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PROBLEM-BASED LEARNING APPROACH AND MATHEMATICS PROBLEM-SOLVING PERFORMANCE OF GRADE 9 STUDENTS

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Abstract:
This research assessed the efficacy of Problem Based-Learning (PBL) approach and the math problem-solving performance of the Grade 9 students in one of the boarding schools in Talisay City, Cebu, for school year 2024-2025. This study was conducted using a descriptive correlational research design with 232 respondents selected through stratified random sampling. Two research instruments were facilitated, which were the math problem-solving test questionnaire and the respondent's perception of the efficacy of the elements of PBL. The data gathered were treated using the weighted mean, standard deviation, Pearson product-moment correlation, and t-test. The results revealed that the elements of the PBL, the authentic elements, developing elements, collaborative elements, and authentic assessment elements were evident in mathematics instruction and assessment as perceived by the respondents. Results also showed that the majority of the respondents performed satisfactorily in their math problem-solving activities, while a significant number performed above the average. Further analysis revealed that there was a significant relationship between the efficacy of problem-based learning and math problem-solving performance of the respondents. It is concluded that PBL helps the respondents in analyzing math problems, developing solutions, and applying knowledge in practical contexts, which are necessary in real life. Hence, it is recommended that PBL be widely used in teaching mathematics.

Keywords: mathematics education, problem-based learning, math problem-solving performance, descriptive-correlational design, Talisay City, Cebu

1. Introduction

Problem-solving activity in Mathematics poses significant problems among students in many aspects. Several factors, including short-term memory, long-term memory, the capacity to recall mathematical knowledge, and visual and spatial perceptual abilities, might contribute to students' poor understanding of mathematical problems (Gafoor &

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Kurukkan, 2015). Students' inability to understand the problem, what data should be used to solve it, and what to do with the problem's provided facts are issues related to analytical and critical thinking abilities, which are crucial for solving math problems. By encouraging students to look for new approaches when dealing with mathematics problems, critical thinking helps improve creative problem-solving solutions (Su *et al.*, 2015). It is suggested to practice active engagement, transfer of learning, understanding theories, and thinking map skills as ways to enhance critical thinking (Saunders & Wong, 2020). In this way, it will enable students to apply their prerequisites and prior lessons that are crucial to developing a solution and interpreting them when presented with math-related problems.

Every mathematical problem requires basic concepts and skills for them to master the concept and solve a specific problem. Additionally, significant amounts of prior knowledge and abstract thought are required to comprehend basic mathematical concepts and acquire the requisite abilities (Wakhata *et al.*, 2023). Through this, the students will be able to familiarize and understand concepts such as manipulating variables in Algebra and solving word problems.

Problem-based learning (PBL) is an approach that makes use of real-world problems to enrich students' critical thinking and problem-solving skills (Razak *et al.*, 2022). It is introduced to help the students deal with the problems they have encountered when solving Math-related problems (Obut *et al.*, 2024). The PBL approach develops critical thinking, problem-solving abilities, and a deeper comprehension of math concepts by engaging students in real-world problems (Manuaba *et al.*, 2022). It is a learner-centered approach since students discuss groups' pertinent issues before the preparation and self-study process to recall their prior knowledge (Tong *et al.*, 2021). Additionally, this approach aids students in acquiring skills that are essential in real-life circumstances, like teamwork, communication, and self-directed learning (Warnock & Mohammadi-Aragh, 2016).

In the teaching process using PBL, the approach begins with introducing meaningful, challenging, and contextualized, real-world problems to the students that require critical thinking and problem-solving skills (Smith *et al.*, 2022). Students will then brainstorm and discuss possible solutions and approaches to solve the problem (Yew & Goh, 2016). Necessary resources and guidance to support students' exploration and understanding of mathematical concepts related to the problem are then provided. It is then that students are guided in analyzing and evaluating their solutions, helping them identify errors and misconceptions as they try to present an answer to the problem (Samsudin *et al.*, 2021). This encourages students to reflect on and do self-assessments of what they have learned and will be capable of assessing their skills in solving word problems (Kumar *et al.*, 2023). The outcome of PBL is manifested in the ability of the students to analyze problems, interpret outcomes, improve problem-solving skills, have a deeper understanding of mathematical concepts, and have increased motivation and engagement to solve problems.

There are reports showing the impact of PBL in improving the students' ability to solve problems. The strategy has been shown to boost students' interest in mathematics,

increase their capacity for problem-solving, and enhance their aptitude for learning mathematics (Xia *et al.*, 2008). Thus, it is anticipated that using the PBL technique will improve students' mathematics learning outcomes.

The conventional way of teaching, which focuses on teacher-centered instruction, leads to passive learning. According to Lapek (2018), a teacher-led approach can hinder the development of essential 21st-century skills such as critical thinking and problem-solving skills. This approach leaves a little room for learners to engage in active exploration, collaboration and real-world problem-solving (Dole *et al.*, 2016). In contrast, approaches like PBL actively involve students in discovering solutions to real-life issues, equipping them with skills for independent inquiry and adaptability in rapidly changing environments.

Thus, the following circumstances prompted the researchers to investigate the relationship between the mathematical performance of the students on a given problem-solving activity and their perceptions of using a PBL to understand their experiences in solving Math-related problems and help them improve their performance in Mathematics.

2. Literature Review

This section highlights literature and studies that focus on how PBL enhances the students' competence in solving problems, specifically in Mathematics.

