Developing 4Cs Skills through Problem-Based Learning Method in the Subject of Mathematics

Saima Akram
Mphil Scholar, University of Education, Attock Campus.

Dr. Umer Farooq
Assistant Professor, University of Education, Attock Campus.

Dr. Aneela Alam
Visiting Faculty, University of Education, Attock Campus.

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Abstract

The study aimed to use Problem-based learning (PBL) method for developing 4Cs skills (communication, collaboration, creativity, and critical thinking) among the students enrolled in the subject of mathematics. It was an experimental study where pre-test post-test equivalent group design was utilized. Study participants were 9th grade students. Based on the pretest findings, the sample was separated into two equal groups. The experimental group, received instruction using the problem-based learning method, was given opportunity to work independently, discussing work with their group members, assessing other fellows' work, and finally express their ideas in front of the entire class. Students in the control group, on the other hand, worked individually using traditional learning approaches. The procedure was carried out for a period of 30 days. The difference in the mean scores of the groups was determined using the t-test. The significant differences were found between both groups, with better results in the experimental group. The study concluded that PBL learning is preferable than traditional learning for developing 4Cs skills in the subject of mathematics.

Keyword: 4Cs skills, Problem Based Learning, Experimental study, Mathematics' learning, Pakistani context

1. Introduction

Education in the 21st century has become more hard, tough, and complex, demanding the application of higher-order thinking abilities in both learning and teaching. Critical thinking, creativity, collaboration, and communication (4 Cs) are all essential higher-order thinking skills that must be incorporated into the learning and teaching process. (Plucker et al., 2016). In order to adapt and tackle the ever-changing workforce, learners also require development of these 4Cs skills in their personality. If they get success in developing these traits or skills, they will be capable of being critical, intelligent, expressive, comprehensible, and creative.

However, in developing these skills, an individual can face unusual challenges, such as unpredictability and difficulty (Craig et al., 2018)

Today's students must be proficient in reading, writing, and mathematics, as well as critical thinking, creative thinking, and oral or written communication, in order to be prepared for a career that needs higher-order thinking and communication skills (Dede, 2010). In that manner, individual will know when and how to administer a type of program, being able to managed and analyze its progress and also be flexible enough even to address difficulties in a variety of contexts. As a result, someone with these abilities may not only assess, evaluate, and create the system they have chosen, but also administer it. This talent can help a person become more adaptable (Koh et al., 2015).

To develop these 4Cs skills, instead of just memorization, remembering and repetition, it is recommended that children should be immersed in problem-solving scenarios and tasks to achieve these skills (Craig et al., 2011). Furthermore, for learners to acquire these abilities, they should to ask HOT queries and give help to improve student literacy (Sulastri, Rintayati, & Sarwono, 2019). PBL is a learning strategy that focuses on the analysis, implementation, and discussion of a given topic (Aini et al., 2019; Masitoh & Fitriyani, 2018; Amalia et al., 2017). Problem-Based Learning is a constructivist educational approach. It is a learning approach in which students assess, analyze, and apply difficulties in small groups with peers. In that whole process the teacher serves as a facilitator, assisting students in developing and expressing their ideas (Asyari et al., 2016). This technique marks the student-centered learning origination as students are the key participants in the learning process. The role of teachers is only to support them while implementing learning activities and focusing on problem-solving in everyday situations (Sofyan et al., 2016).

By providing learning opportunities that improve 4Cs skills, like choosing the problem-based learning (PBL) technique, teachers can help their students acquire these required skills. PBL is a learner-centered approach in which students create their own ideas and acquire important knowledge with the help of the teacher instead of merely responding to the teacher's lecture. As a conclusion, PBL different from teacher-centered approaches in which school teachers give learners the information they need. PBL makes students into active "innovators of knowledge" rather than simply "consumers of information." (Othman, et al., 2014). Students in a PBL environment also acquire knowledge by trying to solve challenges. Students grow more self-sufficient and equipped to face the changing world with confidence. (Prettyman et al., 2012).

