

Enhancing Critical Thinking Skills Through Problem-Based Learning in Physics Among Secondary School Students in Sargodha, Pakistan

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ABSTRACT

The purpose of this study was to investigate the impact of problem-based learning approach on critical thinking skills of 10th grade students, in the subject of physics. In this quasi-experimental study the students of two intact groups of Government Comprehensive boy's high school and Government Girls Pilot high school Sargodha, Pakistan. Two section from each school were selected and allocated as experimental and control group. A sample of 149 students was selected from two public sector secondary schools. The students of both groups were arranged with respect to their pre-test scores and were divided into three subgroups; high, average and low achievers. This experiment was carried out for a period of two months using pre-test post-test control group design. Critical thinking Test in Physics), was developed to use as pre-test and post-test. The reliability of the instrument was found to be 0.89. Parametric tests, t-test and ANOVA were used for the data analysis. On the basis of the results gotten, it was concluded that the students taught through problem based learning techniques, performed better than the students of control group on achievement and were better in their critical thinking skills (analyzing, synthesis and evaluation). It is recommended that curriculum developer may incorporate this teaching approach in the curriculum guidelines in physics for construction of intended learning outcomes for secondary level students of all kinds.

Keywords: Critical thinking skills, Problem-based learning, Physics, Inclusive education

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INTRODUCTION

Science education at secondary level prepare pupils to build all three bloom taxonomy domains, that is, cognitive, affective and psychomotor to grasp the natural occurrences in their physical environment in a conceptual way. Science study at secondary level is further divided into its branches - physics, chemistry, biology, geology etc. among them physics is the most near to everyday life especially in the modern age. As physics addresses energy and matter and studies mutual relationship of energy and matter and its properties in the field of mechanics, quantum mechanics, plasma, electrostatic, electricity and nuclear physics. Physics education is considered to be very fundamental in understanding the world around us, it concern both macroscopic and microscopic state of matter (Watkins & Mazur, 2013).

Constructivism believes that learners play an active role in constructing meaning by themselves (Le Cornu & Peters, 2005). Constructivist theories have their roots in Piaget and focus on the active character of the learner, interacting with the environment

either singly or with others (Packer & Goicoechea, 2000). Constructivism emphasizes the importance of the knowledge, beliefs, and skills that an individual brings to the experience of learning (Garbett, 2011). Constructivism posits that people construct their understanding and knowledge of the world through experiencing things and reflecting on those experiences (Barak, 2017). Constructivism as a learning theory believes that learning is an active process; knowledge is constructed from experience and a personal interpretation of the world (Applefield, Huber, & Moallem, 2000). Constructivism benefits students in many ways as asserted by Christie that it help students pursue personal interests and purposes; use and develop learner abilities; build on the learners' prior knowledge and experiences and develop life-long learning (Bada & Olusegun, 2015). The task of moving away from the comfort zone of the behavioristic paradigm to the constructivist paradigm is challenging but if we really want to prepare our students for the 21st century we have to take this challenge up, and equip them with critical thinking skills so that they are able to come up with creative solutions in these fast-changing circumstances (Siddiqui, 2019).

The learning of new sets of abilities required by students and instructors alike, is the main educational issue of the twenty-first century. These skills may include critical thinking, problem-solving, artificial intelligence, creativity, and adaptability to new circumstances. To cope with this challenge, we need to take stock of the prevailing paradigms of learning in different places. There has always been a difference of opinion about the goals, dynamics and assessment of education in different places due to culture, tradition and religious affliction and also, due to some form of abilities and disabilities. This difference has its roots in competing philosophical positions that construct, justify and rationalize particular educational approaches (Siddiqui, 2019). However, the constructivist paradigm has direct implications for teachers and their style of teaching in different teaching situations. In this paradigm they need to move away from the transmission mode to critical pedagogy by facilitating the students' active participation at all levels. This would also mean creating an enabling environment for students to express their ideas freely. This teaching style is certainly more challenging as compared to the teacher-fronted 'lecture mode', but is essential in order to imbue confidence in the students and reinforce a positive self-image so that they can become independent thinkers (Kim, 2005).