PBL originated in higher education contexts during the late 1960s. It is described as a learning approach that emerges from the process of actively engaging with and working toward understanding or resolving a problem (Smith *et al.*, 2022). This approach allows students to collaborate in groups to tackle real-world tasks or challenges (Matlala, 2021). This hands-on approach encourages active engagement and problem-solving skills development among students (Tong *et al.*, 2021).

Hmelo-Silver (2004) noted the goals of PBL:

1) Developing the ability to apply learned concepts,
2) Cultivating efficient skills in solving problems,
3) Enhancing self-paced learning (SDL),
4) Promoting group work proficiency, and
5) Fostering self-motivation.

These elements help students acquire knowledge that can be applied in various contexts, allowing adaptability and versatility. This also promotes student autonomy during the mastery of the concept. This resulted in students exploring, discovering, and engaging actively in their educational journey.

Several authors also mentioned PBL's techniques and the particular skills that were developed, such as the capacity to think critically, evaluate, and solve complex, real-world problems; to cooperate; to exhibit effective communication skills; and to use content knowledge and intellectual skills to become lifelong learners (Duch *et al.*, 2001). Problems should also be realistic and relevant to learners' experiences to boost intrinsic

motivation. Good problems give students feedback so they may assess how well their knowledge, reasoning, and learning techniques worked (Hmelo-Silver & Eberbach, 2011) The effectiveness of PBL is often assessed by examining students' learning outcomes, cognition, metacognition, attitudes, and actions across different teaching approaches. These factors are commonly used as indicators to gauge the impact of PBL in promoting student learning and development (Lu *et al.*, 2018). Several studies have illustrated that PBL influences students' mathematical skills, including problem-solving skills.

In a study by Tong *et al.* (2021), findings reveal that most students in group activities that use the approach allow them to improve their calculation and problem-solving skills compared to the group of students that uses the conventional method. Students find the activity exciting and show eagerness in learning to take similar lessons in the future. Math learning activities by nature facilitate critical thinking development by utilizing a contextualized problem in the PBL. Additionally, Aslan (2021) affirmed that students' learning achievement with the PBL approach was significantly higher than that of students in a group with the conventional approach. This illustrates that the PBL approach has influenced the students' way of approaching the mathematical problems presented to them.

Hu (2017) also found that students develop strong mathematical thinking habits in their problem-solving through the guidance of the teacher. It allows them to explore the inherent nature of mathematics on their own and develop an interest in mathematics based on their desire to foster creative awareness about mathematics. It also indicates that the use of PBL offers an atmosphere where students can solve math problems independently without a lot of help from the learning providers. However, students may seek suggestions if in case they are faced with some problems that are difficult to resolve (Jian & Yang, 2022).

In a research conducted by Smith *et al.* (2022) on the set of principles of PBL model if STEM education schools, the following principles are generated through data analysis: (a) It emphasizes the development of adaptable knowledge, skills, and capabilities, (b) It promotes active and strategic metacognitive reasoning, which involves students thinking about their own thinking, (c) It fosters collaboration among students, driven by their intrinsic motivation and (d) It presents problems that are embedded in real and rich contexts.

Padmavathy and Mareesh (2013) also conducted a study on problem-based learning in Mathematics and discovered that the PBL approach is more effective in teaching Mathematics where teachers can develop critical thinkers, decision-makers, and problem solvers, which is much necessary in the competitive world. It impacts learners to have a positive attitude toward the Math subject, increases active participation, motivation, and interest, and improves their performance.

A study on the influence of PBL senior secondary school students' performance reported a difference in the students' performance using PBL and the traditional teaching method (Fatade, 2013). The results illustrate that students performed better in the interactive classroom set-up of the PBL, where students were challenged through the questions and reasoning provided. This is also affirmed in the study of Etiubon and

Ugwu (2016), which shows that students' understanding of Mathematics using PBL is achieved through highly interactive and stimulating methods, where questions are used to challenge students' critical thinking in relation to the assigned tasks. In this scenario, students were able to own up their learning and learn independently. Exposing students to a variety of routine and non-routine problems allows them to apply mathematical concepts and understanding to real-life situations (Tupas, 2012). This approach makes mathematics more relevant and enhances students' interest in the subject, making them more eager to solve problems (Harefa, 2023).

While many pieces of research have proved the impact of PBL in Math teaching and learning instructions, a study on the relationship between PBL and the problem-solving skills of Grade 9 students, results showed that while the learners perceived the approach to be effective, there shows no enough evidence that PBL significantly improve the Math performance of the students (Arbo & Ching, 2022).

Moreover, compared to the conventional way of teaching Mathematics, PBL can be more time-consuming (So & Kim, 2009). It was also observed that the approach is less appropriate, especially for low-performing students. Additionally, it requires careful planning and preparation, such as designing meaningful, challenging, and contextualized problems that align with the curriculum (Hmelo-Silver, 2004). Also, with this approach, students need sufficient time to explore and solve complex problems, which may result in less coverage of content within a given timeframe. Additionally, some students may actually need assistance and need help with how the PBL works, as it requires them to take ownership and be more responsible for their learning and may provide a complex level of structure than traditional teaching methods. Lastly, assessing student learning in PBL can be challenging (Alkhasawneh *et al.*, 2008). Assessments like paper-pencil tests and standardized tests that make use of conventional methods are shown to not effectively assess the extent of understanding and problem-solving skills developed through PBL. Educators need to develop alternative assessment strategies that align with the goals and outcomes of PBL (Alt & Raichel, 2020).