Mathematics is considered one of the most core subjects in the world of education that learners must study among a variety of courses (Meylinda & Surya, 2017; Usman Fauzan & Aldila Afriansyah, 2017; Arifin & Herman, 2018;). Each person has a distinct ability to comprehend mathematical concepts that has a big influence on one's ability to solve issues or arithmetic challenges. Many learners still believe that mathematics is chellenging, which makes it less attractive (Das, 2020; Arifah et al., 2019; Surya & Syahputra, 2017).

Students in the subject of mathematics may also get benefit from the problem-based learning technique for developing 4Cs skills. PBL is an excellent teaching strategy for building 4Cs abilities in mathematics (Harti & Agoestanto, 2019). PBL learning is a teaching approach in which students are exposed to mathematics on a regular basis in order to solve problems and evaluate their capacity to think critically, produce innovative ideas, and communicate with

other students. Students have a strong grasp of knowledge, which supports them in solving mathematics difficulties at all times (Roh, 2003). Therefore, the current study was carried out to see if problem-based learning is a productive method for developing 4Cs skills in the pupils, in the field of mathematics.

1.1 Problem Based Learning and 21st Century Skills

The goal of 21st century teaching is to teach students how to develop their own ideas and get feedback from others on how to make them better (Prettyman et al., 2012). Students who build these skills via authentic learning activities such as PBL are more equipped for the real world since they are studying a range of 21st century abilities. (Strimel & Teacher, 2014). As it is said that in order to properly acquire 21st century abilities, the students must learn from "relevant, real-world settings through participating in trustworthy PBL activities" (Partnership, 2015, p. 9). PBL have proven to boost comprehension of basic concepts and to foster innovative learning among the students (Ernst & Clark, 2007). Higher levels of both logical reasoning and imagination are needed for PBL in order to address the challenges. PBL can also help students to become more creative which involves coming up with original and novel concepts and products. It is said that creativity must be 'developed, not taught' (Kelley et al., 2019). Students must therefore be provided chances to work creatively in order to develop their creative potential. For this, the ideal settings for encouraging innovation are practices and lessons based on the problem-based design approach (Loveland & Dunn, 2014; Morrison et al., 2015). Research shows that students are better prepared to excel in the life by using PBL method (Mosier et al., 2016; Juliana & Lapek, 2018).

Instructional learning model of Makrakis and Kostoulas-Makrakis (2014) was adopted by the researcher for applying problem based learning in classroom. Re-conceptualizing the PBL model into current study is shown in Fig. 1. This framework serves as an organizer for developing, implementing, and evaluating a PBL strategy that is specifically tailored to the field of education for sustainability.

