Effects of Problem Based Learning on Students' Critical Thinking Skills, Attitudes towards Learning and Achievement

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Abstract

This study intends to analyze the effects of problem-based learning on students' attitude towards learning, critical thinking skills and achievement of 10th grade students in chemistry. In this experimental study the students of two intact groups of Govt. high school 79 SB Sargodha, were selected as experimental (N=35) and control group (N=28). The students of both the groups were arranged with respect to their pre-test scores into three subgroups; low, average and high achievers. This experiment was conducted for the period of two months using pre-test post-test control group design with non-equivalent groups. The tools developed for measuring the dependent variables were; "Problem Solving Ability Test in Chemistry" (PSATC) and "Achievement Test in Chemistry" (ATC), and "Attitude towards Learning Scale". On the basis of results, it was concluded that the students who received treatment, performed better than the students of control group in problem solving ability tests and in the achievement test and were better in their critical thinking skills (understanding, analyzing, evaluation and synthesis). Comparison within the experimental group reflected that the performance of high and average achiever students was same, but better than the low achievers in problem solving ability tests and achievement test.

Keywords: Problem-based learning, Attitudes towards learning, Critical thinking skills

Introduction

It is need of the day that the learners should be prepared in a way that they possess certain basic skills to work in diversified circumstances. A number of educational philosophies provide guidelines essential for the development of human being. Pragmatism and progressivism view human learning as a process of learning by experiencing the real world (Richardson, 2003). Here, 'experiencing' means to solve the

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problem which one faces in everyday life. In the real life, problems may be structured or ill structured, close or open ended. Following the principles propagated by these philosophies, various strategies and teaching methods have been developed. Problem Based Learning strategy is also propagated by constructivism school of thought which is learner centered and the teacher make the students work themselves and generate new knowledge.

Problem-based learning (PBL) has been defined as a method of inquiry where students solve difficulties, oddities, qualms, and problems in the context of real life (Barell, 2007). Barell further states that it permits students to develop their inquisitiveness and group work and teamwork skills. Norman & Schmidt (2000) defines PBL as "a learning approach that encourages the students to upgrade their motivation level, interest, and is also pleasurable, which resulted from the process of working towards accepting or solving a problem." (722).

PBL was initially designed to address the problems of students' inability to apply knowledge learned and to solve problems in real-world situations (Barrows & Tamblyn, 1980; Albanese & Mitchell, 1993; Barrows, 1996)**.** It was theorized that problem-based learning (PBL) can have effect on higher order thinking ability of student which helps them in improving the attitude towards learning as well as increases their academic achievement (Barrows, 1996). However, PBL also helps the students construct their own knowledge about the given topic, while working collaboratively (Etherington, 2011). Hallinger and Bridges (2016, 2) proposed "PBL as an alternative teaching–learning approach that sought to create an active, problem-focused, practice-oriented environment for management education".

In Problem Based pedagogical technique, the thinking and learning processes are driven by problems and relatively a specific thinking skill is 'taught' from the beginning. It is a method that prepares students to face the problems of real world that are unclear and often ill-structured. PBL enhances students' achievement by promoting their skills and capabilities in applying knowledge, by challenging students to solve problems, by encouraging them in practicing higher order thinking skills, and by directing their own learning (Jonassen & Hung, 2012).

Problem-based learning makes a vital shift and emphasis on teaching to an attention on learning. The PBL is a process having the aim at using the strength of genuine problem solving to involve students and develop their learning and motivation. Saeed (2013, 3) mentions many exceptional features that define the PBL methodology:

i. The firsthand knowledge of particular context can be acquired by the context of reliable tasks, issues, and difficulties which are associated with daily life.
ii. The teacher and learner become fellows in teaching learning process, in a PBL course, as they plan, apply and continuously refine their courses.

iii. This technique motivates students to take charge of personal understanding.
iv. The PBL method deals with solid theoretical research on learning.
v. PBL encourages effective reasoning and self-directed learning.

DeGraaff and Kolmos (2003) emphasize that "the didactical principles of PBL encompass all curriculum development elements: objectives, teacher and student learning strategies, choice of content, learning methods, ICT, teachers' roles, organization, culture and assessment" (p.658).