Constructivist paradigm is students' centered pedagogy of inquiry in which the students construct their knowledge through prior understanding and involve to solve problems in real life context to satisfy their curiosities and uncertainties. It is constructive approach, self- directed, shared and relative process (Li, 2001). Moreover, Alsaleh (2020) explored that students can judge, show reflective judgment, critically identify the problems and develop problem solving behavior. Additionally, Alsaleh (2020) also explained that who critically thinks gives the precise judgment. However, Ennis (1993), revealed that critical thinking skill was deductive and also inductive in nature. The students are properly facilitated and guided by developing in them self-motivated learning style which is helpful for them to improve their critical thinking skills and approach to solve the daily life problems. Constructivist paradigm not only enhances the learning but

it also inculcates the sense of cooperation, patience and attitude towards learning among the teacher and students (Akpan & Beard, 2016). However, constructivist paradigm is most effective way of developing critical thinking among the students (Gray, 1997). Whereas, Biggs (1999), found that constructivism holds the belief that meaning should not be imposed or transmitted by direct instruction, but allows the students generate information created by previous learning activities. However, Kim (2005) revealed that what is expected of a teacher in a constructivist classroom very similar to the authentic learning as follow.

- i. Encourage student's leadership, cooperation, seeking information, and the presentation of the ideas,
- ii. Modify their instructional strategies in the process of teaching based on students; thought, experience and or interests
- iii. Encourage free discussions by way of new ideas inviting student questions and answers
- iv. Help students to test their ideas
- v. Encourage students to challenge the concepts and ideas of others
- vi. Use cooperative teaching strategies through student interactions and respect, sharing ideas and learning tasks

In a constructivist setting, knowledge is not objective; mathematics and science are viewed as systems with models that describe how the world might be rather than how it is. These models derive their validity not from their accuracy in describing the real world, but from the accuracy of any predictions, which might be based on the (Bozkurt, 2017). The role of the teacher is to organize information around conceptual clusters of problems, questions and discrepant situations in order to engage the student's interest (Adom, Yeboah, & Ankrah, 2016). Teachers assist the students in developing new insights and connecting them with their previous learning not minding their abilities. Ideas are presented holistically as broad concepts and then broken down into parts to accommodate the diversity in the students' abilities. The activities are student centered and students are encouraged to ask their own questions, carry out their own experiments, make their own analogies and come to their own conclusions (Yoders, 2014). Therefore, constructivist teachers of science promote group learning, where two or three students of different abilities discuss approaches to a given problem with little or no interference from the teacher. What happens to and with such small groups of students can be used as a whole class arrives at consensus of the various small group analysis (Foote, Battaglia, & Vermette, 2014).

In nutshell, the role of the constructivist teacher can be seen as quite different from that of traditional teachers. So becoming a constructivist teacher may prove a difficult transformation since most instructors were prepared for teaching in the traditional, objectivist manner. It requires a paradigm shift and requires the willing abandonment of familiar perspectives and practices and the adoption of new ones (Brooks & Brooks, 1999).

- i. Become one of many resources that the student may learn from, not the primary source of information.

- ii. Engage students in experiences that challenge previous conceptions of their existing knowledge.
- iii. Allow student responses to drive lessons and seek elaboration of students' initial responses. Allow student some thinking time after posing questions.
- iv. Encourage the spirit of questioning by asking thoughtful, open-ended questions.
- v. Encourage thoughtful discussion among students.

Statement of the Problem

Most policies on education, states that the curriculum should deal with social problems; try to develop critical thinking skills, problem solving ability, self-motivated learning abilities, and team work among students. Probably the students and teachers struggle due to the gap between theory and practice model and become less motivated to learn. Therefore, they are rarely prepared to solve and face the real-world problems at their different levels of abilities. Thus, in educational settings the use of real-life problems, which help them when they face life in their future practice, is of importance, hence, the study of enhancing critical thinking skills through constructivist teaching approach in inclusive education among secondary school students in the 21st century. That is why this study examine the enhancement of higher order thinking skills - critical thinking skills and achievement, by implementing the new procedures of teaching - constructivist paradigm, which was based on the problem-based learning techniques. These help the students, to solve the daily life problems with full confidence, on the basis of prior knowledge they got from this approach.