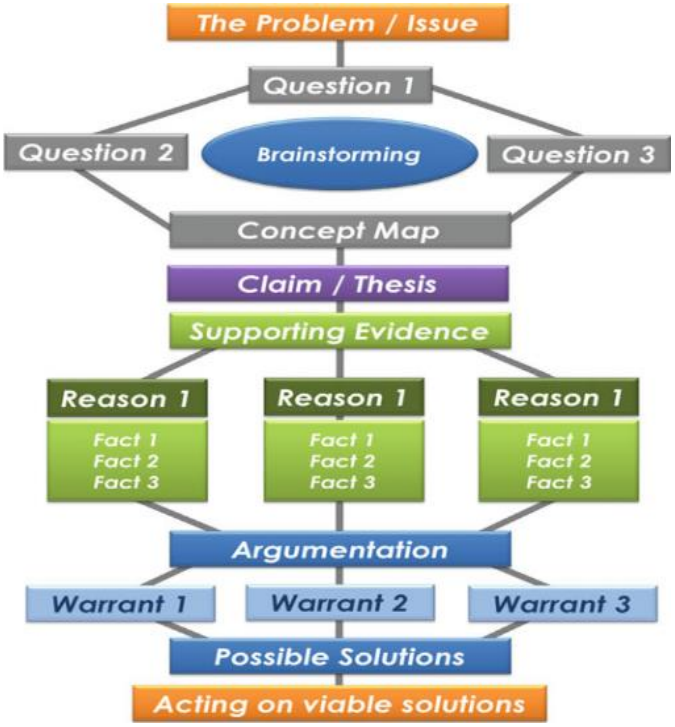


Figure 1 PBL instructional learning model by Makrakis & Kostoulas-Makrakis (2014)

The researcher modified the instructional learning model for applying problem based learning in classroom according to the needs of the study and keeping in view the contextual demands as shown in figure 2.

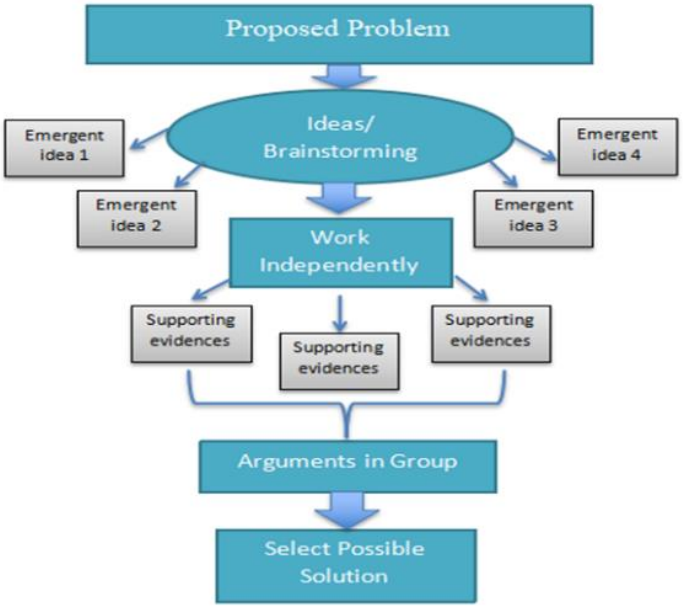


Figure 2 Modified PBL Instructional learning model

According to the modified model, in Problem Based learning, learners must be motivated and challenged by meaningful questions. Therefore, in the first phase, learners were engaged in the creative thinking process known as brainstorming to generate ideas, retrieve prior information, create or reconstruct knowledge. In this process students' were motivated to work independently on the specific problem and come up with an accurate solution. Students made decisions along the process based on the evidence and knowledge needed to reject, modify, or even confirm their initial opinions. After that students constructed strong arguments in group to support their evidence to solve the problem. A crucial component of PBL is giving students the chance to reflect on their own learning. Student reflections included more than just analysis of their own work; they also used to summarize their main findings, justify significant choices, and outline strategies for incorporating criticism and moving ahead. At the end, students present their work in front of the whole class.

1.2 Research Questions

What is the impact of problem-based learning on the development of 4Cs skills i.e. critical thinking, creativity, communication skills, and collaboration skills, among the students in the subject of mathematics?

1.3 Research Hypothesis

In this study the following hypotheses were tested:
Ho_1 Teaching through PBL method has no effect on developing 4Cs skills among students.
Ho_3 PBL has no effect on improving the critical thinking skills of the students.
Ho_4 PBL has no effect on improving the creativity skills of the students.
Ho_5 PBL has no effect on improving the communication skills of the students.
Ho_6 PBL has no effect on improving the collaboration skills of the students.

2. Methods

In this experimental study, a pretest-posttest equivalent group design was utilized. The study's participants were ninth-grade secondary school students. The students were split into two groups: experimental and control, depending on the results of the pre-test. The results of the pretest were utilized to compare the two groups. The sample for the study consisted of 40 students in the ninth grade, of whom 20 were in the control group who were instructed using the traditional approach and 20 were in the experimental group who were instructed using the problem-based learning method.

