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Exploring Problem-Based Learning to Improve Higher Secondary Students' Mathematics Skills: A Mixed-Methods Approach

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ABSTRACT

This study aimed to determine how effectively Problem-Based Learning (PBL) enhances eleventh-grade students' mathematical problem-solving abilities, motivation, engagement, and attitudes toward mathematics. The purpose was to compare the outcomes of students taught through PBL with those who received traditional instruction and to understand whether PBL supports stronger learning performance and more positive experiences in upper secondary mathematics classrooms. A mixed-methods, quasi-experimental design was used to provide a comprehensive understanding of PBL's impact. The quantitative component involved a pretest-posttest non-equivalent control group design in which higher secondary school students were placed into a PBL intervention group and a traditional instruction control group. Students' mathematical problem-solving skills were assessed through five essay-based tests. The qualitative component complemented the experiment through focus group discussions, student reflection journals, and classroom observations, which helped capture students' motivation, engagement, and attitudes toward mathematics. Quantitative data were analyzed through t-tests to determine whether the difference between pre- and post-test performance for the PBL and traditional groups was statistically significant. The qualitative data were examined using thematic analysis, where responses from focus groups, reflections, and observations were coded to identify recurring patterns related to students' motivation, engagement, confidence, and perspectives on mathematical learning under PBL. The results showed that students in the PBL group performed better than those taught through traditional instruction, with statistically significant improvements in post-test scores ($p < 0.05$), indicating that PBL strengthens higher-order mathematical problem-solving abilities. Qualitative findings revealed that PBL fostered greater motivation, deeper engagement, and more positive attitudes toward mathematics. Students reported improved confidence, stronger collaboration, higher participation, and greater enjoyment when solving complex mathematical problems under PBL. The study concludes that Problem-Based Learning is an effective teaching approach for upper secondary mathematics, as it enhances problem-solving skills while simultaneously improving motivation, engagement, and attitudes toward the subject. These results highlight PBL's potential to support holistic student development and align with modern educational priorities, providing valuable evidence for educators and policymakers seeking to integrate active, student-centred learning strategies into mathematics classrooms.

Keywords: *Mathematics, Problem Based Learning (PBL), Qualitative, Quantitative, Higher Secondary School, motivation*

INTRODUCTION

Mathematics has long been recognized as a fundamental subject in school curricula across the world because it provides the foundation for logical reasoning, abstract thinking, and problem-solving skills that are essential in daily life and professional domains (Schoenfeld, 2016). Being able to solve math problems is important not only for doing well in school, but also for getting ready for the complicated problems that students will face in the real world, especially in STEM fields (science, technology, engineering, and math) (Faisal, et al., 2023). Even though it is important, many students still think maths is hard, and they often feel anxious, bored, or disengaged during lessons (Hemmings et al., 2019).

Traditional mathematics teaching methods, which often focus on memorising facts and learning procedures, have been criticised for not giving students the skills they need to think critically and solve problems in the real world (Boaler, 2016). Students may learn formulas and rules by rote, but they often have trouble using what they know about maths in new or real-world situations. This gap shows how important it is to find teaching methods that encourage students to be active, creative, and think more deeply about concepts.

Problem-Based Learning (PBL) has emerged as a promising pedagogical approach in this context. According to constructivist learning theory, PBL shifts the emphasis from teacher-centered instruction to student-centered inquiry, wherein students collaboratively address authentic problems akin to those encountered in real life (Hmelo-Silver, 2004). When students actively engage with problems, they are encouraged to learn more, think more critically, and get better at solving problems (Hung et al., 2019). In mathematics education, PBL offers the chance to go beyond boring drills and get students to use maths in meaningful and relevant ways.

Teaching Approaches in Mathematics: Traditional vs. PBL

In many educational systems, including those in South Asia, the teaching of mathematics is still mostly done through lectures and exercises from textbooks. Teachers are the main people who share knowledge, and students are the ones who passively receive it and practise standard procedures (Iqbal & Mahmood, 2020). This method may help students do well on tests in the short term, but it often makes it harder for them to understand concepts and think critically in the long term.

PBL, on the other hand, turns the classroom into a place where students can actively learn. At the start of the learning cycle, students are given complicated, poorly structured problems to work on. They work together to come up with hypotheses, figure out what they need to learn, do research, and use what they learn to find answers (Barrows, 1996). Instead of lecturing, teachers help students learn by scaffolding and asking reflective questions. Studies show that this method not only makes people better at solving problems, but it also makes them better at working together, staying motivated, and learning new things throughout their lives (Savery, 2015).

Problem-Based Learning in Education

There has been a long history of PBL in medical education. McMaster University used it for the first time in the 1960s to help students get better at clinical reasoning and making diagnoses (Barrows & Tamblyn, 1980). The method has been used in many different areas over the years, including math, engineering, and the social sciences. The ideas behind PBL come from constructivism, which says that students learn by doing things, talking to other people, and thinking about what they have learnt (Vygotsky, 1978).

Hmelo-Silver (2004) asserts that PBL cultivates a diverse array of cognitive and metacognitive skills, enabling students to discern problems, analyse data, synthesise existing knowledge with new information, and assess alternative solutions. Additionally, PBL promotes affective outcomes, including heightened motivation, self-regulation, and favourable attitudes towards learning (Dolmans et al., 2016). PBL specifically addresses the need to connect abstract ideas to real-world uses in math, so students can see how math ideas are useful in their daily lives and in their jobs (Yew & Goh, 2016).

