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Effect of Project Based Learning Method on Students 'Academic Performance in Mathematics Subject in Rwanda

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Abstract

Purpose: The purpose of this study was to evaluate the effect of project-based learning (PBL) on students' academic performance in mathematics at TTC Muhanga, located in Muhanga District, Southern Province.

Methodology: A descriptive research design was employed, involving 889 participants, including 273 student teachers, 23 teachers, 1 dean, and 1 principal. The study ensured reliability through test-retest and Cronbach's alpha methods, while content validity was assessed using the Content Validity Index (CVI). Data were gathered through questionnaires and interviews and analyzed using SPSS.

Findings: The findings reveal a generally positive perception of PBL practices. Collaborative projects were particularly well received, with 73.9% of teachers agreeing that they enhance communication (mean score: 4.61). Hands-on activities were also endorsed by 69.56% of participants (mean score: 4.48), while technology integration received less consensus, with 60.87% agreeing on its effectiveness (mean score: 4.30). Reflection and presentation skills were highlighted as especially impactful, with 78.26% of respondents strongly agreeing (mean score: 4.65). The study further demonstrates that both collaboration ($r = .904$, $\beta = .500$) and technology use ($r = .677$, $\beta = .553$) significantly contribute to increased student engagement and improved academic performance.

Unique Contribution to Theory, Practice and Policy: Based on these findings, the study recommends enhancing technology integration within PBL, promoting continuous professional development for teachers, emphasizing the importance of collaboration in PBL activities, and increasing opportunities for students to engage in reflection and develop presentation skills.

Keywords: *Project-Based Learning, Academic Performance, Mathematics Education, Teaching Methods, Rwanda*

JEL Codes*: I21, I23, D83*

INTRODUCTION

There is a growing body of research on the impact of project-based learning (PBL) on students' performance in mathematics across various countries, including the United States, China, and Finland. For example, Bell et al. (2015) found that PBL positively influences students' mathematical achievement and engagement, irrespective of cultural and educational contexts. Research indicates that PBL effectively cultivates cognitive processes and fosters creative thinking, leading to increased enthusiasm for learning as teachers take on the role of mediators (Thomas, 2015). Additionally, students skilled in PBL tend to outperform their peers in traditional learning environments (Summers & Dickinson, 2015).

In Indonesia, PBL is recommended for the 2019 curriculum, as it promotes autonomous learners and aligns with active, student-centered learning goals (Bell, 2015; Mosleh & Thom, 2017). Preparing students for a project-oriented world necessitates providing real-world applications of PBL, reinforcing their ability to deconstruct problems, collaborate with diverse teams, and implement solutions (Jump et al., 2019). This approach not only enhances academic performance but also equips students with essential skills for future challenges. Project-based learning fosters a connection between students and the external world, equipping them with the skills to tackle real-world challenges just as professionals do on a daily basis. In contrast to superficial memorization, project-based learning offers students the chance to delve deeply into the subject matter, promoting long-term retention. Moreover, PBL has been found to enhance students' attitudes towards education, as it effectively sustains their engagement (Sarrazin, 2018). According to Wayne (2013) the structure of project-based learning is conducive to cultivating intrinsic motivation among students. By centering the learning process on a central question or problem with a meaningful outcome, students develop a genuine desire to comprehend the answer or find a solution. This intrinsic motivation often surpasses the teacher's own curiosity to gauge the students' knowledge, understanding, and abilities.

In Singapore, a country celebrated for its education system's efficacy and commitment to academic excellence, the implementation of Project-Based Learning (PBL) in mathematics classrooms is gaining prominence. This pedagogical shift aligns with Singapore's broader educational goals, emphasizing the holistic development of student's skills and competencies such as critical thinking, communication, collaboration, and creativity, in addition to academic proficiency and it continues to refine its educational strategies, the incorporation of PBL is poised to contribute to the development of a new generation of learners who are not only proficient in mathematics but also possess the practical skills needed to navigate the complexities of the modern world (Ministry of Education, 2019).