2.1 Data collection instrument

Teacher-made tests and collaboration rubric assessments were the two research tools used in the study. The researcher developed identical pre- and post-tests after thoroughly analyzing the test development procedure. To assess critical thinking skills, the researcher utilized the work of Firdaus et al. (2015). To evaluate the creativity the researcher followed the work of Saragih and Habeahan (2014). The indicators of mathematical communication ability, according to National Council for teaching mathematics (NCTM) which were chosen for current study are as follows: (1) be able to demonstrate and visual mathematical concepts in writing, orally, and visually; (2) be able to understand, interpret and comprehend

mathematical concepts both orally and visually; (3) ability to use terminology, mathematical notations, and structures to express concepts, report relationships, develop construct simulations.

The study included a subjective-type test to measure students' written communication, creativity, and critical thinking abilities. A committee of educators and specialists from the fields of education and mathematics evaluated the test's validity. The test-retest process was used to assess the test's reliability. The alpha value of 0.85 showed that the final test was reliable enough to be employed in this research. The collaboration rubric assessment, on the other hand, was utilized to assess students' collaboration skills in both groups. The basic indicators were group goals, group contribution, consensus building abilities, and time management. Pre and post assessments were also conducted to examine pupils' collaborative abilities.

2.2 Procedure of the Study

In current study, problem-based learning method was used for developing 21st century skills in the students. The participants of the study were equally divided in experimental and control group, based on their pre-test results. The same educational objectives and instructional course was covered by both groups. The control group was taught using the conventional lecture method which was shown in figure 3. Where a teacher presents a mathematical concept, reviews the procedure required to find the solution, and then student practice these procedure with additional problems.

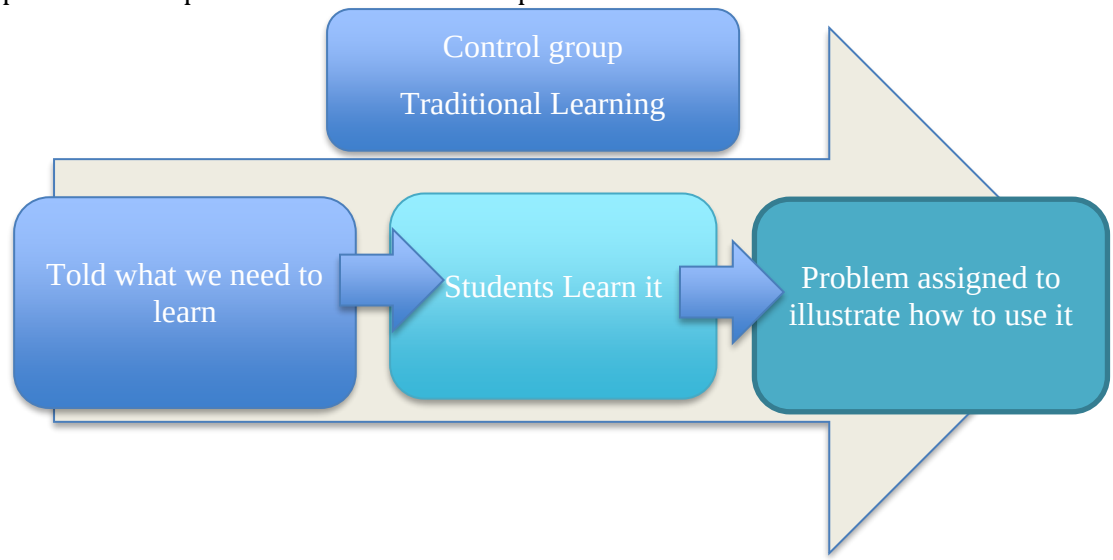
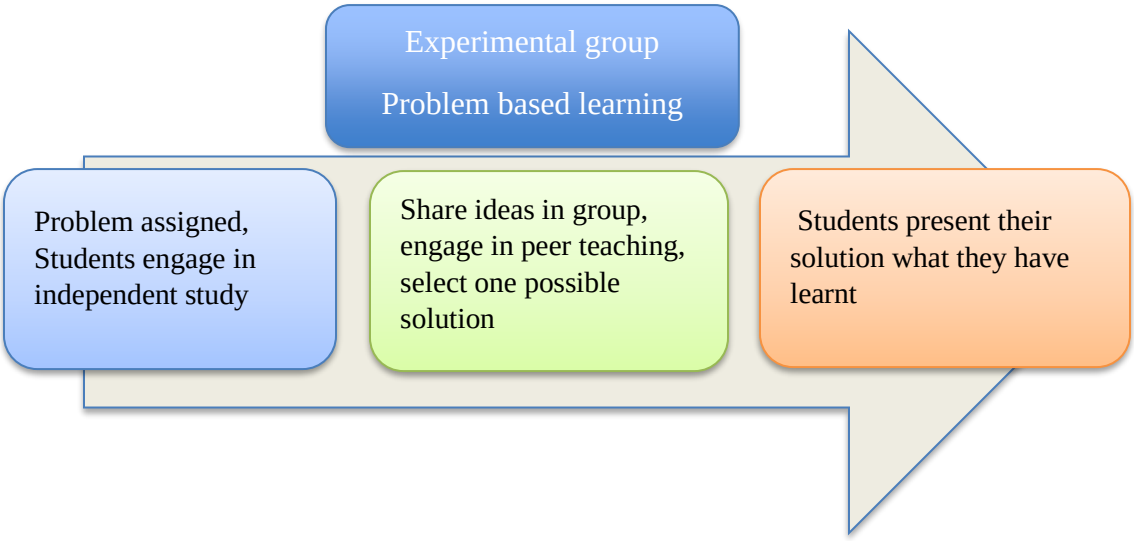


