açıkgöz, 2003; Onargan et al., 2004).

It has been supported in the literature that PBL positively influence on problem solving, creative thinking, academic achievement, attitude, scientific process. For example, Yaman and YalçÕn (2005) investigated the effects of PBL group having higher scores in creative thinking measures in comparison to control group. Besides, both Tavukcu (2006) and Bayrak (2007) investigated the effects of PBL on academic achievements, scientific process skills and attitudes towards lesson of students through a pretest-posttest control group design, and

they revealed that the PBL group had higher scores in academic achievement, attitude towards lesson and scientific process skill measures in comparison to the control group.

Due to more strength within a classroom instructor has no chance to provide equal concentration to each and every students at once in traditional learning method. So problem based learning might be utilized as instructional way to enhance the academic achievement of the students. The present study focused on to find the effectiveness of problem based learning on the cognitive development of students at secondary level and propose the strategy for the effective learning of chemistry subject.

3. Research Methodology

3.1 Research Design

Pre-test, post-test identical gathering configuration was utilized for this study. This design was suitable for the present study as it involved randomly assigning subjects between two groups, a test group and a controlled having equal number of students in each. As pretest and posttest was same for both the groups so pretest was taken before applying Problem based learning method and posttest after application of the method.

3.2 Population

Population consisted of 165 chemistry students of IX class in all the three Working Folks Grammar Secondary Schools in District Haripur Khyber Pakhtunkhwa.

3.3 Sample

90 students were chosen as sample of the study. On the premise of pre-test marks the sample learners were divided in to 2 sets i.e. controlled and experimental on the base of three categories that are brilliant, average and slow learners by using equivalent group design. So each group constituted 45 subject each of the same abilities.

3.4 Treatment

3.4.1 Traditional Based Learning Task

Teacher taught controlled group by giving concept about four chapters **(**naming**:** structure of atom, periodic table and periodicity of properties, structure of molecules and physical states of matter**)** with traditional approach while experimental group was taught through PBL. The lesson plan of traditional method (Lecture) was based on Herbartian approach.

3.4.2 Problem Based Learning Task

The PBL activity was prepared by the researcher and a subject teacher having same experience and qualification of 5-8 years, M.Sc. and M.Ed. Before

the application of PBL, 5 groups were made in which there were nine students in each group. Teacher introduced the topic in the form of problem and briefed the concept so that every group member understands what to do. Then teacher asked questions relevant to the problem that students were taught before (brainstorming) which helped them in solving a problem. During treatment, students worked in small groups and by their active participation, sharing of ideas through discussion to find solution of the given problem. Problem was analyzed by asking open-ended questions that motivated students to focus on their respective goal. Here the role of teacher was as a guide and there would be cooperative, purposeful atmosphere in which students would have control of discussion. Towards the end of PBL teacher asked questions of formulated objectives in order to know about achievement of goals. Then each member of group was asked to explain problem on their own part. The lesson plan of PBL teaching model on the topics was based on instructional objectives to check knowledge, comprehension, application, synthesis, analysis and evaluation level of the students.

3.5 Time

The study continued for 6 weeks. The lengths of period were 40 minutes. Both groups were taught at the same time in parallel session.

3.6 Research Instrument

A pre-test was used to divide students into two groups on the basis of test results. . It consisted of 100 multiple-choice items from Chapter No. 2 to Chapter No. 5 of the Chemistry course book for Class IX. 25 items were chosen from each chapter to measure all levels of cognitive domain.

The pre-test was taken from 90 learners and on the account of test results, students were separated into two set and named randomly as experimental and controlled having 45 students in each group. The same test taken from experimental and controlled groups as a post-test to contrast the effect of teaching chemistry by problem solving method and traditional method on students' achievement.

