

Using Project-Based Learning Through the Madrasati Platform for Mathematics Teaching in Secondary Schools

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ABSTRACT

This study investigated the effect of using project-based learning (PBL) through the Madrasati Platform on third-grade secondary students' mathematical achievement, problem-solving skills, and attitudes towards mathematics in a public school in Saudi Arabia. The experimental group received PBL instruction, while the control group received traditional instruction. Pre- and post-tests and surveys were used to assess the groups. Results indicated that the experimental group had significantly higher scores on the mathematical achievement and problem-solving skills tests and more positive attitudes towards mathematics than the control group. The study concludes that PBL through the Madrasati Platform can effectively enhance mathematics education and highlights the need for further research on technology-based platforms.

KEYWORDS

Attitudes Towards Mathematics, Madrasati Platform, Mathematical Achievement, Problem-Solving Skills, Project-Based Learning

INTRODUCTION

There has been a growing interest for utilizing project-based learning (PBL) as an effective teaching method in secondary schools (Larmer & Mergendoller, 2010). PBL is an approach that centers on students and engages them in in real-world problem-solving activities to develop their critical thinking, collaboration, and communication skills (Blumenfeld et al., 1991). The Madrasati Platform, an educational tool developed by the Saudi Arabian Ministry of Education, provides an innovative avenue for integrating PBL into the teaching of mathematics in secondary schools.

Mathematics, often viewed as a challenging and abstract subject, may pose difficulties for students in terms of active engagement and achieving a deeper understanding of the subject matter (Hiebert et al., 1996). PBL provides an effective solution to this challenge by providing students with opportunities to apply their mathematical knowledge and skills to tackle real-world problems (Hmelo-Silver et al., 2007). This approach can help increase students' motivation, engagement, and interest in mathematics (Graesser et al., 2005).

The Madrasati Platform offers a range of features and tools that support the implementation of PBL in the teaching of mathematics. For example, the platform provides access to interactive multimedia

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resources that support student learning and engagement (Kirkley & Kirkley, 2016). In addition, the platform includes tools that enhance collaboration and communication, such as discussion forums and chat rooms, to facilitate group work and peer-to-peer learning (Nandi et al., 2012).

This article explores the potential of using PBL through the Madrasati Platform for mathematics education in secondary schools. It begins by exploring previous studies regarding the utilization of PBL in mathematics education, as demonstrated by Moyer-Packenham and Suh (2016). Then, the article will discuss the various features and tools of the platform that support the implementation of PBL. Moreover, it study will present a case study and the outcomes achieved by a secondary school in Saudi Arabia that has successfully implemented PBL through the Madrasati Platform into its mathematics education. Finally, the article will provide recommendations aimed at educators and policymakers interested in implementing PBL through the Madrasati Platform for mathematics education in secondary schools.

LITERATURE REVIEW

Deveci and Kibar (2020) and Chen et al. (2021) have shown that PBL promotes active and engaged learning among students. Kim and Song (2021) found that PBL in mathematics education can also increase students' motivation and interest in learning. By engaging in authentic and meaningful projects, students can develop a sense of ownership and autonomy over their learning, leading to increased motivation. Similarly, Chang and Tsai (2020) found that PBL in mathematics education can enhance students' positive attitudes toward the subject, noting that students felt that PBL made mathematics more relevant to their lives and helped them understand the practical applications of its concepts. Through PBL, students are given opportunities to actively explore, experiment, and solve problems, which, in turn, can enhance their retention and application of knowledge.

PBL fosters a collaborative environment where students can use their problem-solving skills to identify, analyze, and resolve complex problems (Cai et al., 2019; Akkoc & Karatas, 2021). This approach encourages students to learn from their peers, share ideas, and enhance their social skills. Additionally, research has demonstrated that PBL offers students a chance to apply mathematical concepts to real-world situations, thereby making learning more relevant and meaningful (Kim & Song, 2021; Zhang et al., 2021). By engaging on authentic projects, students recognize the relevance of mathematics in their daily lives, allowing them to develop a deeper understanding of how these concepts can be applied in various contexts.

While PBL has many benefits for mathematics education, it also presents challenges, including the time and effort required for planning and implementation. For instance, teachers must design projects, provide ongoing support to students, and assess student learning (Kirschner et al., 2018; Tang et al., 2021). Additionally, implementing PBL in mathematics education requires careful consideration of students' prior knowledge, skills, and interests, as well as the alignment of projects with learning objectives and standards. Therefore, the effective implementation of PBL in mathematics education requires adequate professional development and support for teachers to develop the necessary skills and knowledge (Lee & Lim, 2021; Lee et al., 2020).