Several studies on PBL suggest that it has several advantages on the learning performance of the students. PBL can be effective across various disciplines and educational levels. However, it should also be noted that PBL requires careful planning, support, and appropriate assessment strategies to ensure its effectiveness.

The integration of key educational theories such as constructivism, situated learning, metacognition, and transformative learning supports the pedagogical foundation of PBL. These suggest that meaningful learning occurs based on hands-on experiences, contextualized activities, critical reflection, and encountering challenging and real-world problems.

On the other hand, DepEd Order No. 35 s. 2016 and the Enhanced Basic Education Act (RA No. 10533) further reinforce PBL in enhancing the learning standards in education and preparing students in the 21st century.

Furthermore, the different literature and studies reviewed in this study highlight the important role of the PBL approach in students' mathematical problem-solving performance. Numerous studies reviewed emphasize that PBL fosters critical thinking,

collaborative learning, and a deeper understanding of mathematical concepts, enabling students to provide solutions to real-world math scenarios. The theoretical foundation for exploring the impact of PBL in mathematics justifies its application in addressing challenges in students' math problem-solving proficiency.

3. Material and Methods

This study employed a descriptive correlational research design to fully understand the influence of PBL on the math problem-solving performance of the Grade 9 students in one of the private boarding schools in Talisay City, Cebu. The study was conducted among 232 respondents who were already in the second quarter of the school year 2024-2025, as this quarter thoroughly emphasizes problem-solving activities using quadratic equations, quadratic inequality, quadratic function, and variation. These students were selected through stratified random sampling.

The implementation of PBL in the school takes place throughout the academic year as an integral part of the teaching strategy. Both students and teachers were provided with a comprehensive orientation to understand the PBL approach, focusing on its application in delivering math lessons. This ensures familiarity with the PBL process, including its objectives, structure, and expected outcomes. Consequently, the students, having been properly prepared and engaged in the PBL framework, are in a prime position for the study. The gathered data will focus on various aspects of their learning experience, including problem-solving skills, collaboration, and overall engagement with the PBL approach.

In this research, a letter was forwarded to the school administrator to seek approval to pursue the study. After permission was granted, an informed assent was obtained from the respondents. During this phase, students were given an orientation about the study and its purpose and given clear instructions on how to complete the questionnaires. Two questionnaires were used in collecting the data, (1) an adapted and modified questionnaire from Arbo and Ching (2022) was used to measure the students' perception of the efficacy of the elements of the PBL approach and (2) the problem-solving activity questionnaire that contains real-world problems relevant to quarter 2 content standards of the Grade mathematics curriculum. The students' perceptions of the efficacy of PBL elements were assessed using weighted mean and standard deviation. Students' problem-solving performance was assessed using a performance rating scale. Finally, the Pearson Correlation Coefficient and t-test were employed in testing the significance of the relationship between the research variables.

4. Results and Discussion

This section outlines the analysis of data and its interpretation with the goal of determining the efficacy of PBL and its relation to the respondents' math problem-solving performance.

Table 1: Level of Efficacy of Authentic Elements of PBL Approach

Indicators	$\bar{x}$	**SD**	**Verbal Description**
Being exposed to PBL …			
1. helps me be familiarized with word problems.	3.535	0.768	Evident
2. makes me competent to solve word problems given.	3.209	0.787	Somewhat Evident
3. aids me to relate the condition in the problem to real-life contexts.	3.635	0.880	Evident
4. provides me with detailed evidence of authentic situations from the problems.	3.565	0.772	Evident
5. helps me associate learned concepts with real practice.	3.722	0.782	Evident
General Weight	**3.533**	**0.798**	**Evident**

Legend: 4.21-5.00 Highly Evident, 3.41-4.20 Evident, 2.61-3.40 Somewhat Evident, 1.81-2.60 Less Evident, 1.00-1.80 Not Evident

Table 1 illustrates the perceived level of efficacy of the authenticity elements of the PBL approach. It can be observed that item 5 is the highest rated item, where respondents often see PBL helping them in associating learned concepts with real practice. Similarly, Items 1, 3, and 4 reflect respondents' acknowledgment of PBL's relevance in promoting real-life applications. Findings were affirmed in the study of AlAli (2024) that PBL fosters problem-solving activity by immersing students in complex, real-world problems that require critical thinking and application of knowledge to find practical solutions. On the other hand, PBL helps students build strong problem-solving skills by encouraging them to employ theoretical concepts to solve authentic problems (Hmelo-Silver, 2004). However, Item 2 reveals that respondents require additional support to maximize the benefits of PBL and improve their competence in solving word problems.

This indicates that PBL is perceived as effective in enhancing students' problem-solving skills and their ability to relate learned concepts to real-world situations (Savery, 2006). In the study of Singha and Singha (2024), developing problem-solving skills among students will greatly influence the students' learning outcomes. This suggests that when students are exposed to various problem-solving activities, they are more likely to perform better in Math, which indicates an overall improvement in academic performance. The findings indicate the positive impact of PBL's authentic elements in achieving its educational objectives.