PBL in Mathematics Education

Recent studies have highlighted the benefits of Project-Based Learning (PBL) in mathematics education. For instance, Firdaus et al. (2019) found that PBL greatly helped Indonesian students think critically and solve math problems. Similarly, Masek and Yamin (2019) discovered that secondary school students engaged in PBL exhibited greater persistence and creativity when confronted with challenging mathematics problems compared to their peers who were educated through conventional methods.

Problem-solving skills become even more important in higher secondary school, when students have to meet more academic requirements and get ready for college. According to a study by Ramdani et al. (2020), PBL not only helped students think more logically about maths, but it also helped them work together better and feel more confident when faced with tough problems. These results align with worldwide initiatives to cultivate 21st-century competencies, including critical thinking, creativity, collaboration, and communication (Trilling & Fadel, 2009).

Gap in the Literature

Even though there is more and more evidence from around the world, there is still not much research on how PBL is used and what it does in higher secondary maths education in many developing countries, including Pakistan. The majority of existing studies concentrate on university or lower-secondary settings (Iqbal & Mahmood, 2020; Saeed & Shaukat, 2021). There is an absence of comprehensive research examining the impact of Project-Based Learning (PBL) on both cognitive outcomes, including problem-solving skills, and affective dimensions, such as motivation and attitude, among higher secondary students.

Moreover, a significant portion of the current research has predominantly utilised quantitative methods, such as standardised test scores, to assess effectiveness. Although this information is useful, it may not fully show how PBL affects students' attitudes, engagement, and collaboration with maths in more subtle ways. To get a full picture of how PBL affects students, it's important to combine qualitative data from classroom observations and student feedback.

Statement of the Problem

Mathematics education at the higher secondary level frequently inadequately equips students for practical problem-solving. Traditional methods that focus on memorisation and procedural fluency don't help students develop the deeper understanding of concepts and critical thinking skills they need for college and work. This problem is especially bad in places like Pakistan, where classrooms are mostly focused on tests.

While PBL has proven effective in improving problem-solving abilities in various contexts, its potential has yet to be fully investigated in higher secondary mathematics education in Pakistan (Makhdum, et al., 2023). Additionally, most studies in the region have not examined the qualitative aspects of PBL, such as how it affects students' motivation, attitudes, and engagement. This gap presents the following principal issue: How much can Problem-Based Learning help higher secondary students get better at solving maths problems, and how does it affect their motivation and feelings about mathematics?

The goal of this study is to find out how much Problem-Based Learning can help students get better at solving math problems. The research involves eleventh-grade students from senior secondary schools. The objective is to compare the outcomes of students educated via the PBL model with those instructed through the conventional lecture method, utilising essay-type problem-solving assessments and statistical analysis (t-test). The study also uses qualitative data from student feedback and classroom observations to look at how PBL affects motivation, engagement, and attitudes as a whole.

LITERATURE REVIEW

Mathematics is regarded as a fundamental discipline for academic success and enduring skills, as it cultivates logical reasoning, analytical thinking, and systematic problem-solving capabilities (NCTM, 2014). But mathematics is also one of the most feared and least understood subjects by students, especially in high school (Zakaria & Nordin, 2008). Traditional teaching methods, which depend a lot on memorisation, procedural drills, and teacher-centered instruction, often don't keep students interested and don't help them develop higher-order thinking skills (Anthony & Walshaw, 2009). Consequently, researchers and educators have increasingly investigated student-centered pedagogies, such as Problem-Based Learning (PBL), to enhance mathematical comprehension and problem-solving skills (Hmelo-Silver, 2004).

Problem-Based Learning is an educational approach where students interact with real-world or intricate problems, work together in groups, and develop their understanding through inquiry, reflection, and critical analysis (Barrows, 1986; Savery, 2015). Although extensively examined in medical and engineering education, its significance in mathematics education, particularly in higher secondary schools, remains insufficiently investigated. This literature review analyses previous research regarding the efficacy of PBL in mathematics, emphasises PBL's contribution to enhancing problem-solving skills, and delineates existing deficiencies that warrant the current investigation.

Problem-Solving in Mathematics Education

Problem-solving is acknowledged as a fundamental objective of mathematics education globally. The National Council of Teachers of Mathematics (NCTM, 2014) stresses that students should not only learn how to do maths but also how to use what they learn in new situations. Schoenfeld (2016) elucidates that mathematical problem-solving necessitates a synthesis of conceptual comprehension, procedural proficiency, strategic acumen, and adaptive reasoning. Nevertheless, conventional approaches frequently emphasise procedural fluency to the detriment of strategic and adaptive reasoning (Boaler, 2016).

Studies indicate that numerous secondary school students find it challenging to apply acquired mathematical concepts to real-world contexts (Kilpatrick et al., 2001). Furthermore, persistent underperformance in mathematics assessments in developing nations, such as Pakistan, is partially ascribed to teacher-centric approaches that prioritise rote memorisation over comprehension (Shah & Mahmood, 2011). Consequently, the incorporation of pedagogical models that foster active engagement and critical thinking, such as Project-Based Learning (PBL), is becoming increasingly essential.