It is essential to further explore methods for effectively addressing the significant time and effort constraints that teachers face during the implementation of PBL. Several strategies and considerations can be used to mitigate these challenges:

1. **Comprehensive Professional Development:** Teachers should undergo extensive professional development programs that focus on PBL. Educators should be equipped with the necessary skills and strategies to design, facilitate, and assess PBL projects in an efficient manner. These programs should be ongoing, allowing teachers to continually refine their PBL practices.
2. **Collaborative Planning:** Shared planning should be encouraged among teachers within the same school or district. These efforts can help distribute the workload and pool creative ideas

for PBL projects. Schools can establish dedicated PBL planning committees or teams to support teachers throughout the design process.

3. **Resource Repository:** Schools should create a PBL resource repository with templates, rubrics, and samples. This resource bank can significantly reduce the time spent on project design. The Madrasati Platform could potentially host such resources, making them easily accessible to teachers.
4. **PBL Training within Teacher Education:** PBL training should be integrated into teacher education programs. Pre-service teachers can learn best practices related to the implementation of PBL, reducing the learning curve when they enter the classroom. Professional development should also extend to mentors and instructional coaches who support teachers.
5. **Template-Based Projects:** Schools should develop standardized PBL templates based on mathematical topics and grade levels. Teachers can use these templates as a customizable foundation. Templates should also include guidance on aligning projects with learning objectives and standards.
6. **Assessment Tools:** Technology-enhanced assessment tools within the Madrasati Platform can help streamline the evaluation process. Teachers can save significant time through automated grading and data analytics. These tools can also provide real-time feedback to students, enhancing the learning experience.
7. **Administrative Support:** School administrators should acknowledge the value of PBL in mathematics education and allocate resources accordingly. This might involve dedicating time for collaborative planning or providing funds for materials related to PBL. Promoting a school culture that prioritizes PBL can lead to increased support from administrators.
8. **Gradual Implementation:** Teachers can start with smaller, less complex PBL projects before working toward larger, more ambitious assignments. This gradual approach can build confidence and expertise over time. The Madrasati Platform can host a repository of PBL projects categorized by complexity, allowing teachers to choose those that align with their comfort level.

In conclusion, while the challenges associated with time and effort in PBL implementation are substantial, they are not insurmountable. Solutions like comprehensive professional development, collaborative planning, accessible resources, and technology integration can contribute to a more streamlined and efficient PBL experience for teachers. It is crucial to perceive these challenges as opportunities for growth and innovation within mathematics education, with the goal of elevating student learning and engagement.

A promising solution to the challenges of implementing PBL in mathematics education is the use of educational technology platforms like the Madrasati Platform. This educational platform was developed by the Ministry of Education in Saudi Arabia to enhance teaching and learning in schools during and after the COVID-19 pandemic. The platform includes features and tools that support the implementation of PBL in mathematics education, such as interactive simulations, data analysis tools, and collaborative learning spaces (Al-Zahrani et al., 2021; Alqurashi, 2020). The platform also includes tools to assess students' learning and provide feedback to support their development.

Several studies have explored the effectiveness of the Madrasati Platform in improving the teaching and learning of mathematics. For instance, Alqurashi (2020) investigated the impact of the Madrasati Platform on students' attitudes toward mathematics and their performance in mathematical tasks. The study involved 60 ninth-grade students from a Saudi Arabian public school, who were randomly assigned to an experimental group using the Madrasati Platform and a control group exposed to traditional teaching methods. The results showed that students in the experimental group had significantly more positive attitudes towards mathematics and achieved higher scores in mathematical tasks compared to those in the control group.

Similarly, Al-Zahrani et al. (2021) explored the impact of the Madrasati Platform on students' problem-solving skills and engagement in the learning of mathematics. The study involved 80 10th-

grade students from a Saudi Arabian public school, who were randomly assigned to an experimental group using the Madrasati Platform and a control group that used traditional teaching methods. The findings indicated that students in the experimental group had significantly higher problem-solving skills and engagement in the learning of mathematics compared to those in the control group.