Figure 3 Control group Procedure

Figure 4 Experimental Group Procedure



The experimental group, on the other hand, utilized PBL method. During the class, experimental group was introduced with the idea or concept to be discussed. After that they were involved in brainstorming in which multiple ideas emerged. The researcher grant them 10-minutes to complete this task. Students were not allowed to assist one another during this process. For instance, there are numerous ways to solve some mathematical issues. Students provided a list of possible solutions to the issue and justify why one approach was better and more elegant than the other. After they had finished their individual assignments, the researcher gathered them in a small group to discuss their opinions with relevant evidences for why those opinions were accurate or superior to those of other participants' opinion. Additionally, the researcher gave them instructions to pick a particular idea they found more intriguing to investigate and to develop a statement that captured what they have learned. The entire process was closely studied by the researcher; how they collaborate, what they ought to accomplish in groups, how they talk to one another and use their ideas to solve the issue.

After that, one member of the group was chosen to presents their views with the entire class. In a similar manner, other members participated. Students were not permitted to help one another during the quizzes. Each pupil was therefore in charge of their own knowledge. The teacher declared the outstanding and good teams after calculating individual and team progress scores. The teacher served as a facilitator, responding to the students' queries and providing assistance as needed. For four weeks, the process was continued. At the end, to assess the students' progress in both group a posttest was taken. Figure 4 showed the experimental group procedure.

2.3 Data Analysis

The data was analyzed that was gathered through the pre-posttest and the assessment

rubric. Initially, preliminary analysis was done by applying descriptive statistics i.e mean, Standard Deviation. t-test was used to find out the significant difference between the experimental and control group students' 4Cs skills. Both in-group and between-group comparison was made. For which, independent and paired sample t-test was utilized. The data gathered through assessment rubric was non-parametric where only percentages were calculated. Hence, the difference in calculated percentages assisted in evaluating the difference in both experimental and control group.