Table 2: Level of Efficacy of Collaborative Elements of the PBL Approach

Indicators	$\bar{x}$	**SD**	**Verbal Description**
Being exposed to PBL …			
1. makes me aware of adapting ideas and strategies in solving problems from my instructor.	3.800	0.779	Evident
2. I am now able to solve word problems through interaction with my teacher.	3.548	0.864	Evident
3. I am able to get the idea I want to know by discussing it with my teacher.	3.848	0.856	Evident
4. My learning ability is developed through work collaboration with my teacher.	3.904	0.825	Evident
5. I can present information, findings, and arguments clearly, concisely, and logically in class.	3.043	0.679	Somewhat Evident
6. I am more confident in engaging in the course discussion.	3.226	0.760	Somewhat Evident
7. I can develop ideas and use styles appropriate to the purpose and learning tasks.	3.535	0.739	Evident
8. I can clearly address alternatives, opinions, and perspectives with confidence and logic.	3.139	0.769	Somewhat Evident
9. I can speak clearly and participate actively in class discussions.	3.226	0.837	Somewhat Evident
General Weight	3.474	0.790	Evident

Legend: 4.21-5.00 Highly Evident, 3.41-4.20 Evident, 2.61-3.40 Somewhat Evident, 1.81-2.60 Less Evident, 1.00-1.80 Not Evident

Table 2 indicates the perceived efficacy of the collaborative elements of the PBL. Item 4, which received the highest rating, highlights respondents' belief that teacher-student collaboration significantly enhances their learning capabilities. Similarly, Items 1 and 3 emphasize the importance of teacher guidance and interaction in fostering problem-solving skills. This aligns with the findings of Cagatan and Quirap (2024), who reported a significant relationship between teacher-student collaboration and learning outcomes. A study by Dolmans *et al.* (2005) emphasizes the crucial role of teacher and student collaboration, where the teacher acts as a facilitator in guiding students through the problem-solving process and fostering a collaborative environment.

However, some items rated as "somewhat evident," such as Items 5, 6, 8, and 9, suggest areas for improvement. These findings indicate the need for greater emphasis on building students' confidence and clarity in communication and discussion during collaborative activities.

Overall, the findings demonstrate that the collaborative elements of PBL positively influence learning, though targeted efforts to address identified gaps could further enhance its impact. Collaborative learning in PBL settings enhances problem-solving abilities, which promote teamwork, communication and shared responsibility for finding solutions, thus leading to deeper learning and better knowledge applications (Sugianto, 2022).

Table 3: Level of Efficacy of Developing Elements of the PBL Approach

Indicators	$\bar{x}$	**SD**	**Verbal Description**
Being exposed to PBL …			
1. helps me enhance my ability to learn.	4.291	0.786	Highly Evident
2. enhances my critical thinking skills.	4.070	0.784	Evident
3. improves my strategy for learning.	4.022	0.779	Evident
4. helps me to enhance my computational skills.	3.909	0.839	Evident
5. ensures mastery of the most essential learning competency	3.609	0.756	Evident
General Weight	3.980	0.789	Evident

Legend: 4.21-5.00 Highly Evident, 3.41-4.20 Evident, 2.61-3.40 Somewhat Evident, 1.81-2.60 Less Evident, 1.00-1.80 Not Evident

Table 3 shows the perceived level of efficacy of the developmental elements of the PBL approach. Items 1, 2, and 3 received a significantly higher rating from the respondents. This reflects respondents' strong belief that PBL significantly improves their learning capacity and appreciation for PBL's emphasis on fostering advanced thinking and learning strategies. This demonstrates that PBL has played its role in developing the needed skills for the students, such as enhancing the ability to learn the concepts in Mathematics, computation and critical thinking skills, developing strategies for learning and mastery of the learning competencies.

A study by Sungur and Tekkaya (2006) reaffirmed the effects of PBL, where it not only enhances the students' critical thinking skills but improves students' ability to regulate learning proofs and develop effective learning strategies. PBL also fosters self-directed learning where students can develop effective strategies in addressing complex problems (Awan, 2017). The findings highlight PBL's efficacy in cultivating skills such as learning capacity and critical thinking (Voon *et al.*, 2022). These skills enable students to achieve a profound comprehension of concepts through comprehensive development.

Table 4: Level of Efficacy of Authentic Assessment Elements of PBL Approach

Indicators	$\bar{x}$	**SD**	**Verbal Description**
Being exposed to PBL …			
1. provides learning assessments that establish my creativity, conciseness, and logical ability.	3.604	0.715	Evident
2. allows me to experience answering assessments with high-quality questions that engage us to solve them correctly.	3.670	0.849	Evident
3. helps me think and use different strategies in solving math problems.	3.839	0.833	Evident
4. provides assessments that are linked to references for future endeavors.	3.522	0.775	Evident
5. provides a variety of assessments for me to enhance my problem-solving skills.	3.778	0.803	Evident
General Weight	3.683	0.795	Evident

Legend: 4.21-5.00 Highly Evident, 3.41-4.20 Evident, 2.61-3.40 Somewhat Evident, 1.81-2.60 Less Evident, 1.00-1.80 Not Evident

Table 4 reveals that respondents view the authentic assessment elements of the PBL approach. Item 3, which receives the highest rating, emphasizes the effectiveness of varied assessment methods in developing problem-solving competencies. Similarly, Items 1, 2, 4, and 5 highlight how assessments align with real-world applications of problem-solving activities. The findings reflect a positive evaluation of PBL's use of assessments to improve learning outcomes. Authentic assessments provide students with opportunities to evaluate their learning and improve their performance while also clarifying expectations prior to assessment (Blumberg, 2015).