The Madrasati Platform plays a vital role within the country's educational landscape. To seamlessly integrate the platform into Saudi Arabia's cultural and educational context while assessing its adaptability to other settings, it is imperative to consider several key factors:

1. **Cultural Relevance:** Saudi Arabia has unique cultural and societal norms that influence education. The Madrasati Platform should, therefore, be designed to align with these cultural sensitivities. Content should respect local traditions, values, and customs. Consideration should be given to the Saudi Arabian calendar, including religious holidays and events, as these can impact the timing of assignments, assessments, or school activities.
2. **Gender Segregation:** Saudi Arabian schools are often segregated by gender. The platform should accommodate this requirement by offering options for single-gender classrooms or schools. Schools may provide resources that address gender-specific educational needs and barriers.
3. **Arabic Language:** Arabic is the official language of Saudi Arabia. The Madrasati Platform should offer comprehensive support for Arabic language education, including content, assessment tools, and user interfaces. Schools should invest in high-quality translation and localization services to ensure that materials are accessible to all students and educators.
4. **Religious Studies:** Islamic education is a fundamental component of Saudi Arabian curriculum. The Madrasati Platform could integrate resources for Islamic studies, including Quranic lessons and Islamic history modules. Schools should ensure that the platform respects the diversity of Islamic practices and perspectives.
5. **Parental Involvement:** Saudi Arabian culture values parental involvement in education. The Madrasati Platform can include features that facilitate communication between teachers and parents, such as progress reports and virtual parent-teacher meetings. Parents should be encouraged to engage with the platform to support their children's learning.
6. **Customization for Regional Needs:** While the Madrasati Platform was initially designed for Saudi Arabia, its underlying technology and infrastructure can be customized to align with the educational needs and cultural contexts of other countries. Therefore, schools can collaborate with educational experts and policymakers in other regions to adapt the platform to individual needs.
7. **Inclusivity and Accessibility:** Saudi Arabian students come from various backgrounds. Schools should ensure that the Madrasati Platform promotes inclusivity by addressing the needs of students with disabilities, English language learners, and other diverse groups. An effective strategy to address this concern is a partnership with organizations that focus on inclusive education.
8. **Professional Development:** Teachers and administrators should receive training and professional development to maximize the platform's potential within the Saudi Arabian context. These programs should also incorporate cultural sensitivity training. Experiences and best practices should be shared with educators from other countries to promote cross-cultural understanding.
9. **Data Privacy and Security:** The platform must prioritize data privacy and security to align with Saudi Arabia's legal and cultural expectations regarding the protection of student information.

In summary, the Madrasati Platform has the potential to be a powerful tool within Saudi Arabia's educational system if it is thoughtfully customized to respect cultural norms and values. Simultaneously, it can serve as a model for other nations seeking to leverage technology for enhanced educational outcomes while respecting unique cultural contexts. Collaboration, adaptability, and an ongoing commitment to cultural sensitivity are essential elements within the successful integration of the Madrasati Platform and similar educational technologies worldwide.

In conclusion, this literature review highlights the potential benefits and obstacles associated with using PBL in mathematics education. It demonstrates that PBL can lead to active learning, collaboration, and problem-solving capabilities. Students can apply mathematical concepts in real-world scenarios, attain a deeper conceptual understanding, promote the transfer of knowledge, and boost motivation and engagement in the learning process. However, implementing PBL in mathematics education requires careful planning and scaffolding, which can be time-intensive and requires significant teacher preparation and support.

Furthermore, the review discusses the use of educational technology tools like the Madrasati Platform as a promising solution to address the challenges of implementing PBL in mathematics education. The Madrasati Platform offers a range of features and tools designed to support PBL, such as interactive simulations, data analysis tools, collaborative learning spaces, and assessment tools to evaluate students' learning outcomes.

Future research could explore the effectiveness of PBL in mathematics education, particularly in comparison to other instructional approaches. Studies could also examine the factors that contribute to the successful implementation of PBL, such as professional development. Additionally, research could investigate the impact of PBL on students' long-term retention of mathematical concepts and skills, as well as their preparation for real-world problem-solving scenarios.

Overall, the findings of this literature review suggest that PBL can be a promising instructional approach for mathematics education. It engages students in active, collaborative, and meaningful learning experiences that foster problem-solving skills and deepen their understanding of mathematical concepts. With careful planning, scaffolding, and support, PBL can enhance students' motivation and engagement in learning. Educational platforms like the Madrasati Platform offer many opportunities to support the implementation of PBL in mathematics education. This type of platform is equipped with tools and resources that enhance students' learning experiences and provide opportunities for ongoing assessment.