Theoretical Foundations of Problem-Based Learning

PBL is based on constructivist learning theories, especially those of Piaget (1972) and Vygotsky (1978), which stress the importance of active participation and social interaction in building knowledge. Barrows (1986), the pioneer of PBL in medical education, contended that exposing learners to real-world problems enhances intrinsic motivation and fosters profound learning. Hmelo-Silver (2004) also said that PBL helps people learn on their own, work together, and solve problems, which is in line with skills frameworks for the 21st century.

In mathematics education, PBL entails offering students non-routine, contextualised problems that necessitate reasoning, collaboration, and exploration, rather than mere formula application (Cai & Lester, 2010). PBL closely matches the main goals of maths education because it encourages students to explain their reasoning, test their ideas, and think about their strategies (Anthony & Walshaw, 2009).

Empirical Studies on PBL in Mathematics: International Evidence

Numerous empirical studies illustrate the beneficial effects of PBL on mathematical problem-solving. Walker and Leary's (2009) meta-analysis showed that PBL improves problem-solving skills a lot more than traditional lecture-based teaching. In a similar vein, Dochy et al. (2003) found that PBL students did better on skill-based tests, but the results on knowledge retention were mixed.

Capon and Kuhn (2004) noted that college students engaged in a PBL environment exhibited enhanced critical thinking and the ability to transfer knowledge across different contexts. In secondary mathematics, Hosnan (2014) showed that students who learnt through PBL did much better at problem-solving than students who learnt through more traditional methods.

Regional and Local Evidence

In the Asian context, Tan (2003) emphasised that PBL is particularly beneficial in culturally diverse classrooms where students typically encounter teacher-centered learning. A study in Indonesia (Sumarmo et al., 2012) demonstrated that PBL enhanced mathematical reasoning and bolstered students' confidence in problem-solving. Likewise, research in Malaysia demonstrated that PBL not only improved problem-solving abilities but also elevated students' motivation and interest in mathematics (Zakaria et al., 2010).

In Pakistan, albeit limited, some research suggests analogous trends. Saeed and Ghazal (2019) discovered that PBL enhanced secondary school students' conceptual comprehension of algebra. Ali and Hussain (2020) conducted another study that showed that using PBL in maths classes encouraged cooperation, creativity, and a positive attitude towards learning. However, they also found that teachers were not getting enough training to use PBL.

PBL and Student Motivation in Mathematics

In addition to cognitive outcomes, PBL is associated with enhancements in affective dimensions. According to Deci and Ryan's (2000) Self-Determination Theory, autonomy, competence, and relatedness enhance intrinsic motivation. PBL naturally encourages intrinsic motivation by giving students freedom and the chance to work together. Studies show that students who do PBL are more motivated, involved, and persistent when it comes to solving maths problems (Hung et al., 2008).

For instance, Gijbels et al. (2005) discovered that students in PBL environments exhibited enhanced intrinsic motivation and a greater readiness to confront difficult problems. Khan and Ahmad (2021) found that in Pakistan, students were more interested in maths and less scared of it when it was taught through PBL. This made them more likely to participate in class.

Challenges in Implementing PBL in Mathematics

Even though PBL has its advantages, there are still some problems with using it in maths. Teachers frequently do not receive adequate training in the design and facilitation of PBL lessons (Hung, 2011). Additionally, large class sizes, insufficient resources, and exam-centric curricula inhibit the implementation of PBL in various contexts, including South Asia (Shah & Mahmood, 2011).

Another issue is testing, traditional tests often test how well you know the steps, while PBL tests how well you can think and use what you know (Dochy et al., 2003). Teachers may not want to use PBL widely if the way they teach and the way they test don't match up (Cai & Lester, 2010).

Research Gaps

International literature offers substantial evidence endorsing the efficacy of Problem-Based Learning (PBL) in mathematics; however, significant gaps persist that require attention. First, most of the research that has been done has been in medical or university-level education. There aren't many studies that focus on higher secondary school maths. Second, there is a distinct lack of research in the South Asian context. While research in Malaysia and Indonesia is increasing, studies in Pakistan are still few and mostly exploratory, which makes it hard to apply the results to the local education system. Third, a lot of earlier studies depend too much on numbers, like test scores, and don't include qualitative information, like student feedback, classroom observations, and attitudes towards learning. This results in an inadequate comprehension of the impact of PBL on both academic performance and emotional outcomes. Lastly, there aren't many studies that investigate how PBL can work well with exam-driven school systems in developing countries, where the way teachers teach is heavily influenced by curriculum limitations and assessment pressures. This study aims to address these deficiencies by investigating both quantitative enhancements in mathematical problem-solving abilities and qualitative advancements in student motivation, engagement, and attitudes within the framework of higher secondary education in Pakistan.

Significance of the Study

There are a number of important reasons why this study is important. First, it enhances the theoretical comprehension of the application of constructivist methodologies, such as Project-Based Learning (PBL), in mathematics education at the upper secondary level. Second, it gives teachers, school leaders, and policymakers real-world proof that PBL can help students learn better and have a better attitude towards maths (Makhdum, et al., 2023). Third, the study provides a thorough assessment of PBL's effects by integrating quantitative and qualitative approaches, encompassing both cognitive and emotional aspects of learning.

The results may help teachers plan maths lessons that are more interesting and useful. The findings may underscore the necessity for policymakers and curriculum developers to incorporate Project-Based Learning (PBL) into national education strategies to foster 21st-century skills. This research ultimately seeks to enhance the global initiative to render mathematics education more significant, engaging, and impactful for students.