This implies that authentic assessment elements of PBL are beneficial in fostering logical thinking and problem-solving abilities while also strengthening the connection between PBL activities and real-world applications. In a study by Ampadu and Adjei-Boateng (2021), the authentic assessment in PBL deepens students' understanding and improves their ability to apply learned concepts in practical settings. Additionally, the assessment strategies of PBL, such as real-world tasks, enhance students' engagement and help them connect their learning to solving and learning real-world problems (Sihite & Pangaribuan, 2023).

Table 5: Level of Efficacy of the Elements of the PBL Approach

Elements	$\bar{x}$	**SD**	**Verbal Description**
Authentic Elements	3.533	0.798	Evident
Collaborative Elements	3.474	0.790	Evident
Developing Elements	3.980	0.789	Evident
Authentic Assessment Elements	3.683	0.795	Evident
General Weight	3.668	0.793	Evident

Legend: 4.21-5.00 Highly Evident, 3.41-4.20 Evident, 2.61-3.40 Somewhat Evident, 1.81-2.60 Less Evident, 1.00-1.80 Not Evident

Based on table 5, the developing elements receive the highest rating, which signifies that PBL enables students to develop critical thinking skills and problem-solving skills (Tanna *et al.*, 2022). These skills are significant in finding solutions when dealing with real-life contexts. Also, the authentic elements, collaborative elements and authentic assessment elements receive a significant rating, which implies that students' learning experiences allow them to apply learned concepts in looking for solutions, fostering key competencies in analyzing and reasoning. These findings reaffirm PBL's potential as a transformative educational strategy, offering a modern framework that aligns with 21st-century educational goals. A study on the broad impact of PBL on student outcomes, the study highlighted the positive influence of PBL on students' analysis and reasoning, self-drive, engagement, and retention of knowledge (Cook & Artino, 2022). PBL facilitates deeper learning and prepares students for real-world challenges in a collaborative environment (Ni'mah *et al.*, 2024).

To fully realize the potential of PBL, targeted refinements are necessary. This includes providing adequate training for educators in PBL implementation and designing more inclusive and engaging problem scenarios. By addressing these areas,

PBL can further enhance its impact which would also prepare students to excel in diverse real-world settings.

Table 6: Mathematics Problem-Solving Performance of the Respondents

Score	Verbal Description	f	%
32-40	Outstanding	46	19.83
24-31	Very Satisfactory	75	32.33
16-23	Satisfactory	91	39.22
8-15	Fairly Satisfactory	18	7.76
0-7	Poor	2	0.86
	Total	**232**	**100**

Table 6 shows that most respondents achieved satisfactory performance in their math problem-solving activities, comprising 39.22% (n=91) of the respondents. Additionally, 32.33% (n=75) attained very satisfactory performance, and 19.83% (n=46) excelled with outstanding performance. Meanwhile, 7.76% (n=18) scored fairly satisfactorily, and a small subset, 0.86% (n=2), demonstrated a level requiring significant improvement.

These results emphasize that most of the respondents have commendable problem-solving skills, indicating a strong understanding of the concepts and strategies taught. However, a small subset of students with below-average performance points to the need for targeted interventions, such as additional guidance or differentiated instruction, to help them improve their outcomes.

Overall, the distribution of scores reflects a positive trend in math problem-solving performance, suggesting that most students are effectively grasping and applying the concepts. This underscores the success of the PBL used, while also identifying aspects for improvements to ensure all learners achieve their full potential.

Table 7: Test of Significance of Relationship Between the Efficacy of PBL Approach and Math Problem-Solving Performance of the Respondents

Variables	r-value	Strength of Correlation	p-value	Decision	Remarks
Efficacy of the PBL Approach and Math Problem Solving Performance	0.497	Weak Positive	0.000	Reject Ho	Significant

*significant at p<0.05 (two-tailed)

The analysis through PPMC reveals a correlation coefficient $r = 0.497$, which signifies that there is a moderately strong correlation between the two variables tested. In addition, further analysis through t-test showed a p-value of 0.000, which is less than 0.05. Thus, the null hypothesis is rejected, which suggests that there is a significant relationship between the efficacy of the PBL approach and math problem-solving performance of the respondents.

The findings demonstrate that the PBL approach significantly influences helping students connect mathematical concepts to real-life situations, making the math subject more relevant and engaging (Arbo & Ching, 2022). This relevance increases students'

interest and motivates them to approach problem-solving with greater enthusiasm (Tupas, 2012).

PBL also enables students to connect to real-world applications and allows students to perform better in their math problem-solving activities (Shanta, 2022). It also enhances students' ability to connect theoretical knowledge to real-world applications, especially in mathematics, by engaging in practical problem-solving activities (Savery, 2006).

Additionally, the collaborative elements of PBL enable students to collaborate with peers and teachers, improve communication of possible answers to problems and thus lead to perform satisfactorily in their math problem-solving activities. The result reaffirmed the study of Hmelo-Silver and Barrows (2021) on the collaborative nature of PBL that students' interaction with peers and teachers enhances communication skills, fosters teamwork and leads to improved problem-solving abilities where students can share strategies and collectively develop solutions.