4. Data Analysis

Table 1 Difference in achievement scores of controlled and experimental groups (pretest)

Chapters	Test	N	Mean	SD	SE Mean	t	P
Structure of Atom	Control	45	16.09	2.71	0.40	-0.199	0.843
	Experimental	45	16.20	2.58	0.38		
Periodic table and periodicity	Control	45	13.09	3.57	0.53	0.239	0.811
	Experimental	45	12.91	3.47	0.52		
Structure of molecules	Control	45	10.62	4.00	0.51	-0.555	0.580
	Experimental	45	11.00	3.05	0.45		
Physical states of matter	Control	45	12.20	4.26	0.63	0.228	0.820
	Experimental	45	12.00	4.07	0.61		
Total	Control	45	52.00	10.46	1.56	-0.050	0.960
	Experimental	45	52.11	10.57	1.58		

The t value is -0.199 and p value is 0.843 for chapter "Structure of Atom". As $p>0.05$, it implies that the distinction between the two groups is not statistically significant. The t value is 0.239 and p value is 0.811 for chapter "Periodic table and periodicity of properties". As $p>0.05$, it implies the variation among the two groups is not statistically significant. The t value is -0.555 and p value is 0.580 for chapter "Structure of Molecules". As $p>0.05$, it implies that the distinctions among the two groups is not statistically significant. The t value is 0.228 and p value is 0.820 for chapter "Physical states of matter". As $p>0.05$, it implies that the distinctions among two groups is not statistically significant.

Table 2 Difference in achievement scores of low achievers (pretest)

Chapters	Test	N	Mean	SD	SE Mean	t	P
Structure of Atom	Control	13	14.08	2.78	0.77	-0.162	0.872
	Experimental	12	14.25	2.53	0.73		
Periodic table and periodicity	Control	13	10.46	3.76	1.04	-0.025	0.980
	Experimental	12	10.50	3.80	1.097		
Structure of molecules	Control	13	8.92	2.18	0.60	0.564	0.578
	Experimental	12	8.42	2.31	0.67		
Physical states of matter	Control	13	7.23	2.59	0.72	-1.051	0.304
	Experimental	12	8.50	3.42	0.99		
Total	Control	13	40.69	5.20	1.44	-0.353	0.727
	Experimental	12	41.67	8.35	2.41		

The t value is -0.162 and p value is 0.872 for chapter "Structure of Atom". As p>0.05, it implies that the distinctions among the two groups is not statistically significant. The t value is -0.025 and p value is 0.980 for chapter "Periodic table and periodicity of properties". As p>0.05, it implies that the distinctions among the two groups is not statistically significant. The t value is -0.564 and p value is 0.578 for chapter "Structure of molecules". As p>0.05, it implies that the distinctions among the two groups is not statistically significant. The t value is -1.051 and p value is 0.304 for chapter "Physical states of matter". As p>0.05, it implies that the distinctions among the two groups is not statistically significant.

Table 3 Difference in achievement scores of control and experimental groups in pretest (medium achievers)

Chapters	Test	N	Mean	SD	SE Mean	t	P
Structure of Atom	Control	21	16.27	1.74	0.38	0.516	0.608
	Experimental	20	16.00	1.81	0.40		
Periodic table and periodicity	Control	21	12.71	2.24	0.49	-0.246	0.807
	Experimental	20	12.90	2.59	0.58		.
Structure of molecules	Control	21	9.81	3.06	0.67	-1.349	0.185
	Experimental	20	11.00	2.55	0.57		
Physical states of matter	Control	21	12.76	2.00	0.44	0.878	0.385
	Experimental	20	12.05	3.10	0.69		
Total	Control	21	51.57	3.63	0.79	-0.231	0.818
	Experimental	20	51.95	6.52	1.46		

The t value is 0.516 and p value is 0.608 for chapter "Structure of Atom''. As p>0.05, it implies that the distinctions among the two groups is not statistically significant. The t value is -0.246 and p value is 0.807 for chapter "Periodic table and periodicity of properties". As p>0.05, it implies that the distinctions among the two groups is not statistically significant. The t value is -1.349 and p value is 0.185 for chapter "Structure of Molecules". As p>0.05, it implies that the distinctions among the two groups is not statistically significant. The t value is 0.878 and p value is 0.385 for chapter "Physical states of matter". As p>0.05, it implies that the distinctions among the two groups is not statistically significant

Table 4 Difference in achievement scores of high achievers (pretest)