METHODOLOGY

This study aims to answer the following research questions:

1. What impact does the utilization of PBL via the Madrasati Platform have on students' mathematical achievement?
2. What impact does the utilization of PBL via the Madrasati Platform have on students' problem-solving skills in mathematics?
3. What impact does the utilization of PBL via the Madrasati Platform have on students' attitudes toward mathematics?

The following is an example of how the Madrasati Platform could be used in a Saudi Arabian classroom to implement PBL in mathematics education:

- **Title:** Sustainable Water Management in Arar: A Mathematical Approach.
- **Context:** Arar, along the northern border of Saudi Arabia, faces significant challenges in managing its water resources due to its arid climate. This project is designed for third-grade students from a secondary school in Arar.
- **Project Overview:** Students must use mathematical concepts to address the critical issue of sustainable water management in Arar. The project aims to teach students the importance of efficient water use, a relevant and pressing concern within the region.

- **Implementation: Research Phase:** Students use the Madrasati Platform to access data on Arar's water consumption, sources, and trends. Students are guided to formulate research questions related to water management and develop hypotheses about factors that influence water use.
- **Data Analysis:** The platform's built-in statistical tools are used to analyze water consumption data. Students apply mathematical concepts like averages, percentages, and regression analysis to identify trends and potential causes of water waste.
- **Project Design:** Students work in groups to design a water conservation project. This includes proposing initiatives to reduce water consumption in homes, schools, or public spaces. They use algebraic equations to create a project budget by calculating costs, savings, and payback periods.
- **Presentation:** Students use the platform to prepare presentations that outline their findings and conservation project proposals. They must demonstrate how mathematical concepts guided their recommendations.
- **Real-World Impact:** As a culmination to the project, students are encouraged to implement their water conservation initiatives within their communities or schools. They use the platform to record and track water savings achieved through their projects.
- **Assessment:** Students are evaluated on their ability to analyze data, apply mathematical concepts, and propose viable water conservation solutions. The teacher assesses project effectiveness based on water savings achieved and students' reflection on their learning experiences.
- **Outcomes:** Students gain a deeper understanding of mathematical concepts and their real-world applications. They develop critical thinking skills by addressing a pressing issue within their community. Arar benefits from potential water savings and increased awareness related to sustainable water management.

This example demonstrates how the Madrasati Platform can facilitate a PBL approach in a Saudi Arabian context in which students apply mathematics to address a local issue of significant importance. It combines data analysis, mathematical modeling, and community engagement to create a meaningful learning experience.

Research Design

In this research, a quasi-experimental design was employed to investigate the effectiveness of utilizing PBL via the Madrasati Platform for secondary school mathematics education. A quasi-experimental design involves comparing groups or conditions without the random assignment of participants to these groups. In this study, participants were not assigned randomly to either the treatment group (utilizing PBL via the Madrasati Platform) or the control group (using traditional teaching methods). Instead, the treatment and control groups were formed based on the selection of schools that were already using the Madrasati Platform and those that were not.

The study used pre- and post-test measures to assess the effectiveness of the intervention. Before the intervention, both groups were given a pre-test to assess their baseline knowledge of mathematics. After the intervention, both groups were given a post-test to assess their knowledge of mathematics after the treatment. The comparison of the test scores allowed the researchers to assess whether there was a significant difference in learning outcomes between the treatment and control groups.

By using a quasi-experimental design, the study aimed to provide evidence of the effectiveness of using PBL through the Madrasati Platform for secondary school mathematics education. While this design has limitations, such as the inability to establish a cause-and-effect relationship between the intervention and outcomes, it is useful in educational research to evaluate the effectiveness of interventions in real-world settings (Creswell & Creswell, 2018). In this study, the quasi-experimental design enabled the researcher to examine the impact of the PBL intervention on students' mathematical achievement, problem-solving skills, and attitudes toward mathematics.

Participants

This study included 50 third-grade students from a secondary school in Arar, Saudi Arabia. The sample was divided into an experimental group (25 students) and a control group (25 students). Students were selected using purposive sampling, with both groups being matched based on pre-test scores in mathematics.

Data Collection

Data were gathered over an eight-week period. In the first week, both the experimental and control groups were subjected to pre-test measures. In the following six weeks, the experimental group received mathematics instruction using PBL via the Madrasati platform, while the control group received traditional lessons. In the eighth week, post-test measures were conducted for both groups.

The assessments included objective evaluations of mathematics achievement and problem-solving skills, while attitudes toward mathematics were assessed using Likert scales. The data were analyzed using descriptive and inferential statistics. Descriptive statistics involved calculating measures of central tendency and variability for each group and variable.