Furthermore, the results also suggest that PBL provided students an opportunity to enhance their computation skills, critical thinking skills and learning strategies (Simanjuntak *et al.*, 2021). This allows students to master math concepts, which leads to improved mathematics problem-solving performance. The study of Kassab *et al.* (2023) on how PBL works it highlights how PBL promotes the development of necessary skills by engaging in different complex problem-solving tasks. The mastery of core concepts in the PBL environment results in enhanced problem-solving performance.

Moreover, it signifies that the evaluation of students' performance in PBL settings through formative and summative assessments enables them to have a satisfactory performance in their math problem-solving activities. To reinforce students' math performance, authentic real-world scenarios should be used in the evaluation processes. Including real-world problem-solving tasks enhances students' understanding and application of mathematical concepts (Koh *et al.*, 2019).

Although mathematics can present challenges for many learners, PBL offers a supportive framework that encourages collaboration and active participation. With this approach, students can develop creative solutions and a deeper understanding.

5. Recommendations

In view of the study's findings, it is recommended that Problem-Based Learning (PBL) is continuously implemented throughout the academic year with regular assessments to identify areas for improvement. Teachers should also conduct formative assessments of student performance, which are crucial to improving the implementation of PBL for it to be more responsive to students' needs.

To enhance the impact of PBL in education, students should be provided with authentic and contextualized math word problems. By engaging in these types of problems, students can make use of their mathematical knowledge, which increases their motivation and engagement.

Given that PBL thrives on collaboration, it encourages group work and peer activities. Students should be laid up with various chances to work in diverse groups, where they can share and learn from different perspectives.

6. Conclusion

Based on the research findings, PBL has played a significant role in enhancing the performance of the students, especially in math problem-solving activities. Its efficacy in mathematics instruction is evident and can be further achieved through teacher's training on how to implement and carry out PBL, which includes the designing of engaging, authentic problem scenarios.

The results also highlighted the importance of PBL in education, which is highlighted by its ability to enrich logic and reasoning, critical thinking, collaboration, and problem-solving skills. By integrating real-world and contextual problems into the learning process, PBL aligns with educational objectives that promote in-depth and lifelong learning.

Moreover, PBL proved to help prepare the students to deal with real-life challenges. It provides them with opportunities to analyze situations and problems towards developing solutions and use them in practical contexts, equipping them with essential skills.

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Conflict of Interest Statement

The author declares no conflicts of interest.

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References

AlAli, R. (2024). Enhancing 21st century skills through integrated STEM education using project-oriented problem-based learning. *Geo Journal of Tourism and Geosites, 53*(2), 421-430. DOI: 10.30892/gtg.53205-1217

Alkhasawneh, I. M., Mrayyan, M. T., Docherty, C., Alashram, S., & Yousef, H. Y. (2008). Problem-based learning (PBL): assessing students' learning preferences using VARK. *Nurse education today, 28*(5), 572-579. DOI: 10.1016/j.nedt.2007.09.012

Alt, D., & Raichel, N. (2020). Problem-based learning, self- and peer assessment in higher education: towards advancing lifelong learning skills. *Research Papers in Education, 37*(3), 370–394. https://doi.org/10.1080/02671522.2020.1849371

Ampadu, E., & Adjei-Boateng, E. (2021). Problem-Based learning. In Advances in educational technologies and instructional design book series (pp. 280–293). https://doi.org/10.4018/978-1-5225-3949-0.ch015

Arbo, J.B. & Ching, D.A. (2022). Problem-Based Learning Approach in Developing Mathematical Skills. International Journal of Science, Technology, *Engineering and Mathematics*, Volume 2 Issue 1, pp. 26 - 47. DOI: https://doi.org/10.53378/352873

Aslan, A. (2021). Problem-based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers & Education, 171*, 104237. https://doi.org/10.1016/j.compedu.2021.104237

Awan, Riffat-Un-Nisa. (2017). Effects of Problem-Based Learning on Students' Critical Thinking Skills, *Attitudes towards Learning and Achievement. 20.*

Blumberg, P. (2015). Assessing Students During the Problem-Based Learning (PBL) process. International Association of Medical Science Educators.

https://www.iamse.org/mse-article/assessing-students-during-the-problem-based-learning-pbl-process/

Cagatan, A. N. P., & Quirap, E. A. (2024). Collaborative learning and learners' academic performance. *International Journal of Multidisciplinary Research and Analysis, 07*(03). https://doi.org/10.47191/ijmra/v7-i03-57

Cook, D. A., & Artino, A. R. (2020). Motivation to learn: An overview of contemporary theories. *Medical Education, 54*(5), 479-487. doi: 10.1111/medu.13074.

DO 35, s. 2016 – The Learning Action Cell as a K to 12 Basic Education Program School-Based Continuing Professional Development Strategy for the Improvement of Teaching and Learning | Department of Education. (2016, June 7). Department of Education. https://www.deped.gov.ph/2016/06/07/do-35-s-2016-the-learning-action-cell-as-a-k-to-12-basic-education-program-school-based-continuing-professional-development-strategy-for-the-improvement-of-teaching-and-learning/

Dole, S., Bloom, L., & Kowalske, K. (2016, April). Transforming pedagogy: Changing perspectives from teacher-centered to learner-centered. *Interdisciplinary Journal of Problem-Based Learning, 10*(1), 45-58. https://doi.org/10.7771/1541-5015.1538