3. Results and Discussion

3.1 Analysis of the 4Cs Skills of Experimental group

Table 1 Experimental group Pretest and Posttest finding

Group	N	M	SD	sig. (2-tailed)	t	df
Pretest	20	21.50	8.768			
				.000	13.494	19
Posttest	20	33.10	7.926			

To evaluate the students' progress in 4Cs Skills the results of experimental group pretest and posttest are presented in table 1. The results shows that between the pretest and the posttest (M = 21.50, SD = 8.768), (M = 33.10, SD = 7.926), the dependent sample t-test revealed a significant improvement in results (t (19) = 13.494, p = 0.000). According to the findings, students in the experimental group who were taught employing a problem-based approach in the classroom scored higher in the posttest.

3.2 Comparison of 4Cs skills of Experimental and Control Group

Table 2 Control and experimental group finding on the posttest

Group	N	M	SD	sig. (2-tailed)	t	df
Control	20	28.25	6.094			
				.036	2.169	38
Experimental	20	33.10	7.926			

The control and experimental group posttest are also compared to observe the difference in both group. The results of both group are presented in table 2. The experimental group students (M = 33.10, SD = 7.926) as compared to control group's (M = 28.25, SD = 6.094) demonstrated significantly better result (t (38) = 2.169, p = 0.036). The result shows that the experimental group 4Cs skills achievement were improved in the posttest as compare to

control group**.** So on the basis of result the null hypothesis was rejected.

3.3 Analysis of critical thinking skill

Table 3 Experimental group and control group critical thinking skill achievement on post-test.

Group	N	M	SD	sig. (2-tailed)	t	df
Control	20	10.80	2.504			
				.011	2.658	38
Experimental	20	13.25	3.274			

For more details, the results of each skill are evaluated individually. Students' achievement of critical thinking skill of both groups are presented in table 3. With an alpha level of.05 there was a remarkable difference in both group results (t (38) = 2.658, p = 0.011).The experimental group's average score was greater than the control group's. The result show that the experimental group critical thinking improved in PBL environment as compared to control group. On the basis of results the null hypothesis was rejected.

3.4 Analysis of creativity skill

Table 4 Experimental group and control group creativity skill achievement on the posttest.

Group	N	M	SD	sig. (2-tailed)	t	df
Control	20	9.60	3.218			
				.031	2.244	38
Experimental	20	12.00	3.539			

Students' achievement of creativity skills in both groups are presented in table 4. Both groups' creativity performance on the posttest was compared using an independent t-test. Table 5 reveals that the experimental and control groups had a remarkable difference in scores (t (38) = 2.244, p = 0.031), with the experimental group's mean score being greater than the corresponding group's mean score. Students' creativity skill increased as they immersed in PBL method. The result does not support the null hypothesis as per the null hypothesis was rejected.

3.5 Analysis of communication skill

Table 5 Experimental group and control group written Communication skill achievement on the posttest.

Group	N	M	SD	sig. (2-tailed)	t	df
Control	20	6.70	2.226			
				.041	2.114	38
Experimental	20	8.20	2.261			

To compare students' communication skills both group achievement are presented in table 5. Table 5 reveals that the both groups had a compelling difference in results (t (38) = 2.114, p = 0.041) as the experimental group performance was improved in posttest as compared to the control group's. The difference is also indicated by the mean of both groups. On the posttest, the experimental group's student communication skills become improved. On the basis of result the null hypothesis was rejected.

3.6 Analysis of collaboration skill

Table 6 Collaboration Rubric Assessment of experimental group and control group.

Group	N	Pre-Assessment	Post-Assessment
Control	20	40%	45%
Experimental	20	40%	65%

The collaboration skills was observed by the researcher. Researcher observed all the activities in group and provides an assessment on the observation sheet. The results of the collaboration skills assessment are presented in table shows that in post-rubric observation, the experimental group's cooperation ability improves more than the control group**.** This is because students in the PBL environment work in groups as well as individuals and show their work in front of the entire class. There was a remarkable difference in pretest and posttest observation on the bases of the result null hypothesis was rejected.