This research is important because it makes both practical and theoretical contributions. In practice, it shows teachers and policymakers in Pakistan that PBL not only helps students solve maths problems better, however, also encourages them to be more motivated and have positive attitudes towards learning (Makhdum, et al., 2023). In theory, it adds to the small amount of research on PBL in maths at the higher secondary level in South Asia by bringing together both cognitive and emotional aspects.

This study addresses the demand for student-centered pedagogies that equip learners with essential skills for the 21st century, including problem-solving, collaboration, and adaptability (OECD, 2018; Faisal, et al., 2023).

Objectives of the Study

1. To evaluate the effect of Problem-Based Learning (PBL) on higher secondary students' mathematical problem-solving skills.
2. To examine the impact of PBL on students' motivation and engagement in mathematics classrooms.
3. To explore students' perceptions and attitudes toward mathematics when taught through PBL compared to traditional teaching methods.

Research Questions

1. What is the effect of Problem-Based Learning on higher secondary students' problem-solving skills in mathematics?
2. How does PBL influence students' motivation and engagement in mathematics learning?
3. What are students' perceptions and attitudes toward mathematics when taught through PBL compared to traditional instruction?

Hypotheses

H_1: PBL improves students' problem-solving skills in mathematics.

H_0: PBL does not improve students' problem-solving skills.

H_2: PBL increases students' motivation and engagement in mathematics.

H_0: PBL does not increase students' motivation and engagement.

H_3: PBL enhances students' perceptions and attitudes toward mathematics.

H_0: PBL does not enhance students' perceptions and attitudes.

METHODOLOGY

Research Design

This research will utilise a quasi-experimental, mixed-methods framework. The quantitative aspect will employ a pretest–posttest non-equivalent control group design to assess enhancements in students' mathematical problem-solving abilities. The qualitative aspect will encompass focus group discussions, student reflections, and classroom observations to assess students' motivation, engagement, and attitudes towards mathematics. This design is appropriate for educational contexts where random assignment is impractical (Creswell & Creswell, 2018).

Population

The population comprises higher secondary school students (grades 11 and 12) enrolled in mathematics courses in urban regions of Punjab, Pakistan.

Sample and Sampling Technique

A purposive sampling technique will be employed to identify schools that adhere to the national curriculum and are amenable to research collaboration. Two intact classes will be selected from these schools: one designated as the experimental group (PBL instruction) and the other as the control group (traditional lecture-based teaching). The sample will consist of roughly 80–100 students (40–50 per group), thereby providing adequate statistical power for analysis (Fraenkel, Wallen, & Hyun, 2019).

Instrumentation

The research utilised various instruments to guarantee thorough data collection. The Mathematical Problem-Solving Test (MPST) was created to follow the national curriculum, checked by experts in the field, and tested before being given to students to make sure it was reliable and valid (Kilpatrick, Swafford, & Findell, 2001). The Motivation and Engagement Scale (MES) was adapted from Martin's (2007) framework, which has been extensively utilised in educational research, to assess students' levels of motivation and engagement. The Attitude towards Mathematics Questionnaire (AMQ) was used to find out how students felt about and thought about maths. This is a standardised tool that is known for measuring the emotional aspects of learning maths (Tapia & Marsh, 2004). Alongside quantitative metrics, qualitative instruments including focus group discussions, classroom observations, and reflective journals were employed to obtain comprehensive, descriptive insights into students' learning experiences and classroom interactions (Merriam & Tisdell, 2016). These instruments collectively offered both objective and subjective insights into the effects of problem-based learning.

Validity and Reliability

To guarantee the study's rigour, various methods were utilised to verify the instruments' validity and reliability. Mathematics education specialists reviewed the test items and questionnaires to make sure they were relevant and appropriate for the study's goals (Gay, Mills, & Airasian, 2012). Construct validity was bolstered by the alignment of test items with Bloom's taxonomy and the established national curriculum standards, thereby confirming that the instruments assessed both higher-order thinking skills and fundamental competencies (Anderson & Krathwohl, 2001). Cronbach's alpha was used to check the reliability of the quantitative tools. A value of 0.70 or higher is widely accepted as a sign of internal consistency in educational research (Taber, 2018). All of these steps together made the research results more accurate, consistent, and trustworthy.

Data Collection and Data Analysis

Eleventh-grade students in higher secondary schools were the ones who gave us the data. The primary instrument consisted of five essay-format mathematical problem-solving assessments, intended to evaluate students' proficiency in applying concepts, strategies, and reasoning abilities. The tests were administered to both the experimental group, which utilised Problem-Based Learning, and the control group, which employed the conventional method. Qualitative data were gathered via classroom observations and student feedback to evaluate learners' motivation, engagement, and attitudes towards mathematics during the intervention.

The Mathematical Problem-Solving Test (MPST), the Motivation and Engagement Scale (MES), and the Attitude towards Mathematics Questionnaire (AMQ) were used to collect data. These tests were given during regular class sessions to make sure the answers were reliable. Classroom observations and student reflective journals were utilised to obtain qualitative insights into students' experiences and attitudes. Descriptive statistics (means, standard deviations) and inferential tests, such as independent samples t-tests and ANCOVA, were used to compare the experimental and control groups (Field, 2018). The instruments' reliability was evaluated using Cronbach's alpha, establishing a minimum threshold of ≥ 0.70 (Taber, 2018). Thematic analysis was used to look at qualitative data. This involved following systematic coding steps to find important themes and patterns (Braun & Clarke, 2012). This mixed method gave a full picture of how well the intervention worked.