Chapters	Test	N	Mean	SD	SE Mean	t	P
Structure of Atom	Control	11	18.09	2.70	0.81	-0.218	0.829
	Experimental	13	18.31	2.18	0.60		
Periodic table and periodicity	Control	11	16.91	1.97	0.59	1.660	0.111
	Experimental	13	15.15	3.00	0.83		
Structure of molecules	Control	11	14.18	2.71	0.82	0.759	0.456
	Experimental	13	13.38	2.43	0.68		
Physical states of matter	Control	11	17.00	2.37	0.71	1.511	0.145
	Experimental	13	15.15	3.41	0.95		
Total	Control	11	66.18	5.86	1.77	1.440	0.164
	Experimental	13	62.00	7.97	2.21		

The t value is -0.218 and p value is 0.829 for chapter "Structure of Atom". As p>0.05, it implies that the distinctions among the two groups is not statistically significant. The t value is 1.660 and p value is 0.111 for chapter "Periodic table and periodicity of properties". As p>0.05, it implies that the distinctions among the two groups is not statistically significant. The t value is 0.759 and p value is 0.456 for chapter "Structure of Molecules". As p>0.05, it implies that the distinctions among the two groups is not statistically significant. The t value is 1.511 and p value is 0.145 for chapter "Physical states 0f matter". As p>0.05, it implies that the distinctions among the two groups is not statistically significant.

Table 5 Difference in achievement scores of control and experimental groups (posttest)

Chapters	Test	N	Mean	SD	SE Mean	t	P
Structure of Atom	Control	45	16.20	2.58	0.38	-8.116	0.000
	Experimental	45	20.98	2.99	0.45		
Periodic table and periodicity	Control	45	12.91	3.47	0.52	-7.976	0.000
	Experimental	45	19.18	3.97	0.59		
Structure of molecules	Control	45	11.00	3.05	0.45	-9.635	0.000
	Experimental	45	17.96	3.77	0.56		
Physical states of matter	Control	45	12.00	4.07	0.61	-9.624	0.000
	Experimental	45	19.53	3.32	0.495		
Total	Control	45	52.11	10.57	1.58	-11.353	0.000
	Experimental	45	77.64	10.76	1.60		

The t value is -8.116 and p value is 0.000 for chapter "Structure of Atom". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant. The t value is -7.976 and p value is 0.000 for chapter "Periodic table and periodicity of properties". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant. The t value is -9.635 and p value is 0.000 for chapter "Structure of molecules". As $p<0.05$, it implies that the distinction among the two groups is statistically significant. The t value is -9.624 and p value is 0.000 for chapter "Physical states of matter". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant.

Table 6 Difference in achievement scores of low achievers (posttest)

Chapters	Test	N	Mean	SD	SE Mean	t	P
Structure of Atom	Control	13	16.61	3.01	0.84	-3.850	0.001
	Experimental	12	21.75	3.65	1.05		
Periodic table and periodicity	Control	13	13.46	3.41	0.94	-3.025	0.006
	Experimental	12	18.50	4.85	1.40		
Structure of molecules	Control	13	13.30	2.06	0.57	-1.861	0.076
	Experimental	12	15.83	4.41	1.27		
Physical states of matter	Control	13	14.08	3.25	0.90	-2.919	0.008
	Experimental	12	17.75	3.02	0.87		
Total	Control	13	57.46	7.05	1.96	-4.396	0.000
	Experimental	12	73.83	11.26	3.25		

The t value is -3.850 and p value is 0.001 for chapter "Structure of Atom". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant. The t value is -3.025 and p value is 0.006 chapter "Periodic table and periodicity of properties". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant. The t value is -1.861 and p value is 0.076 for chapter "Structure of molecules". As $p>0.05$, it implies that the distinctions among the two groups is not statistically significant. The t value is -2.919 and p value is 0.008 for chapter "Physical states of matter". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant.