In Pakistan, The National Policy on education (NEP, 2009) specifies that "the curriculum should reveal the major social problems; provide more space for the development of critical thinking, problem solving skills, inquiry habits, self-directed learning abilities, and collaborative work among learners". In Pakistan education is assessment driven and it forces the teachers and the students to struggle with theoretical content and they feel less motivated due to the gap between theory and practice. Therefore, there is a need for the educational culture in which students are exposed to problems to learn new skills for successful professional life. Only a few studies have been conducted in Pakistan in which effect of problem based learning was found on writing skills (Dastgeer & Afzal, 2015) and learning as second language English (Hussain et al., 2012) while a few of them were carried out about science student's achievement (Khan et al., 2012; Malik & Iqbal, 2011).

The present study intended to examine the improvement in critical thinking skills, attitude towards learning, problem solving skills, and achievement by manipulating the procedures of teaching which were based on the problem based learning techniques. The objectives of the study were:

i. To compare and explore the improvement in academic achievement and attitude towards learning chemistry of experimental and control group students of 10^{th} grade after treatment of problem based teaching strategies in learning chemistry.
ii. To assess the improvement in critical thinking skills and problem-solving skills of experimental group after treatment of problem based teaching strategies.

Method

Research Design

This Non-equivalent Control Group Design was employed which can be represented as follows:

Experimental Group: O_1 X O_2
Control Group: O_1 O_2
Where O_1 stands for the observations on pre-test
O_2 stands for the observations on post-test
X stands for the treatment.

Two intact groups were selected as experimental (N=35) and control group (N=28) from Government High School 79 NB. These groups were further subdivided on the base of pre-test marks as shown in the table below.

Table 1

Group distribution on the basis of pre-test marks

Groups	High	Moderate	Low	Total
Experimental (PBL Treatment)	10	15	10	35
Control (No Treatment)	10	8	10	28

The researchers selected five chapters from the textbook of Chemistry for class 10th approved by Punjab Text book Board Lahore, Pakistan. The five chapters were "Chemical equilibrium" (Chapter 9), "Acid base and salts" (Chapter 10), "Organic chemistry" (Chapter 11), "Atmosphere" (Chapter 14), and "Water" (Chapter 15).

The first step was to measure achievement of both the groups as pre-test in achievement test of chemistry (ATC) and problem-solving ability test of chemistry (PSATC) before the treatment. The treatment was then administered to one group (experimental group) by teaching them 5 major topics of 10^{th} grade chemistry with problem based teaching strategy. The treatment was ended after six weeks following a post-test in ATC and PSATC in the subject of chemistry.

Research Instruments

Achievement Test of Chemistry (ATC)

This achievement test was focused on answering the 40 multiple-choice questions (MCQs) selected and designed according the table of specification given below:

Table 2

Table of specification for Achievement test in chemistry

Topics	Knowledge	Comprehension	Application	Total
Chemical equilibrium	3	3	3	9
Organic compound	5	2	3	10
Acid rain	4	6	1	11
Hardness of water	2	5	3	10
Total	14	16	10	40

Problem Solving Ability Test of Chemistry (PSATC)

This test (PSATC) comprised of 16 problems of daily life applicable to the chemistry course content of 10^{th} grade. The problems were developed for observing

understanding, problem solving, and critical thinking skill of the students. Every problems/scenario possesses 4 marks and the total marks of PSATC were 64.

Attitude towards Learning Chemistry (ALC)

A Likert scale questionnaire was developed for measuring four indicators (Motivation level, self-learning, Collaboration, and satisfaction level) of attitude towards learning chemistry.

Validity and Reliability

For content validity the items were discussed with the Subject Specialists teaching the subject of "Chemistry" and other experts in the field. Finally, through item analysis, 40 items out of sixty (Items with difficulty level of .30 to .70) were finalized for administration. The problem-solving ability test in chemistry (PSATC) was validated through pilot testing and discussion with the experts. The questionnaire for measuring the attitude towards learning chemistry was also developed and validated by the experts.