Dolmans, D. H. J. M., De Grave, W. S., Wolfhagen, I. H. A. P., & Van Der Vleuten, C. P. M. (2005). Problem-Based Learning: Future Challenges for Educational Practice and Research. *Medical Education, 39*(7), 732-741. DOI: 10.1111/j.1365-2929.2005.02205.x

Duch, B. J., Groh, S. E., & Allen, D. E. (2001). The Power of Problem-Based Learning. https://www.researchgate.net/publication/242560724_The_Power_of_Problem-Based_Learning

Etiubon, R. U., & Ugwu, A. N. (2016). Problem-Based Learning and students' academic achievement on Thermodynamics (A case study of University of Uyo, Akwa - Ibom State, Nigeria). *IOSR Journal of Research & Method in Education (IOSR-JRME), 6*(5), 36-41. DOI: 10.9790/7388-0605023641

Fatade, A. O., Mogari, D., and Arigbabu, A. A. (2013). Effect of Problem-based Learning on senior secondary school students' achievements in Further Mathematics. *Acta Didactica Napocensia, 6*(3), 27–44. https://files.eric.ed.gov/fulltext/EJ1053664.pdf

Gafoor, K.A. & Kurukkan, A. (2015). Learner and Teacher Perception on Difficulties in Learning and Teaching Mathematics: Some Implications. https://doi.org/10.13140/RG.2.2.21816.14085

Harefa, D. (2023). The Relationship Between Students' Interest in Learning and Mathematics Learning Outcomes. *AFORE Jurnal Pendidikan Matematika, 2*(2), 112–122. https://doi.org/10.57094/afore.v2i2.1054

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn?. *Educational psychology review, 16*, 235-266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Hmelo-Silver, C. E., & Barrows, H. S. (2021). Facilitating collaborative learning: A problem-based learning approach. Educational Psychology Review, 33(4), 949-974. https://docs.lib.purdue.edu/ijpbl/vol1/iss1/4/

Hmelo-Silver, C. E., & Eberbach, C. (2011). Learning theories and problem-based learning. In Problem-based learning in clinical education: The next generation (pp. 3-17). Dordrecht: Springer Netherlands. DOI: 10.1007/978-94-007-2515-7_1

Hu, Q. Q. (2017). Problems are the logical starting point of mathematics learning - a brief discussion on the application of problem-guided learning method in junior high school mathematics teaching. *Digital Design, 6*(09), 225–244. https://doi.org/10.19551/j.cnki.issn16729129.2017.09.229

Jian, R., & Yang, Z. (2022). Problem-based learning in Chinese K-9 Mathematics Education. In Proceedings of the 2022 International Conference on Science Education and Art Appreciation (SEAA 2022) (pp. 210–218). https://doi.org/10.2991/978-2-494069-05-3_27

Kassab, S. E., El-Baz, A., Hassan, N., Hamdy, H., Mamede, S., & Schmidt, H. G. (2023). Construct validity of a questionnaire for measuring student engagement in problem-based learning tutorials. *BMC Medical Education, 23*(1), 844. DOI: 10.1186/s12909-023-04820-1

Koh, K., *et al.* (2019). The Role of Authentic Assessment Tasks in Problem Based Learning. Education Resources Information Center. https://files.eric.ed.gov/fulltext/EJ1302881.pdf

Kumar, T., Soozandehfar, S. M. A., Hashemifardnia, A., & Mombeini, R. (2023). Self vs. peer assessment activities in EFL-speaking classes: impacts on students' self-regulated learning, critical thinking, and problem-solving skills. *Language Testing in Asia, 13*(1), 36. https://doi.org/10.1186/s40468-023-00251-3

Lapek, J. (2018). Promoting 21st century skills in Problem-Based learning environments. CTETE - Research Monograph Series, 1(1), 66–85. https://doi.org/10.21061/ctete-rms.v1.c.4

Lu, J., Bridges, S., & Hmelo-Silver, C. (2018). Problem-based learning. In R. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (Cambridge Handbooks in Psychology, pp. 298-318). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139519526.019

Manuaba, I. B. P., -No, Y., & Wu, C. (2022). The effectiveness of problem-based learning in improving critical thinking, problem-solving and self-directed learning in first-year medical students: A meta-analysis. *Plos One, 17*(11). https://doi.org/10.1371/journal.pone.0277339

Matlala, S. (2021). Educators' perceptions and views of problem-based learning through simulation. *Curationis, 44*(1). https://doi.org/10.4102/curationis.v44i1.2094

Ni'mah, A., *et al.* (2024). Problem-Based Learning (PBL) Methods Within an Independent Curriculum (A Literature Review*). Sintaksis: Publikasi Para ahli Bahasa dan Sastra Inggris, 2(*4), 165-174. https://doi.org/10.61132/sintaksis.v2i4.859

Obut, V. G., Jumawan, M. D., Baluyos, G. R., & Bacus, J. A. (2024). Exploring the Students' Struggles in Learning Mathematics: Basis for Enhancement. https://uijrt.com/articles/v5/i3/UIJRTV5I30013.pdf

Padmavathy, R. D., & Mareesh, K. (2013). Effectiveness of problem based learning in mathematics. *International Multidisciplinary e-Journal, 2*(1), 45-51.