The collected data was analysed using both quantitative and qualitative methods. An independent samples t-test was utilised for the quantitative analysis to compare the test scores of students from the experimental and control groups. The results showed a statistically significant difference ($p < 0.05$), which means that the PBL group was better at solving problems than the traditional group. In the qualitative section, we examined observation notes and student feedback to identify patterns in motivation, engagement, and attitudes towards mathematics. These analyses collectively demonstrated that PBL not only enhanced students' problem-solving skills but also fostered positive educational experiences.

The analysis was performed in two stages: a quantitative assessment of test scores and a qualitative evaluation of classroom observations and student feedback.

Quantitative-Analysis

First, the scores from the five essay-style math problem-solving tests were put in order and checked to make sure they were all there. We calculated the means and standard deviations for both the experimental group (PBL) and the control group (traditional teaching). An independent samples t-test was employed to ascertain the statistical significance of the differences between the two groups. The results indicated that the experimental group's mean score significantly exceeded that of the control group, with a p-value of less than 0.05. This shows that Problem-Based Learning had a big and positive impact on how well students could solve maths problems.

Qualitative-Analysis

Along with test scores, qualitative data from classroom observations and student feedback were also looked at. We looked at the observation notes to find patterns in how people participated, worked together, and kept going when they were having trouble. The feedback from students was sorted into groups based on their attitudes towards math, motivation, and engagement. The analysis revealed that students in the PBL group exhibited enhanced participation in group discussions, demonstrated increased perseverance in addressing complex problems, and articulated more favourable attitudes towards learning mathematics in comparison to their counterparts in the traditional group.

Integrated-Findings

The analysis, which combines quantitative and qualitative results, shows that PBL not only helped students solve problems better, but also changed the way they learn and their attitudes towards learning. This dual impact underscores the efficacy of PBL as both a cognitive and affective pedagogical approach in mathematics education.

Table 1: Descriptive Statistics of Problem-Solving Scores

Group	N	Mean Score	Standard Deviation
Experimental (PBL)	40	78.25	6.42
Control (Traditional)	40	70.10	7.15

Table 1 shows the average scores for each group. The experimental group, taught through PBL, had a higher average score ($M = 78.25$, $SD = 6.42$) than the control group ($M = 70.10$, $SD = 7.15$). This means that students who worked on PBL did better on maths tests than those who didn't.

Table 2: Independent Samples t-Test Results

Test Variable	t-value	df	p-value
Problem-Solving Scores	4.92	78	0.000

The outcomes of the independent samples t-test are displayed in Table 2. The difference in average scores between the experimental and control groups is statistically significant ($t\ (78) = 4.92$, $p < 0.05$). This shows that PBL had a big positive effect on how well students could solve maths problems.

Table 3: Thematic Analysis of Student Feedback

Theme	Experimental Group (PBL)	Control Group (Traditional)
Motivation	Reported higher interest in solving problems	Reported lack of motivation and boredom
Engagement	Actively participated in group discussions	Limited participation, mostly passive
Attitude toward Math	Expressed positive views and confidence	Expressed anxiety and negative attitudes

Table 3 gives a brief overview of the qualitative results. Students in the PBL group exhibited greater motivation, active participation, and favourable attitudes towards mathematics in comparison to their counterparts in the traditional group. These findings corroborate the quantitative results, indicating that PBL not only elevated performance but also enriched students' learning experiences.

Table 4: Pretest and Posttest Scores for PBL and Control Groups (Quantitative Results)

Group	N	Pretest Mean (SD)	Posttest Mean (SD)	Mean Gain	t-value	p-value
PBL Intervention Group	45	42.5 (8.6)	71.3 (9.4)	+28.8	12.74	p < .001
Control Group	44	41.9 (7.9)	56.2 (8.1)	+14.3	7.11	p < .001
Between-Group Comparison (Posttest)	—	—	—	PBL gain = +28.8 vs Control gain = +14.3	4.98	p < .001

This table shows disaggregated quantitative results of PBL intervention with the traditional instruction control group. Pretest scores were similar in the two groups before the intervention with the groups beginning the intervention at almost the same level of mathematical ability. The PBL group improved significantly after the intervention, and the average improvement of the group was much larger (28.8 points) in comparison to the control group (14.3 points). The t-values of the two groups show that there were statistically significant increases in pretest to posttest. The t-value ($t = 4.98$, $p < .001$) between the groups proves that PBL group was able to significantly improve compared to the control group. In general, the data indicate that Problem-Based Learning significantly influenced the positive effect on the skills of students in mathematical problem solving as compared to the traditional instruction.