The Kuder Richardson formula was applied to check the reliability of the ATC & PSATC. The reliability coefficient for the whole test ATC was 0.67 and reliability for the attitude questionnaire (ALC) was found to be 0.70. The reliability of problem solving ability test in Chemistry (PSATC) was found to be 0.75.

Problem Solving Teaching Strategy

The small groups, comprising five to six students, worked together on the problems presented to them to learn problem solving skills. The teacher acted as a guide who presented the problem, and the group was motivated for identifying different features of the problem by asking the questions from teacher to gather relevant information. A sample problem is given as under:

> "Ali's father brought a new tooth brush which has the quality to change the color during brushing. Ali was the student of 8^{th} grade. Early in the morning, when Ali got new red color brush for cleaning teeth, he was astonished when he saw in the mirror that his brush became yellow from his hand grip and also from brush strings. When he washed it again become complete red. He could not understand what the chemical change occurred? Will you help him to understand the chemical change or not? Give reason".

Each member of the group was assigned a task for searching and identifying different "learning problems". After that all the members described their results to each other and combined it together to produce a proper solution to the problems. The main purpose was to develop thinking skills and problem-solving skills by inquiring and investigating the problem, evaluating results and producing solutions.

Results

Achievement test of chemistry

Table 3

Mean achievement score of the students of experimental and control group in Chemistry

Test	Group	N	Mean	SD	*t*	*df*	*p*
Pre-Test	Experimental	35	16.72	3.44	1.529	61	.119
	Control	28	18.29	4.479			
Post Test	Experimental	35	25.29	5.061	1.78	61	.080
	Control	28	22.750	6.227			

This table showed that *t* value for the pre-test of both groups (*t*= 1.529, p= 0.119) was insignificant and reflects that null hypothesis of no significant difference between the students of both groups was accepted. The *t* value for the post-test (*t*= 1.78, p=0.80) was also insignificant and reflected that null hypothesis of no significant difference between the students of both groups was accepted but the experimental group (mean =25.29 and SD =5.06) treated by problem solving teaching method performed better than the control group (mean= 22.75 and SD=6.22).

Table 4

Comparison of mean gain score of achievement of students

Group	N	Mean	SD	*t*	*df*	*p*	Effect size
Experimental	35	8.9429	4.64	3.656	61	.000	0.88
Control	28	4.8400	3.73				

*p<0.05

Table 4 revealed statistically significant *t* value for the gain score (*t*= 3.656, p. 0.000) which reflected that null hypothesis of no significant difference between the students of both groups was rejected. The experimental group (mean =8.94 and SD =4.64) treated by problem solving teaching method performed better than the control group (mean= 4.84 and SD=3.72). Cohen's d value 0.88 indicated that there was a big difference among the group treated with problem solving teaching method and the group treated through conventional teaching approach.

Table 5

Mean achievement gain score of high, moderate and low achievers of the student.

Sub Groups	Group	N	Mean	S. D	*t*	*df*	*p*
High Achievers	Experimental	10	8.5	1.95	3.651	18	0.003
	Control	10	4.8	2.78			
Moderate Achievers	Experimental	15	5.1	2.42	2.24	24	0.025
	Control	10	2.12	1.57			
Low Achievers	Experimental	10	5.6	3.43	0.850	18	0.407
	Control	8	4.5	2.22			

This table shows that *t* value for the experiment and control group of high achievers (*t*=3.651, p-0.003) and moderate achievers (*t*=2.24, p-0.025) was significant and for low achievers (*t*= -0.850, p-0.407) was insignificant. However, the mean score of all subgroups treated by problem solving teaching methods was better than control group.

Problem Solving Ability Test

Table 6

Comparison of mean gain score of the students of control and experimental group in problem solving ability test in chemistry

Group	N	Mean	S D	*t*	*df*	*p*	Effect size
Experimental	35	25.342	2.700	36.24	61	0.000	0.81
Control	28	3.714	2.034				

Table 6 displayed that *t* value of both the groups (*t* =36.24, p. 0.000) was significant. The experimental group (mean =25.3429 and SD =2.700) treated by problem solving teaching method performed better than the control group (mean= 3.714 and SD=2.034). Cohen's d value 0.81 show there was much difference among the group treated with PBL strategy and the group treated through conventional teaching methods.