Table 7 Difference in achievement scores in post-test (medium achievers)

Chapters	Test	N	Mean	SD	SE Mean	t	P
Structure of Atom	Control	21	18.43	1.96	0.43	-2.049	.047
	Experimental	20	20.05	3.02	0.67		
Periodic table and periodicity	Control	21	15.19	2.82	0.62	-3.094	0.004
	Experimental	20	18.40	3.78	0.85		

Structure of molecules	Control	21	11.95	2.92	0.64	-6.071	0.000
	Experimental	20	17.60	3.03	0.68		
Physical states of matter	Control	21	14.95	3.17	0.69	-4.586	0.000
	Experimental	20	19.40	3.03	0.68		
Total	Control	21	60.52	7.57	1.65	-5.294	0.000
	Experimental	20	75.45	10.34	2.31		

The t value is -2.049 and p value is 0.047 for chapter "Structure of Atom". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant. The t value is -3.094 and p value is 0.004 for chapter "Periodic table and periodicity of properties". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant. The t value is -6.071 and p value is 0.000 for chapter "Structure of Molecules". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant. The t value is -4.586 and p value is 0.000 for chapter "Physical states of matter". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant.

Table 8 Difference in achievement scores in post-test (high achievers)

Chapters	Test	N	Mean	SD	SE Mean	t	P
Structure of Atom	Control	11	20.18	2.40	0.72	-1.726	0.098
	Experimental	13	21.69	1.89	0.52		
Periodic table and periodicity	Control	11	17.45	1.63	0.49	-3.578	0.002
	Experimental	13	21.00	2.92	0.81		
Structure of molecules	Control	11	16.36	3.26	0.98	-3.287	0.003
	Experimental	13	20.46	2.85	0.79		
Physical states of matter	Control	11	18.91	3.08	0.93	-1.902	0.070
	Experimental	13	21.38	3.25	0.90		
Total	Control	11	72.91	7.53	2.27	-3.621	0.002
	Experimental	13	84.54	8.09	2.24		

The t value is -1.726 and p value is 0.098 for chapter "Structure of Atom". As $p>0.05$, it implies that the distinctions among the two groups is not statistically significant. The t value is -3.578 and p value is 0.002 for chapter "Periodic table and periodicity of properties". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant. The t value is -3.287 and p value is 0.003 for chapter "Structure of molecules". As $p<0.05$, it implies that the distinctions among the two groups is statistically significant. The t value is -1.902 and p value is 0.070 for chapter "Physical states of matter". As $p>0.05$,

it implies that the distinctions among the two groups is not statistically significant.

5. Discussion

The present study supported the results of Khan (2008). Findings also concluded that by using traditional method students did not learn properly. The current study also supported the results of Akınoğlu & Tandoğan (2007) who argue that conceptual development of the learners was influenced particularly and their misinterpretations were reduced by using Problem-based learning model. The study supported the results of Planinić, Ivanjek, Sušac, Pećina, Krsnik, Planinić & Jakopović (2008) who suggested that there occurs an abstract change in the students by proper teaching. Azizoglu (2004) in his findings contended that if students ready to ask important inquiries as per the circumstance and clarify relationship then huge learning occur. The current study emphasizes on student's involvement more and more as compared to the teacher.

The study results of (Tarhan, Ayar-Kayali, Urek & Acar, 2007) showed that the instructions based on Problem-based learning methodology was superior to the direction based on traditional methods on promoting the understanding of student's science perception. The current research also prove that the traditional method is just like spoon feeding. This study demonstrates the outcomes of Hewson & Hewson, 1983; Kurz-Milcke, Nersessian & Newstetter, 2004; Hewson & Thorley, 2006. In several studies there had been found a relationship between Problem-based learning strategy and achievement indicated by (Cancilla, 2001; Yuzhi, 2003; Schmidt & Moust, 2000; Chin & Chia 2004; White 2001; Groh 2001; Lacek 2001; who favored that Problem-based learning approach was proved to be successful for student's problem solving ability.

6. Conclusions

1. There is no significant difference among the two groups in pre-test scores for chapter 2 Structure of Atoms, chapter 3 Periodic table and periodicity of properties, chapter 4 Structure of Molecules and chapter 5 Physical states of matter.
2. There is no significant difference among the two groups in pre-test scores of low achievers for chapter 2, chapter 3, chapter 4 and chapter 5.
3. There is no significant difference among the two groups in pre-test scores of mediocre for chapter 2, chapter 3, chapter 4 and chapter 5.
4. There is no significant difference among the two groups in pre-test scores of high achievers for chapter 2, chapter 3, chapter 4 and chapter 5.
5. There is significant difference among the two groups in post test scores for chapter 2, chapter 3, chapter 4 and chapter 5.