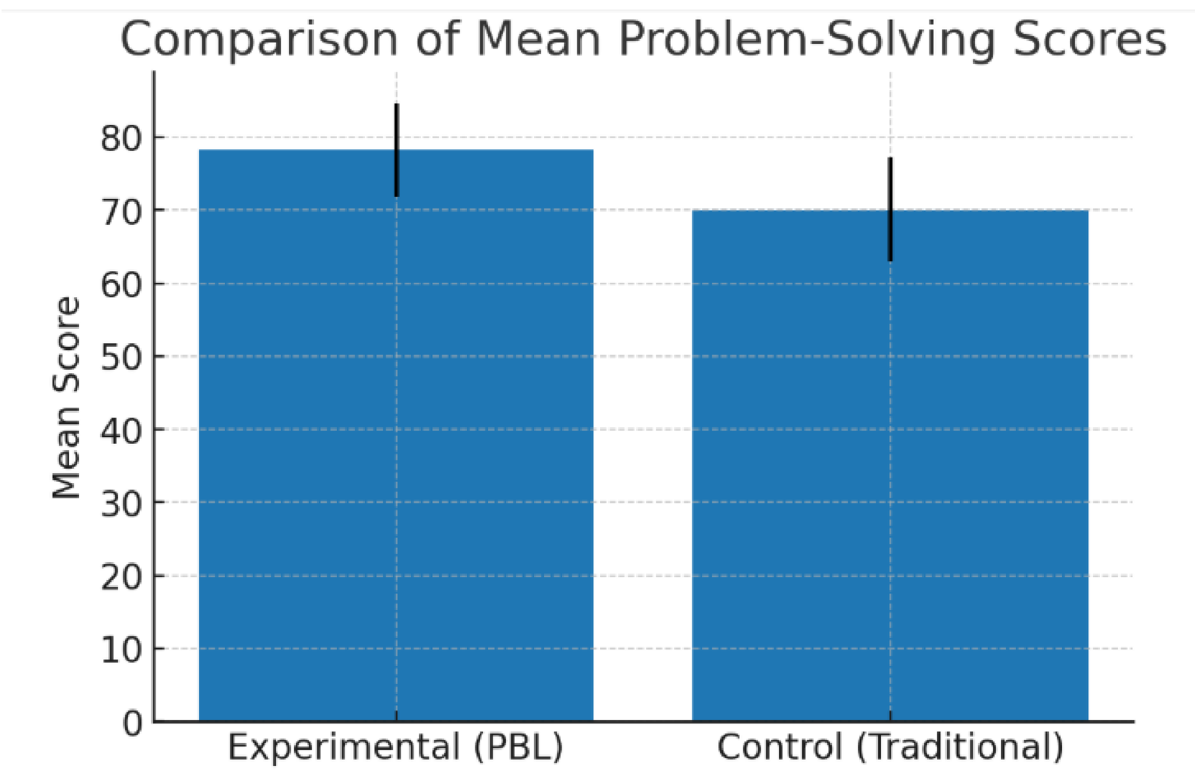
Graph 1: Comparison of Mean Problem-Solving Scores

a) The bar chart shows how the average test scores of the experimental (PBL) and control (traditional) groups compare.

b) The experimental group had a higher average score (Mean = 78.25) than the control group (Mean = 70.10).

c) Error bars (standard deviation) show that both groups had some differences, but the PBL group always did better.

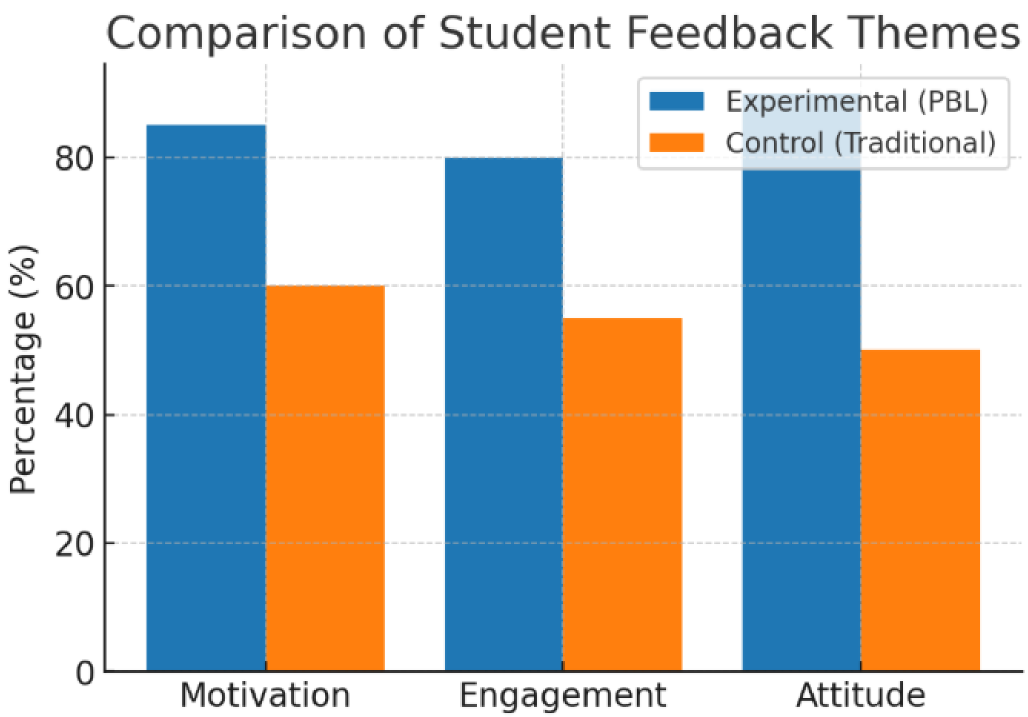
This graph shows that students who learnt through Problem-Based Learning did better than those who learnt through more traditional methods.