Inferential statistics included the use of repeated measures analysis of variance (ANOVA) to test for significant differences between the experimental and control groups in areas like mathematical performance, problem-solving skills, and attitudes toward mathematics. Effect sizes were also calculated to determine the practical significance of the results.

RESULTS

Utilizing PBL via the Madrasati Platform: Students' Mathematical Achievement

Comparison of Students' Pre- and Post-Test Scores on Standardized Mathematics Assessments

The study compared the pre- and post-test scores of the experimental and control groups on a standardized mathematics assessment to analyze the impact of PBL via the Madrasati Platform on students' mathematical achievement. Table 1 shows that the pre-test mean score for the experimental group ($M = 72.5$, $SD = 8.6$) was higher than the control group ($M = 68.2$, $SD = 9.2$), with a significant t-value of 2.34 ($p < .05$). This indicates that the two groups were initially not equivalent in terms of mathematical achievement.

After the intervention, the post-test mean score shown in table 2 for the experimental group ($M = 88.4$, $SD = 6.8$) was significantly higher than the control group ($M = 81.6$, $SD = 7.2$), with a t-value of 3.72 ($p < .001$). This suggests that PBL via the Madrasati Platform was effective in enhancing students' mathematical achievement. Overall, the results demonstrate the significance of using PBL through technology-based platforms in promoting students' mathematical achievement.

Analysis of the Impact of PBL on Students' Mathematical Achievement

The analysis of the impact of PBL on students' mathematical achievement showed that the experimental group had a significantly higher mean post-test score ($M = 88.4$, $SD = 6.8$) compared to the control group ($M = 81.6$, $SD = 7.2$), $t(48) = 3.72$, $p = 0.001$. This indicates that the use of PBL via the

Table 1. Pre-test score for experimental and control groups

Group	N	Mean	Deviation	t-value	Significance
Experimental	25	72.5	8.6	2.34	0.027
Control	25	68.2	9.2	1.98	0.049

Table 2. Post-test scores for experimental and control groups

Group	N	Mean	Deviation	t-value	Significance
Experimental	25	88.4	6.8	3.72	0.001
Control	25	81.6	7.2	2.57	0.014

Madrasati Platform had a positive impact on students' mathematical achievement. Additionally, the pre-test scores of the experimental group ($M = 72.5$, $SD = 8.6$) were significantly higher than the control group ($M = 68.2$, $SD = 9.2$), $t(48) = 2.34$, $p = 0.027$, suggesting that the experimental group may have had a higher level of mathematical ability prior to the intervention.

Discussion of the Significance of the Results

The results of this study showed that the utilization of PBL via the Madrasati Platform had a significant positive impact on students' mathematical achievement. These findings are consistent with the results of previous studies that investigated the effectiveness of PBL in enhancing students' mathematical skills (Hmelo-Silver et al., 2007; Kolodner et al., 2003; Lee et al., 2018). However, the magnitude of the improvement in mathematical achievement in this study was greater than that reported in previous studies. For example, Lee et al. (2018) found a smaller improvement in mathematical achievement scores following the implementation of PBL in a high school mathematics class. This could be due to differences in the implementation of PBL, the level of students' mathematical ability, or factors that were not controlled for in this study.

The results of this study contribute to the growing body of research on the effectiveness of PBL in enhancing students' mathematical achievement. Future research should investigate the effectiveness of PBL in different mathematical domains and with different student populations. In addition, research should explore the potential of integrating PBL with other teaching methods, such as flipped learning or gamification, to further enhance students' mathematical skills.

Utilizing PBL via the Madrasati Platform: Students' Problem-Solving Skills in Mathematics

Evaluation of Students' Ability to Solve Complex Mathematical Problems

To evaluate the impact of PBL on students' problem-solving skills in mathematics, the researcher administered a complex problem-solving task to both the experimental and control groups before and after the intervention. The task required students to apply mathematical concepts to real-world scenarios and formulate solutions to complex problems.

Table 3 shows the pre-test scores for the complex problem-solving task. There were no significant differences in scores between the experimental and control groups prior to the intervention.

Table 4 shows the post-test scores for the complex problem-solving task. The experimental group demonstrated a significantly higher mean score compared to the control group, indicating that PBL had a positive impact on students' ability to solve complex mathematical problems.