6. There is significant difference among the two groups in post test scores of low achievers for chapter 2, chapter 3, chapter 5 whereas there is no significant distinction among the two groups for chapter 4.
7. There is significant difference among the two groups in post test scores of mediocre for chapter 2, chapter 3 and chapter 4 and chapter 5.
8. There is no significant difference among the two groups in post test scores of high achievers for chapter 2, chapter 5 whereas there is significant difference among the two groups for chapter 3 and chapter 4.

7. Recommendations

1. The study demonstrated that PBL is better for chemistry subject so in order to enhance the academic accomplishments of learners, teachers of chemistry subject should use PBL.
2. PBL is one of the collaborative processes that elicit scientific problems with consequential problems. So this method facilitates future science teachers with the prospect to become considerable stakeholder and PBL may be incorporated as an essential part in training for science teacher.
3. Chemistry teacher(s) should be encouraged to use PBL teaching strategy and different in-service training programmes should be conducted in order to introduce and implement PBL.

References

Açıkgöz, K. Ü. (2003). *Aktif Öğrenme (Active Learning)* (5. Baskı). İzmir: Eğitim Dünyası Yayınları.

Akınoğlu, O., & Tandoğan, R. (2007). The Effects of Problem-Based Active Learning in Science Education on Students' Academic Achievement, Attitude and Concept Learning. *Eurasia Journal of Mathematics, Science and Technology Education*, *3*(1), 71-81. doi: 10.12973/ejmste/75375

Azizoglu, N. (2004). *Conceptual Change Oriented Instruction and Students' Misconceptions in Gases.* (PhD Thesis), Middle East Technical University, Turkey.

Barrel, J. (2007). *Problem-Based Learning: An inquiry approach*. Thousand Oaks: Corwin Press.

Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education.* NewYork: Springer.

Barrows, H. (1985). *How to design a problem-based curriculum for the preclinical years*. New York: Springer.

Bayrak, R. (2007). *Probleme Dayalı Öğrenme Yaklaşımı ile Katılar Konusunun Öğretimi* (Yayınlanmış Doktora Tezi). Atatürk Üniversitesi Fen Bilimleri Enstitüsü.

Bloom, B. (1956). *Taxonomy of Educational objectives, Handbook I: Cognitive Domain*. New York: Longmans, Green.

Bodner, G. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education*, *63*(10), 873. doi: 10.1021/ed063p873

Cancilla, D. A. (2001). Integration of environmental analytical chemistry with environmental law: the development of a problem-based laboratory. *Journal of Chemical Education*, *78*, 1652–1660.

Chin, C., & Chia, L. (2004). Problem-based learning: Using students' questions to drive knowledge construction. *Science Education*, *88*, 707–727.

Elvan, Ý. N. C. E., Güven, E., & Aydoðdu, M. (2010). Effect of problem solving method on science process skills and academic achievement. *Journal of Turkish Science Education*, *7*(4).

Ewing, S. C. (1998). Alternative assessment: Popularity, pitfalls, and potential. *Assessment Update: Progress, Trends and Practices in Higher Education, 10* (1), 1-12.

Greenwald, N. L. (2000). Learning From Problems. *The Science Teacher*, *67*(4), 28-32.

Groh, S. E. (2001). Using problem-based learning in general chemistry. In Duch, B. J, Groh, S. E., & Allen, D. E. (Eds.), *A practical "how to" for teaching undergraduate courses in any discipline: The power of problem-based learning* Sterling, VA: Stylus Publishing.

Herreid, C. F. (2003). The Death of Problem Based Learning. *Journal of College Science Teaching*, *32*(6).

Hewson, P., & Thorley, N. (2006). The conditions of conceptual change in the classroom. *International Journal of Science Education*, *11*(5), 541-553. doi: 10.1080/0950069890110506

Hewson, M., & Hewson, P. (1983). Effect of instruction using students' prior knowledge and conceptual change strategies on science learning. *Journal of Research in Science Teaching*, *20*(8), 731-743. doi: 10.1002/tea.3660200804

Hmelo-Silver, C. E. (2004). Problem-Based Leaning: What and How do Students Learn? *Educational Psychology Review*, *16*(3), 235-266.