Razak, A. A., Ramdan, M. R., Mahjom, N., Zabit, M. N. M., Muhammad, F., Hussin, M. Y. M., & Abdullah, N. L. (2022). Improving critical thinking skills in teaching through problem-based learning for students: A scoping review. *International Journal of Learning, Teaching and Educational Research, 21*(2), 342-362. https://doi.org/10.26803/ijlter.21.2.19

Samsudin, A., Afif, N. F., Nugraha, M. G., Suhandi, A., Fratiwi, N. J., Aminudin, A. H., ... & Costu, B. (2021). Reconstructing students' misconceptions on work and energy through the PDEODE* E tasks with think-pair-share. Journal of Turkish Science Education, 18(1), 118-144. DOI: 10.36681/tused.2021.56

Saunders, L., & Wong, M. A. (2020, August 1). Active learning: engaging people in the learning process. Pressbooks. Retrieved from: https://iopn.library.illinois.edu/pressbooks/instructioninlibraries/chapter/active-learning-engaging-people-in-the-learning-process/

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-based Learning*, *1*(1). https://doi.org/10.7771/1541-5015.1002

Shanta, S. (2022). Assessment of Real-World Problem-Solving and critical thinking skills in a technology education classroom. In Contemporary issues in technology education (pp. 149–163). https://doi.org/10.1007/978-981-16-7885-1_10

Sihite, N. M. S. R., & Pangaribuan, N. L. R. (2023). Implementation of problem-based learning by using authentic assessment to improve students' activity and the ability of the students to solve problem. *Jurnal Pendidikan Mipa, 13*(2), 344–349. https://doi.org/10.37630/jpm.v13i2.895

Simanjuntak, M. P., Hutahaean, J., Marpaung, N., & Ramadhani, D. (2021). Effectiveness of Problem-Based Learning Combined with Computer Simulation on Students' Problem-Solving and Creative Thinking Skills. *International Journal of Instruction, 14*(3), 519–534. https://doi.org/10.29333/iji.2021.14330a

Singha, R., & Singha, S. (2024). Application of Experiential, Inquiry-Based, Problem-Based, and Project-Based Learning in Sustainable Education. In Teaching and Learning for a Sustainable Future: Innovative Strategies and Best Practices (pp. 109-128). IGI Global. DOI: 10.4018/978-1-6684-9859-0.ch006

Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P., & Smith, T. (2022). Principles of Problem-Based Learning (PBL) in STEM Education: Using expert wisdom and research to frame educational practice. *Education Sciences, 12*(10), 728. https://doi.org/10.3390/educsci12100728

So, H. J., & Kim, B. (2009). Learning about problem based learning: Student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of educational technology, 25*(1). DOI: https://doi.org/10.14742/ajet.1183

Su, H., Ricci, F.A., & Mnatsakanian, M.A. (2015). Mathematical Teaching Strategies: Pathways to Critical Thinking and Metacognition. *International Journal of Research in Education and Science, 2*, 190-200. https://files.eric.ed.gov/fulltext/EJ1105157.pdf

Sugianto, E. S. (2022). The role of collaborative learning and project based learning to increase students' cognitive levels in science literacy. *Advances in Social Science,*

Education and Humanities Research/Advances in Social Science, Education and Humanities Research. https://doi.org/10.2991/assehr.k.220104.011

Sungur, S., & Tekkaya, C. (2006). Effects of Problem-Based Learning and Traditional instruction on Self-Regulated Learning. *The Journal of Educational Research, 99*(5), 307–320. https://doi.org/10.3200/joer.99.5.307-320

Tanna, P., Lathigara, A., & Bhatt, N. (2022). Implementation of problem-based learning to solve real-life problems. *Journal of Engineering Education/Journal of Engineering Education Transformations/Journal of Engineering Education Transformation, 35*(S1), 103–111. https://doi.org/10.16920/jeet/2022/v35is1/22015

Tong, D. H., Uyen, B. P., & Le Thi Quynh Nhu, L. K. (2021). Application Of Problem-Based Learning to Teaching the Relationships Within a Triangle and Solution of Triangles. *International Journal of Multicultural Education, 7*(7). DOI: 10.5281/zenodo.5137984

Tupas, S. V. (2012). Effectiveness of problem-based learning approach to the students' problem solving performance. *JPAIR Multidisciplinary Research, 9*(1), 248–268. https://doi.org/10.7719/jpair.v9i1.4

Voon, X. P., Wong, S. L., Wong, L. H., Khambari, M. N. M., & Abdullah, S. I. S. S. (2022). Developing computational thinking competencies through constructivist argumentation learning: A problem-solving perspective. *International Journal of Information and Education Technology*. DOI: 10.18178/ijiet.2022.12.6.1650

Wakhata, R. *et al.* (2023). Building on Students' Prior Mathematical Thinking: Exploring Students' Reasoning Interpretation of Preconceptions in Learning Mathematics. *Education Resource Information Center. Vol 15*, no 1. Retrieved from: https://files.eric.ed.gov/fulltext/EJ1391459.pdf

Warnock, J. N., & Mohammadi-Aragh, M. J. (2016). Case study: use of problem-based learning to develop students' technical and professional skills. *European Journal of Engineering Education, 41*(2), 142-153. DOI: 10.1080/03043797.2015.1040739

Xia, X., Lu, C., & Wang, B. (2008). Research on mathematics instruction experiment based problem posing. *Journal of Mathematics Education, 1*(1), 153–163. https://www.researchgate.net/publication/237622382_Research_on_Mathematics_Instruction_Experiment_Based_Problem_Posing/citations

Yew, E. H. J., & Goh, K. M. L. (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