4. Discussion

The purpose of this study was to determine whether or not the traditional approach and the problem-based learning strategy had an impact on the growth of the four Cs in mathematics. It was found that the experimental group's posttest mean score was greater than the control group. After receiving instruction in problem-based learning, the experimental group was

given the freedom to work independently before presenting their ideas to a smaller group. Following that, students critiqued each other's work and shared their own work with their groups. Last but not least, a few students presented their work to the class as a whole. Students in the control group, however, work independently. They listen passively and don't notice anything going on around them. Based on their findings, the study's conclusions validated those of earlier investigations. It was found that students who apply 4C skills and study using a scientific way in the PBL model had higher-order thinking abilities (Widiawati et al., 2018).

Compared to the control group, the critical thinking abilities of the experimental group increased in the posttest. This is because PBL enables students to discuss their ideas with others, to determine the best solution, and to think critically about the challenges they solve. The entire process helps pupils become more critical thinkers. The results corroborate the findings of Puspita and Aloysius (2019), who found that problem-based learning is a successful strategy for fostering students' critical thinking abilities ((Puspita & Aloysius, 2019).

The posttest mean scores of the two groups differed significantly in the area of creativity skills. Students may only acquire material by memorization under the traditional learning approach, but this method gives them greater opportunity to work alone and in groups, apply their creative ideas, and present their ideas to the class as a whole. The findings corroborate those of Saragih and Habeahan (2014), who found that students' responses to questions on their mathematical creativity, when taught through PBL, included solutions that were more exceptional and noteworthy than those of CL students. On the post-test, the experimental group performed better when it came to written communication. Consequently, the null hypothesis was disproved. This may have been the result of students' limited speech and presentation chances in traditional learning environments. The results corroborate what Widiawati et al., 2018 found.

In the PBL, students' teamwork skills improve. Through group discussions, students learn to be more helpful and cooperative to one another in this setting than they would in a typical classroom. Under the traditional approach, students work independently and contact with other students seldom. After working individually for a while, the PBL-taught experimental group presented their findings to a smaller group. They assessed each other's work as well as shared their work with peers. Last but not least, a few students presented their work to the class as a whole. Conversely, students in the control group work independently.

CONCLUSION

For developing 4Cs skills among mathematical students, problem-based learning method should be considered. Rather than the traditional way, students' mathematics critical thinking abilities improved in a PBL setting in which they worked independently and in groups. The PBL method increases students' mathematical creativity and problem-solving skills as well. Through group discussion, students improve their communication and team work abilities as they worked in groups and present their work in front of the class. As the PBL approach emphasizes on the emerging skills and competences that learners require to be successful in the workplace of the twenty-first century, instructors should use it in the teaching. Students should be encouraged to collaborate in small groups and assure that each

member of the group participates equally. The teacher should serve as a facilitator and assist students when they need it. The educator should offer them with challenging real-world mathematics problems that inspire critical thinking. The teacher invites pupils to demonstrate their work to the entire class. It supports the growth of their communication skills. Future researchers should incorporate alternative instructional approaches that assist students' mastery of 4Cs skills into their studies.

The study's findings provide theoretical contributions by promoting theories and literature relevant to the PBL method, such as constructivism theory and PBL approaches are used in creating educational outcomes and learners' abilities to solve problems. The findings supported the hypothesis and the study's objective. This study also aimed to examine the effectiveness of implementing the PBL technique in learners. Furthermore, this study suggests that Pakistani teachers' traditional roles in the classroom be modified to allow learners to become more creative and autonomous learners. Furthermore, this PBL method will have an impact on students' everyday lives and future jobs, particularly female students in secondary schools. The technique and outcomes of this study will be useful for future research as well. The present study looked at the 4Cs skills in mathematics; future researchers should duplicate this study in other fields.

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