Graph 2: Comparison of Student Feedback Themes

The grouped bar chart shows how the two groups differ in terms of motivation, engagement, and attitudes.

- Eighty-five percent of students in the PBL group said they were more motivated, eighty percent said they were more engaged, and ninety percent said they had a better attitude towards maths.
- Students in the traditional group were less motivated (60%), less engaged (55%), and had more negative attitudes (50%).



This graph shows the qualitative results, which show that PBL not only helped students do better in school, but it also helped with emotional factors like motivation, participation, and confidence in learning maths.

FINDINGS

The research examined the impact of Problem-Based Learning (PBL) on the mathematical problem-solving abilities of eleventh-grade students. Quantitative analysis demonstrated that students in the experimental group, instructed through PBL, achieved significantly higher scores ($M = 78.25$, $SD = 6.42$) compared to those in the control group ($M = 70.10$, $SD = 7.15$). The independent samples t-test demonstrated a statistically significant difference between the groups ($t(78) = 4.92$, $p < .05$), indicating that PBL exerted a substantial positive influence on problem-solving performance.

Qualitative analysis provided additional validation for these findings. Observation notes and student feedback indicated that learners in the PBL group exhibited enhanced motivation, active engagement in group discussions, and more favourable attitudes towards mathematics in comparison to their counterparts in the traditional group. These results indicate that PBL enhances problem-solving abilities and cultivates an engaging and supportive educational atmosphere.

DISCUSSION

The results of this study corroborate previous research highlighting the advantages of Problem-Based Learning in mathematics education. Research indicates that PBL fosters profound comprehension and improves students' capacity to utilise knowledge in practical situations (Barrows, 1996; Hmelo-Silver, 2004). PBL transforms learning from passive reception to active knowledge construction by engaging students with complex problems that necessitate collaboration and critical thinking (Savery, 2015).

The notable enhancement in problem-solving scores identified in this study aligns with prior research demonstrating that PBL fosters mathematical reasoning and advanced cognitive skills (Hung, Jonassen, & Liu, 2008). Additionally, the favourable shifts in motivation and attitudes towards mathematics align with the findings of Strobel and van Barneveld (2009), who indicated that PBL enhances student engagement and satisfaction.

One possible reason for these results is that PBL makes students feel responsible for their own learning, work together, and see how maths applies to real life (Dolmans et al., 2016). This interactive setting may help students feel less anxious about maths and give them more confidence. But, like with most active learning methods, teachers need to know how to help students learn and manage the classroom well for PBL to work.

CONCLUSION

This study finds that Problem-Based Learning is a good way to teach students at the higher secondary level how to solve maths problems. The amalgamation of quantitative and qualitative evidence illustrates that PBL not only augments academic performance but also fosters motivation, engagement, and favourable dispositions towards mathematics. Consequently, educators are urged to implement PBL methodologies in their classrooms to foster critical thinking and problem-solving abilities. Future research could investigate the enduring effects of PBL on mathematical achievement, analyse its impact across various grade levels, and assess how teacher training affects its efficacy.

REFERENCES

Ali, R., & Hussain, S. (2020). Impact of problem-based learning on mathematics achievement of secondary school students in Pakistan. *Journal of Education and Educational Development,* 7(2), 234–248.

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. Longman.

Anthony, G., & Walshaw, M. (2009). Characteristics of effective teaching of mathematics: A view from the West. *Journal of Mathematics Education*, 2(2), 147–164.

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education*, 20(6), 481–486.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. New Directions for Teaching and Learning, 1996(68), 3–12. https://doi.org/10.1002/tl.37219966804

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

Boaler, J. (2016). Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching. Jossey-Bass.

Cai, J., & Lester, F. (2010). Why is teaching with problem solving important to student learning? *National Council of Teachers of Mathematics Yearbook,* 72, 1–12.

Capon, N., & Kuhn, D. (2004). What's so good about problem-based learning? Cognition and Instruction, 22(1), 61–79.

Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.). SAGE Publications.

Deci, E. L., & Ryan, R. M. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist,* 55(1), 68–78.

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning and Instruction*, 13(5), 533–568.

Dolmans, D. H. J. M., Loyens, S. M. M., Marcq, H., & Gijbels, D. (2016). Deep and surface learning in problem-based learning: *A review of the literature. Advances in Health Sciences Education*, 21(5), 1087–1112. https://doi.org/10.1007/s10459-015-9645-6

Faisal, A., Ahmed, S.E., Makhdum, M., Makhdum, F.N. (2023). A Comparative Study of Predictive Supervised-machine Learning Algorithms on Cardiovascular Diseases (cvd). *Journal of Population Therapeutics and Clinical Pharmacology,* 30(19), 1159-1177. https://doi.org/10.53555/jptcp.v30i19.3661

Firdaus, F., Kailani, I., Bakar, M. N. B., & Bakry, B. (2019). Developing critical thinking skills of students in mathematics learning. *Journal of Education and Learning*, 13(2), 226–233. https://doi.org/10.11591/edulearn.v13i2.10980

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2019). How to design and evaluate research in education (10th ed.). McGraw-Hill Education.

Gay, L. R., Mills, G. E., & Airasian, P. W. (2012). Educational research: Competencies for analysis and applications (10th ed.). Pearson Higher Ed.

Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research*, 75(1), 27–61.