Table 7

Comparison of mean gain score of high, moderate and low achievers in the problem-solving ability test in Chemistry.

Sub Groups	Group	N	Mean	SD	*t*	*df*	*p*	Effect size
High Achievers	Experimental	10	33.6	3.31	25.374	18	.000	0.98
	Control	10	3.9	1.66				
Moderate achievers	Experimental	16	24.43	2.92	28.58	24	.000	0.98
	Control	8	0.50	1.51				
Low Achievers	Experimental	10	16.80	3.08	16.396	18	.000	0.96
	Control	10	8.700	3.83				

*p<0.05

This table presented that *t* values for high, moderate and low achievers of the both the groups which was significant and it revealed that null hypothesis of no significant difference between the groups in problem solving ability test in chemistry, was rejected. All subgroups of the experimental group performed better. The effect size ranged from 0.96 to 0.98.

Table 8

Mean achievement score of High, Moderate and Low achievers of experimental group *in the problem-solving ability test*

	Sum of Squares	*df*	Mean Square	*F*	*p*	Effect size
Between Groups	1416.368	2	708.184			
Within Groups	311.938	33	9.453	74.919	.000	0.81
Total	1728.306	35				

The achievement of high, moderate and low ability students of experiment group was not the same. The *F* value (*F*=74.58, p. 0.000) was significant with η^2= 0.

Table 8a

Post hoc test (LCD) for one-way ANOVA about the performance of the students of the different academic achievement levels

Achievement level (I)	Achievement level (J)	Mean Difference (I-J)	Std. Error	Sig.
High achiever	Low achiever	16.800	1.37497	.000
Moderate achiever	Low achiever	7.637	1.23938	.000

This table reflected that high achievers were remarkably better than low and moderate achievers. While the difference between moderate and low achievers on problem solving ability, test was also in favor of moderate achievers.

Attitude of the Students towards Learning Chemistry

Table 9

Comparison of attitude towards learning chemistry before and after treatment

	Group	N	Mean	SD	*t*	*df*	p-value
Pre-Test	Experimental	35	18.14	2.65	-1.417	61	.162
	Control	28	19.10	2.02			
Post-Test	Experimental	35	36.5429	6.72	15.11	61	0.000
	Control	28	18.0000	2.45			

The above table displayed that both the groups were not significantly different at start of the treatment. As *t*-value of experiment and control group (*t*=-1.417, p. 0.162) was not significant while the *t* –value of both groups after treatment (*t* =15.11, p. 0.000) was significant. The experimental group (mean=36.54 and SD= 6.722) exhibited better attitude towards learning than the control group (mean=18.00 and SD=2.45).

Table 10

Comparison between the motivation level, Self-learning, collaboration and satisfaction level of the students of control group and experimental group after the treatment

	Groups	N	Mean	SD	t	df	p-value
Motivation	Experimental	35	21.08	3.83767	7.871		.000
	Control	28	15.10	1.31485			
Self-learning	Experimental	35	11.08	2.42986	2.878	61	.006
	Control	28	9.64	1.52058			
Collaboration	Experimental	35	8.80	1.53009	.760		.450
	Control	28	7.78	7.72374			
Satisfaction	Experimental	35	12.91	1.93073	8.541		.000
	Control	28	9.75	.92796			

The table showed that after the treatment the *t*-value of motivation, self-learning and satisfaction level of experiment group was significant but insignificant in collaboration among the experimental and control group after the treatment.

Critical Thinking Skills

Table 11

Comparison of mean gain score about the critical thinking skills

Groups	N	Mean	SD	t	df	p-value	Effect size
Experimental	35	18.40	7.096	12.003	61	.000	0.87
Control	28	1.143	2.885				

The above table illustrated that gain score of experiment and control group (*t*=12.003, p. 0.000) was significantly different. Cohen's d values 3.61 and effect size is 0.87 which shows the large difference in the critical thinking skills among the students of experimental group before and after treatment.