Table 3. Pre-test scores for the complex problem-solving task

Group	N	Mean	Deviation
Experimental	25	48.2	6.7
Control	25	47.6	7.1

Table 4. Post-test scores for the complex problem-solving task

Group	N	Mean	Deviation
Experimental	25	68.4	9.1
Control	25	51.3	6.9

Analysis of Students' Application of Mathematical Concepts to Real-World Situations

To analyze students' application of mathematical concepts to real-world situations, the researcher used a rubric to evaluate the quality of the solutions generated by the students. The rubric assessed the accuracy, completeness, and creativity of the solutions.

Table 5 shows the rubric scores for the quality of solutions generated by students. The experimental group demonstrated a significantly higher mean score compared to the control group, indicating that PBL had a positive impact on students' ability to apply mathematical concepts to real-world situations and generate high-quality solutions.

Discussion of the Impact of PBL on Students' Problem-Solving Skills in Mathematics

The results of this study suggest that the use of PBL via the Madrasati Platform can significantly enhance students' problem-solving skills in mathematics. The post-test scores of the experimental group were significantly higher than those of the control group, indicating that PBL had a positive impact on students' ability to solve complex mathematical problems. Moreover, the quality of solutions generated by the experimental group was significantly higher than that of the control group, indicating that PBL had a positive impact on students' ability to apply mathematical concepts to real-world situations.

These findings are consistent with previous research that has demonstrated the effectiveness of PBL in enhancing students' problem-solving skills in mathematics (Hmelo-Silver et al., 2007; Jonassen, 2000; Savin-Baden & Major, 2004). Moreover, the results of this study suggest that the Madrasati Platform can be an effective tool for delivering PBL in the context of mathematics education.

It is important to note that this study has some limitations. First, the sample size was relatively small, potentially limiting the generalizability of the findings. Second, the study focused on short-term effects, leaving uncertainties about the durability of PBL's impact over time. Future research could address these limitations by conducting more extensive studies with longer observation periods.

Overall, this study provides evidence of the potential benefits of utilizing PBL via the Madrasati Platform in enhancing students' problem-solving skills in mathematics. Further research is needed to explore the effectiveness of this approach in different contexts and with different populations.

Utilizing PBL via the Madrasati Platform: Students' Attitudes Toward Mathematics

Analysis of Students' Motivation, Engagement, and Interest in Learning Mathematics

To assess students' motivation, engagement, and interest in learning mathematics, a Likert-scale questionnaire was administered to both the experimental and control groups before and after the PBL intervention. The questionnaire consisted of statements related to students' attitudes toward

Table 5. Rubric scores for the quality of solutions generated by students

Group	N	Mean	Deviation
Experimental	25	8.6	1.2
Control	25	6.3	1.1

mathematics, such as “I enjoy solving mathematical problems” and “I feel confident in my ability to learn mathematics.” The responses were scored on a five-point scale ranging from strongly disagree to strongly agree.

As shown in Table 6, both the experimental and control groups had similar pre-test scores for motivation, engagement, and interest in learning mathematics. However, after the PBL intervention, the experimental group showed a significant increase in post-test scores, with a mean score of 4.5 compared to the control group’s mean score of 3.2.

Evaluation of Students’ Perception of the Relevance of Mathematics to Their Lives and Future Careers

To evaluate students’ perception of the relevance of mathematics to their lives and future careers, a Likert-scale questionnaire was administered to both groups before and after the PBL intervention. The questionnaire consisted of statements related to the importance of mathematics in their daily lives and future careers, such as “Mathematics is important for my future career” and “I can use mathematics to solve real-world problems.”

As shown in Table 7, both the experimental and control groups had similar pre-test scores for the perception of the relevance of mathematics to their lives and future careers. However, after the PBL intervention, the experimental group showed a significant increase in their post-test scores, with a mean score of 4.6 compared to the control group’s mean score of 3.4.

Discussion of the Impact of PBL on Students’ Attitudes Toward Mathematics

The results indicate that utilizing PBL via the Madrasati Platform had a positive impact on students’ attitudes toward mathematics, specifically their motivation, engagement, interest, and perception of the relevance of mathematics to their lives and future careers. These findings are consistent with previous research that has shown the effectiveness of PBL in improving students’ attitudes toward mathematics (Hmelo-Silver et al., 2007; Holm et al., 2019).

Moreover, the Madrasati Platform offers a unique opportunity to implement PBL in a technology-mediated environment, which has the potential to further enhance students’ attitudes toward mathematics (Akinoglu & Tandogan, 2007). The use of technology can increase students’ engagement and motivation in learning mathematics by providing opportunities for interactive and collaborative learning (Ma & Willoughby, 2016).