Khan, S. A. (2008). *An experimental study to evaluate the effectiveness of cooperative learning versus traditional learning method* (Doctoral thesis). Department of Education, Faculty of Social Sciences, International Islamic University Islamabad, Pakistan.

Kılıç, G.B. (2006). *İlköğretim Bilim Öğretimi*, İstanbul, Morpa Yayınları.

Kurz-Milcke, E., Nersessian, N., & Newstetter, W. (2004). What Has History to Do with Cognition? Interactive Methods for Studying Research Laboratories. Journal of Cognition and Culture, 4(3), 663-700. doi: 10.1163/1568537042484959

Lacek, K. A. (2001). *A Problem-Based Learning Curriculum Unit for High School Chemistry*. Dissertation, California University of Pennsylvania.

Michel, M. C., Bischoff, A., & Jakobs, K. H. (2002). Comparison of problem- and lecture-based pharmacology teaching. *Trends in Pharmacological Sciences*, *23*(4), 168 – 170.

Onargan, T., Cöcen, E., Tatar, Ç., Köktürk, U., Mordogan, H. & Batar, T. (2004). *Maden Mühendisliği Eğitiminde Probleme Dayalı Öğretim İçin Yapılanma Modeli*, Ulusal Mühendislik Kongresi Bildiriler Kitabı.

Planinić, M., Ivanjek, L., Sušac, A., Pećina, P., Krsnik, R., Planinić, M., Jakopović Ž. & Halusek, V. (2008). Nacionalno istraživanje konceptualnog razumijevanja mehanike na populaciji gimnazijskih

maturanata. *Zbornik radova VIII. hrvatskog simpozija o nastavi fizike*, 17-25. (published in Croatian language)

Posner, G. J. & Rudnitsky, A. N. (2001). *Course Design*. Addison Wesley Longman, Inc.

Schmidt, H. G., & Moust, J. H. C. (2000). Factors affecting small-group tutorial learning: A review of research. In D. H. Evensen & C. E. Hmelo (Eds.), *Problem-based learning: A research perspective on learning interactions* (pp. 19–52). Mahwah, NJ: Erlbaum.

Tarhan, L., Ayar-Kayali, H., Urek, R., & Acar, B. (2007). Problem-Based Learning in 9th Grade Chemistry Class: 'Intermolecular Forces'. *Research in Science Education*, 38(3), 285-300. doi: 10.1007/s11165-007-9050-0

Torres, J., Preto, C. & Vasconcelos, C. (2013). PBL Environmental Scenarios: An Analysis of Science Students and Teachers Questioning. *Journal of Science Education*, *14* (2), 71-74.

Tavukcu, K. (2006). *Fen Bilgisi Dersinde Probleme Dayalı Öğrenmenin Öğrenme Ürünlerine Etkisi. Yayınlanmış Yüksek Lisans Tezi*, Zonguldak Kara Elmas Üniversitesi Sosyal Bilimleri Enstitüsü.

Walker, J. T. & Lofton S. P. (2003). Effect of Problem Based Learning Curriculum on Students' Perceptions of Self-directed Learning. *Issues in Educational Research*, *13*(2), 71-100. .

White, H. B. (2001). A PBL course that uses research articles as problems. In B. J. Duch, S. E. Groh, & D. E. Allen (Eds.), *A practical "how to" for teaching undergraduate courses in any discipline: The power of problem-based learning.* Sterling, VA: Stylus Publishing.

Yaman, S., & Yalçın, N. (2005). Fen Öğretiminde Probleme Dayalı Öğrenme Yaklaşımının Problem Çözme ve Öz Yeterlilik İnanç Düzeylerinin Gelişimine Etkisi, H.Ü. *Eğitim Fakültesi Dergisi*, 29, 229-236

Yuzhi, W. (2003). Using Problem–Based Learning and Teaching Analytical Chemistry, *The China Papers*, 28-33.