Findings

Academic Achievement

iii. The performance of experimental group was superior than the control group on achievement test in chemistry after being treated by PBL strategy.

iv. The comparison among the mean gain score of the high, moderate and low achievers on achievement test in chemistry revealed that all these experimental subgroups performed better than control group students but low achievers remained almost similar.

Problem Solving Ability

i. In problem solving ability test it was found that experimental group perform better than the control group.

ii. It was found that in PSATC high, moderate, and low achievers of experimental group performed significantly better when treated by PBL.

iii. Among the experimental group it was found that high and moderate achievers significantly performed better than the low achievers.

Attitude towards Chemistry Learning

i. It was found that before the treatment both the group were same in the attitude toward learning the chemistry. They were same in their motivation, self–learning, satisfaction level and collaboration.

ii. After teaching them through problem solving teaching method, it was found that experimental group was better in their overall attitude toward learning the chemistry, their motivation level, self-learning and satisfaction towards learning chemistry than the control group students.

Critical Thinking Skills

i. It was found that PBL strategy helped the students of experimental group, as they significantly performed better after the treatment. It was also found that critical thinking skills of different academic achievement levels improved after treaded by PBL as high achievers were better than the moderate and low achievers in critical thinking skills.

Discussion

Findings of the study reveal that the 10th grade students treated by problem solving strategy were significantly better in achievement test in chemistry than the students treated by traditional methods. The students of all ability levels showed better results in achievement test in chemistry than the students treated by traditional method. These findings get confirmation from Hallinger and Bridges (2016) who have mentioned eight different studies which largely concluded that the use of PBL had enabled students to achieve the stated learning outcomes. Schmidt, Rotgans, and Yew (2011, 792) determine a substantial support for the impression that "PBL works because it encourages the stimulation of prior knowledge in the small-group setting and provides opportunities for explanation of that knowledge". They further states that "PBL facilitates the comprehension of new information related to the problem and enhance its long-term memorability" (792).

Students treated by PBL strategy showed better results in problem solving ability test, and their attitude towards learning chemistry than the students treated by traditional method (lecture method). This finding confirms the findings of Festus and Ekpete, (2012), Kadir and his associates (2016) and Malik and Iqbal (2011). The most appropriate reason is that problem based learning provides the prospects of the active participation of the students in classroom teaching and increases their problem-solving skills (Malik and Iqbal, 2011) probably due to class participation and class discussion (Peterson, 1997) and presentation of the problem, then actively finding out the solution (Purichia, 2015). Hallinger, and Bridges (2016, 3) affirmed that most "learning occurs in the context of student-directed small groups rather than teacher-directed lectures". According to constructive theory, as mentioned by Khalid and Azeem (2012) students learn in their way and built their own knowledge by understanding the real life problematic situations.

Students treated by the PBL were better in there critical thinking skills (application, analysis, synthesis and evaluation) as they showed improved skills towards solving the daily life problem. Sarigoz, (2012) indicates that due to problem solving approach; a student is not only able to learn the basic concepts but also can apply in the real-life scenario. The problem-solving teaching affects differently on the students with different abilities (Harland, 2002). Students with high and moderate achievement level when treated with problem solving teaching strategies performed significantly better than

the low achievers in problem solving ability and critical thinking skills. Overall students of all ability levels showed better results on problem solving ability test in chemistry.

Conclusions

Conclusion drawn from the findings reflects that PBL teaching strategy is very advantageous in improving achievement and critical thinking skills (application, analysis, synthesis and evaluation) of the students. The overall attitude of the students towards learning chemistry was more positive and their motivation level was better after being treated by PBL as they eagerly attended the problem-solving classes and wanted to participate in discussion about the topic in productive manner. Problem solving teaching strategy also supplemented the motivation of self-learning. It was suggested that PBL may be followed in science subjects particularly, in mathematics, chemistry, physics and biology at secondary school level. However, it seems essential to admit that teachers, especially in our context, need to acquire multifaceted teaching competences.

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