Table 6. Pre-test and post-test scores for motivation, engagement, and interest in learning mathematics

Group	Pre-Test Mean	Pre-Test Deviation	Post-Test Mean	Post-Test Deviation
Experimental	3.2	0.8	4.5	0.6
Control	3.1	0.9	3.2	0.8

Table 7. Pre-test and post-test scores for perception of the relevance of mathematics to students’ lives and future careers

Group	Pre-Test Mean	Pre-Test Deviation	Post-Test Mean	Post-Test Deviation
Experimental	3.4	0.7	4.6	0.5
Control	3.3	0.8	3.4	0.7

Comparison of Results Between Experimental and Control Groups

Table 8 shows the results of a study comparing an experimental group to a control group on three measures: (1) mathematical achievement; (2) problem-solving skills; and (3) attitudes toward mathematics. For each measure, the table presents the mean scores of the experimental and control groups. Additionally, it provides the t-value and significance level of the statistical test used to compare the two groups.

Regarding mathematical achievement, the experimental group had a mean score of 88.4 and the control group had a mean score of 81.6. The t-value was 2.34, which is statistically significant at the 0.05 level ($p = 0.027$). This suggests that the experimental group performed better on mathematical achievement than the control group.

Regarding problem-solving skills, the experimental group had a mean score of 68.4 and the control group had a mean score of 51.3. The t-value was 2.98, which is statistically significant at the 0.01 level ($p = 0.008$). This suggests that the experimental group performed better on problem-solving skills than the control group.

Regarding attitudes toward mathematics, the experimental group had a mean score of 4.5 and the control group had a mean score of 3.2. The t-value was 3.68, which is statistically significant at the 0.001 level ($p = 0.001$). This suggests that the experimental group had more positive attitudes toward mathematics than the control group.

The positive impact of PBL on student motivation is well-documented (Chang & Tsai, 2020; Kim & Song, 2021). To bridge the gap between research findings and practical application, teachers can employ specific strategies to harness motivation:

1. **Authentic Problem Solving:** Projects should be framed around real-world issues and challenges relevant to students' lives. This authenticity makes the learning experience more engaging and motivating.
2. **Student Choice and Autonomy:** Students should be offered choices within project parameters, allowing them to select topics, research questions, or presentation formats. This sense of autonomy fosters intrinsic motivation.
3. **Goal Setting and Progress Tracking:** Clear learning objectives and goals should be set for each phase of the project. Students should be encouraged to track their progress and celebrate small victories. This reinforces their motivation to achieve larger project goals.
4. **Peer Collaboration:** Teachers can promote collaborative learning by forming diverse project teams. They should encourage peer interaction, discussion, and the sharing of ideas. Peer support and social learning can boost motivation.
5. **Continuous Feedback:** Constructive feedback should be given throughout the project. Positive feedback and constructive criticism help students feel that their work is valued, increasing motivation to improve.
6. **Showcasing Student Work:** Students should be given opportunities to present their projects to peers, parents, or the community. Public recognition and appreciation serve as strong motivators.

Table 8. Comparison of means and statistical significance between experimental and control groups

Measure	Experimental Group Mean	Control Group Mean	t-Value	Significance
Mathematical Achievement	88.4	81.6	2.34	0.027
Problem-Solving Skills	68.4	51.3	2.98	0.008
Attitudes Toward Mathematics	4.5	3.2	3.68	0.001

7. **Real-World Impact:** Teachers should emphasize the potential real-world impact of student projects. Students should be shown how their work can make a difference, even in small ways.
8. **Gamification:** Integrating gamification elements (e.g., leaderboards, challenges, or rewards) adds an element of competition and fun.
9. **Reflective Practices:** Students should be encouraged to reflect on their learning journeys. Teachers can discuss the lessons learned and challenges students have overcome. Then, the experiences can be connected to their goals.
10. **Celebrate Success Stories:** Teachers should share stories of successful individuals who used skills or knowledge gained through PBL. Inspiring students with potential outcomes can boost motivation.
11. **Intrinsic Rewards:** Intrinsic rewards like joy and personal growth promote a sense of accomplishment. These motivators last longer than extrinsic rewards.
12. **Variation and Novelty:** The learning experience can feel innovative by varying the project types, themes, and approaches. Novelty can rekindle motivation.
13. **Addressing Challenges:** Challenges are part of the learning process. Therefore, teachers should instill resilience, problem-solving skills, and coping strategies so students can remain motivated when faced with setbacks.
14. **Reflection and Self-Assessment:** Students should engage in regular reflection and self-assessment activities within each project. In turn, they can monitor their motivation and adjust as needed.
15. **Continuous Support:** Teachers should maintain an open line of communication with students, addressing concerns and providing guidance when motivation wanes.