Purpose of the Study

The study's objective was to find out the effect of problems-based learning techniques on critical thinking skills on secondary school students' in the subject of physics. Specifically, the study intends to:

1. Determine the difference in the mean gain scores on critical thinking of physics students taught using Problem-based learning or Lecture method.
2. Determine the difference in mean gain scores on critical thinking among the various achievement levels of physics students taught using Problem-based learning approach.
3. Determine the effect of gender on critical thinking of physics students taught using Problem-based learning.

Hypotheses

The following hypotheses were formulated to guide the study:

1. There is no significant difference in the mean gain scores on critical thinking of physics students taught using Problem-based learning or Lecture method.
2. There is no significant difference in mean gain scores on critical thinking among the various achievement levels of physics students taught using Problem-based learning approach.
3. There is no significant difference in critical thinking of male and female physics students taught using Problem-based learning.

METHODOLOGY

The Quasi-experimental research design was adopted for the study where Pre-test post-test control group was used. This experiment was carried out for a period of two months. The target population for this study consisted of male and female students studying the subject of Physics in public high schools in Sargodha district. All the science students of 10th grade studying in Government Comprehensive Boys High School Sargodha and Government Girls Pilot High school Sargodha were the accessible population for this study. This study was delimited to 10th class Physics students studying in secondary schools of district Sargodha. Random sampling technique was used to select science students, in male and female school. The experimental and control groups (male) each had 46 and 42 students respectively. For female school, the number of selected, that is, (control and experimental groups) each had 31 and 30 students respectively. As a result, there were 77 students in the experimental class and 72 in the control class. The Kuder Richardson formula is applied to check the reliability of the Critical Thinking Test in Physics (*CTTP*). Reliability coefficient (r) of 'critical thinking test in physics' was found to be 0.89. As a result, the instrument was deemed reliable and valid for use in the current study. The Experimental group was taught using Problem-based learning approach while the Control group was taught using the conventional Lecture method. Critical Thinking Test in Physics (*CTTP*) developed by the researchers according to the Bloom taxonomy, that is, higher order thinking levels (analyzing, synthesis and evaluation) was administered to both groups after exposure to treatments. Parametric tests, *t-test* and *ANOVA* were used for the data analysis.

RESULTS

Hypothesis 1

There is no significant difference in the mean gain scores on critical thinking of physics students taught using Problem-based learning or Lecture method.

Table 1

Comparison of mean gain scores in critical thinking post-test score in the subject of physics of control groups and experiment groups

Group	N	Mean	SD	t	df	p-value	Effect Size
Problem-based Learning	77	25.29	5.06	1.78	147	0.000	1.13
Lecture Method	72	20.75	6.22				

Table 2 shows that t value for the experimental group is ($t= 1.78$) was not significant at p -value $0.000 < 0.05$ and reflect that null hypothesis of no significant difference between the students of both control and experimental group was rejected. The experimental group (mean =25.29 and SD =5.06) with effect size (1.13) taught by problem based leaning approach performed better than the control group (mean= 20.75 and SD=6.22) taught through traditional teaching methods in the subject of physics.

Hypothesis 2

There is no significant difference in mean gain scores on critical thinking among the various achievement levels of physics students taught using Problem-based learning approach.

Table 2

ANOVA Results for Various Levels of Academic Achievement

Source	SS	Df	MS	F	Sig.	Effect Size Eta squared (η^2)
Between Groups	597.521	2	289.760	95.527*	0.000	0.70
Within Group	262.709	147	3.127			0.305
Total	860.230	149				

Table 2 shows a significant difference in mean gain scores in critical thinking test in physics among the students having different achievement levels as revealed by $F = 95.527$, p-value equal to 0.000 less than 0.05 with moderate effect size $\eta^2 = 0.70$ and 0.305. For the examination of further differences between the groups, post hoc test (LSD) was used. The following table shows just the significant results.