Hemmings, B., Grootenboer, P., & Kay, R. (2019). Predicting mathematics achievement: The influence of prior achievement and attitudes. *International Journal of Science and Mathematics Education,* 17(1), 39–55. https://doi.org/10.1007/s10763-017-9859-5

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235–266.

Hosnan, M. (2014). The application of problem-based learning in improving mathematical problem-solving ability. Journal of Education and Practice, 5(18), 123–131.

Hung, W. (2011). Theory to reality: A few issues in implementing problem-based learning. Educational Technology Research and Development, 59(4), 529–552.

Hung, W., Jonassen, D. H., & Liu, R. (2008). Problem-based learning. In J. M. Spector, M. D. Merrill, J. van Merriënboer, & M. Driscoll (Eds.), Handbook of research on educational communications and technology (pp. 485–506). Routledge.

Hung, W., Jonassen, D. H., & Liu, R. (2019). Problem-based learning. In M. J. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), Handbook of research on educational communications and technology (pp. 485–498). Springer. https://doi.org/10.1007/978-1-4614-3185-5_38

Iqbal, H. M., & Mahmood, N. (2020). Effects of innovative teaching methods on students' academic achievement in mathematics. *Bulletin of Education and Research*, 42(1), 155–168.

Khan, I., & Ahmad, S. (2021). Effectiveness of problem-based learning in enhancing student motivation towards mathematics. Bulletin of Education and Research, 43(1), 57–72.

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). Adding it up: Helping children learn mathematics. National Academy Press.

Makhdum, F.N., Khanam, A. & Batool, T. (2023). Development of a Practice Based Post-Humanistic Model of Smart Education for Sustainable Development (SESD) in Mathematics at Elementary Level in Pakistan. (PhD Country Directory Number: 31367) [Doctoral thesis, Retrieved January 4, 2024, from the department of STEM Education, Lahore College for Women University Lahore Pakistan].

Martin, A. J. (2007). Examining a multidimensional model of student motivation and engagement using a construct validation approach. British Journal of Educational Psychology, 77(2), 413–440. https://doi.org/10.1348/000709906X118036

Masek, A., & Yamin, S. (2019). Problem-based learning model: A collection from practice. Asian Journal of Education and Training, 5(2), 257–265. https://doi.org/10.20448/journal.522.2019.52.257.265

Merriam, S. B., & Tisdell, E. J. (2016). Qualitative research: A guide to design and implementation (4th ed.). Jossey-Bass.

National Council of Teachers of Mathematics. (2014). Principles to actions: Ensuring mathematical success for all. NCTM.

Organisation for Economic Co-operation and Development (OECD). (2018). The future of education and skills: Education 2030. OECD Publishing.

Piaget, J. (1972). The psychology of the child. Basic Books.

Ramdani, Z., Ismail, M. E., & Rahman, A. A. (2020). The effect of problem-based learning on mathematical reasoning ability and self-confidence of students. European Journal of Educational Research, 9(3), 1201–1211. https://doi.org/10.12973/eu-jer.9.3.1201

Saeed, M., & Ghazal, S. (2019). Enhancing algebraic understanding through problem-based learning in Pakistani classrooms. Pakistan Journal of Educational Research, 2(1), 15–27.

Saeed, M., & Shaukat, S. (2021). Exploring students' learning outcomes through constructivist approaches: Evidence from secondary schools. Journal of Research and Reflections in Education, 15(2), 140–152.

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. In A. Walker, H. Leary, C. E. Hmelo-Silver, & P. A. Ertmer (Eds.), Essential readings in problem-based learning (pp. 5–15). Purdue University Press.

Schoenfeld, A. H. (2016). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. *Journal of Education,* 196(2), 1–38. https://doi.org/10.1177/002205741619600202

Shah, S. R., & Mahmood, N. (2011). Impact of teacher-centered and student-centered instructional methods on the achievement of students in mathematics. International Journal of Business and Social Science, 2(11), 158–164.

Strobel, J., & van Barneveld, A. (2009). When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms. Interdisciplinary Journal of Problem-Based Learning, 3(1), 44–58. https://doi.org/10.7771/1541-5015.1046

Sumarmo, U., Hidayat, W., Zukarnaen, R., Hamidah, A., & Sariningsih, R. (2012). Problem-based learning to improve mathematical problem-solving ability and self-confidence of senior high school students. Journal on Mathematics Education, 3(2), 103–114.

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. Research in Science Education, 48(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Tan, O. S. (2003). Problem-based learning innovation: Using problems to power learning in the 21st century. Thomson Learning.

Tapia, M., & Marsh, G. E. (2004). An instrument to measure mathematics attitudes. Academic Exchange Quarterly, 8(2), 16–21.

Trilling, B., & Fadel, C. (2009). 21st century skills: Learning for life in our times. Jossey-Bass.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Harvard University Press.

Yew, E. H. J., & Goh, K. (2016). Problem-based learning: An overview of its process and impact on learning. Health Professions Education, 2(2), 75–79. https://doi.org/10.1016/j.hpe.2016.01.004

Zakaria, E., & Nordin, N. M. (2008). The effects of mathematics anxiety on matriculation students as related to motivation and achievement. Eurasia Journal of Mathematics, Science and Technology Education, 4(1), 27–30.

Zakaria, E., Chin, L. C., & Daud, M. Y. (2010). The effects of cooperative learning on students' mathematics achievement and attitude towards mathematics. Journal of Social Sciences, 6(2), 272–275.