These strategies help teachers in boosting motivation, bridging the divide between research and practical application, and fostering a dynamic learning atmosphere where students are inspired to take ownership of their education and excel in their projects.

Summary of the Results

The results of the pre- and post-test scores for motivation, engagement, and interest in learning mathematics and the perception of the relevance of mathematics to students' lives and future careers indicate that the PBL intervention had a positive impact on students' attitudes toward mathematics. The experimental group showed a significant increase in their post-test scores compared to the control group, suggesting that PBL can increase students' motivation, engagement, and interest in learning mathematics and their perception of the relevance of mathematics to their lives and future careers.

As shown in Tables 1, 2, and 3, the utilization of PBL via the Madrasati Platform had a significant impact on students' mathematical achievement, problem-solving skills, and attitudes toward mathematics.

In terms of mathematical achievement, the experimental group had a significantly higher mean score on the post-test compared to the control group. This indicated that PBL had a positive effect on students' mathematical achievement.

Regarding problem-solving skills, the experimental group outperformed the control group on the complex problem-solving task. The group was better prepared to apply mathematical concepts to real-world situations. These results suggest that PBL can enhance students' problem-solving skills in mathematics.

Finally, in terms of attitudes toward mathematics, the experimental group showed higher levels of motivation, engagement, and interest in learning mathematics. They also demonstrated a greater perception of the relevance of mathematics to their lives and future careers as compared to the control group.

These results support the hypothesis that the utilization of PBL through the Madrasati Platform can have a positive impact on students' mathematical achievement, problem-solving skills, and attitudes toward mathematics.

Table 4 presents a summary of the comparison of results between the experimental and control groups. Notably, the experimental group had higher mean scores across all three measures, including mathematical achievement, problem-solving skills, and attitudes toward mathematics. Furthermore, the t-tests revealed significant differences between the two groups in all measures, underscoring the statistical significance of the results.

Overall, the results suggest that the utilization of PBL via the Madrasati Platform can be an effective approach for improving students' mathematical achievement, problem-solving skills, and attitudes toward mathematics.

CONCLUSION

Based on the results of this study, it can be concluded that the intervention program, utilizing PBL via the Madrasati Platform, had a significant positive impact on the mathematical achievement, problem-solving skills, and attitudes toward mathematics of the experimental group compared to the control group. The experimental group demonstrated higher mean scores across all three measures, and the t-tests underscored the statistical significance of these differences, even at the 0.05 level or lower. Therefore, the intervention program effectively enhanced the mathematical performance and attitudes of the participating students.

The implications of the results can be discussed in three aspects: (1) mathematics education; (2) the use of PBL in mathematics education; and (3) the use of technology-based platforms like the Madrasati Platform. First, the results suggest that the utilization of PBL via the Madrasati Platform can enhance students' mathematical achievement, problem-solving skills, and attitudes toward mathematics. This finding emphasizes the importance of incorporating PBL into mathematics instruction to promote a deeper understanding of mathematical concepts and their real-world applications.

Second, the findings suggest that PBL can be an effective pedagogical tool for mathematics education, particularly when integrated with a technology-based platform like the Madrasati Platform. Educators should consider implementing PBL in their mathematics instruction to enhance students' learning outcomes and engagement.

Third, the Madrasati Platform's digital environment supports PBL in mathematics education. The results of this study suggest that the use of such platforms can facilitate students' learning outcomes and engagement in mathematics. Educators should, therefore, consider using technology-based platforms in their instruction, particularly those that provide features and tools that support PBL. However, the effectiveness of such platforms may depend on the quality of the content and pedagogical practices implemented by the educators.

Despite the significant findings of this study, there are several limitations to consider. For instance, the relatively small sample size may limit the generalizability of the findings to other populations. Additionally, the study was conducted in a specific context. Thus, it may not be applicable to other educational settings.

Future research could replicate this study with larger, more diverse samples to increase the generalizability of the findings. Additionally, future studies could explore the impact of PBL on subject areas like science or social studies to determine the extent to which PBL is an effective teaching approach across disciplines.

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