Table 2b

Results of Post hoc (LCD) Test

Achievement level (I)	Achievement level (J)	Mean Difference (I-J)	Std. Error	Sig.
High Achiever	Average Achiever	5.25	.52	.000*
	Low Achiever	6.73	.49	.000*
Average Achiever	Low Achiever	1.48	.43	.001*

Table 2b reveals that a positive mean difference (5.25) with p-value $0.000 < 0.05$ indicating that high achiever students within experimental groups performed better than average achievers. Similarly positive mean difference (6.73) with p-value $0.000 < 0.05$ depicts that high achiever students performed better than low achievers. Likewise, positive mean difference (1.48) with p-value equal to 0.000 and less than 0.05, exhibits that performance of averages is also significantly better as compare to students of low achievers with experimental groups.

Hypothesis 3

There is no significant difference in critical thinking of male and female physics students taught using Problem-based learning.

Table 3

Comparing Mean Gain Scores in Critical Thinking Between Male and Female Students Within Experimental Groups

Gender	N	Mean	SD	t	df	p-value	Effect Size
Male	46	11.89	2.79	6.95	75	0.000	1.39
Female	31	7.37	3.23				

Table 3 shows a significant difference in mean gain scores in critical thinking in physics between male and female students of experimental groups, as indicated by $t(75) = 6.95$, $df = 75$ & p-value equal to 0.000. Hence, greater mean gain score ($M = 11.89$ & $SD = 2.79$) with the larger effect size of Cohen's d value = $1.39 > 0.8$ reveals that male

students had greater mean gain scores in critical thinking test in physics as compared to female students ($M=7.37$ & $SD= 3.23$) within experimental groups treated with problem based leaning approach.

DISCUSSION OF FINDINGS

Teaching and learning using the constructivist instructional approach such as, Problem-based learning was more effective than traditional lecture teaching techniques in improving the critical thinking abilities of 10th grade male and female physics students. It was found that the performance of students in the experimental group in the critical thinking test in physics treated with problems-based learning techniques was outstanding than the students in the control group taught through lecture teaching methods. It was also found that the performance of male students in the critical thinking test in physics was better as compared to female students in the experimental group. These findings are consistent with that reported by Baker, Anderson and Dorn (1993) that constructivist teaching approach helped students to enhance their critical thinking skills. Also, Beyer (1995) reported that Problem-based learning improved students' attitude towards the learning of physics. The most appropriate reason is that problem based learning techniques provides the opportunity for the active involvement of the students in teaching learning process and enhances their critical thinking skills most probability due to class participation in class discussion and presentation of the problem, than actively finding out the solution (Bellaera, Weinstein-Jones, Ilie, & Baker, 2021). The constructive theory shows that, students learn by building their own knowledge to understanding the real-life problematic situations. In the same way, Saeed et al. (2012) revealed that students of all ability levels showed better results in critical thinking test in physics than the students treated by Ausabel's meaningful learning approach as compared by students of control group treated by conventional teaching approach. Students treated by the problem solving ability teaching strategy were improved in there critical thinking skills (application, analysis, synthesis and evaluation) towards solving the daily life problem as reported by Yeo (2008). Similarly, Malik and Iqbal (2011) found that students of all the ability levels showed better results on problem solving ability test in chemistry.

CONCLUSION

Findings from this study has shown that constructivist approach such as Problem-based learning strategy has proved to be beneficial in the subject of physics for grade 10th students. This approach also enhances the critical thinking skills and academic achievement of students. The study also shows a significant difference in mean gain scores in critical thinking in physics between male and female students when taught using Problem-based learning in favour of the male gender.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations have been made:

1. Curriculum developers should incorporate Problem-based teaching and learning approach in the curriculum guidelines in Physics in view of its effectiveness in promoting critical thinking.

2. Pre-service teacher training institutions should incorporate constructivist instructional approach such as problem-based learning techniques as part of the training with emphasis on development of critical thinking skills among the students.

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