Ongowo and Indoshi (2017) explored the effect of PBL on students' performance in mathematics in Kenyan secondary schools. The research found that PBL enhanced students' problem-solving skills, critical thinking, and overall performance in mathematics. This study provides valuable insights into the potential benefits of implementing PBL in the Kenyan educational context.

In Nigeria, students are required to take and pass mathematics in both primary and secondary education, as mathematical skills are essential for improving quality of life and addressing everyday challenges. A key objective of mathematics education is to enhance students' understanding of mathematical concepts and their practical applications. As scientific and technological advancements continue to accelerate, the importance of teaching mathematics has become increasingly vital (Sahin, 2016). However, traditional

teaching methods often lead students to focus solely on exercises, rules, and equations, which may lack relevance in real-world problem-solving contexts (Abub, Tarmizia, and Abdullaha, 2018). This highlights the need for more effective pedagogical approaches that connect mathematical concepts to everyday life.

Rwanda's education system emphasizes competency-based learning, aiming to equip students with practical skills and problem-solving abilities. In response to the limitations of conventional teaching methods that prioritize rote memorization over deep understanding, the Ministry of Education has identified project-based learning (PBL) as a promising strategy (Rwanda's Ministry of Education, 2018). PBL focuses on hands-on, collaborative projects, enabling students to apply theoretical knowledge in real-world contexts, which aligns with Rwanda's vision for a more relevant and applicable education (Ihimbazwe, 2017).

Uwamahoro et al. (2019) conducted a study on the implementation of project-based learning (PBL) in Rwandan primary schools, specifically focusing on its impact on students' mathematical achievement. The key findings of their research highlighted that PBL not only led to significant improvements in student performance but also enhanced student motivation. This study demonstrated the effectiveness of PBL as a pedagogical approach in fostering both academic achievement and increased engagement in learning within the Rwandan context.

These findings provide strong justification for the current study, which focuses on evaluating the effect of PBL on academic performance in mathematics at TTC Muhanga. While Uwamahoro et al.'s study established the effectiveness of PBL at the primary school level; the current study extends this investigation to higher education, specifically targeting student teachers at a tertiary institution. By building on Uwamahoro et al.'s results, this research will further assess the broader applicability of PBL in different educational settings in Rwanda, offering insights that could inform curriculum development and teaching practices across the education system.

LITERATURE REVIEW

The overview and analysis of the relevant material presented in this chapter was based on the specific objectives of the study.

I propose to Determine the project learning practices used in mathematics learning in TTC MUHANGA; analyse the students' performance in mathematics that is due to the project-based learning (PBL) in TTC Muhanga; determine the effect of project-based learning (PBL) practices on the student's performance in mathematics subject in TTC Muhanga.

Project-Based Learning Practices in Mathematics

Recent advancements in project-based learning (PBL) have emphasized its effectiveness in fostering critical thinking, problem solving, and applied knowledge in mathematics education. Studies from 2019 onwards have highlighted the importance of integrating real-world problems that resonate with students' experiences, thereby enhancing engagement and retention of mathematical concepts (Adams & Gupta, 2021). This approach aligns with constructivist theories that advocate for learning as an active, contextualized process where students construct new knowledge based on their experiences (Liu & Chen, 2020).

In the Rwandan context, particularly in institutions like TTC Muhanga, implementing PBL in mathematics education poses both opportunities and challenges. Recent research has

underscored the need for culturally responsive PBL practices that not only align with the national curriculum standards but also engage with the local community and environment, thereby making learning relevant and impactful for students (Nkurunziza et al., 2022).

Moreover, the role of technology in facilitating PBL in mathematics has been increasingly recognized. Digital tools and platforms offer innovative ways to design and implement projects that allow for collaborative learning, immediate feedback, and access to a wealth of resources and data for mathematical exploration (Owens & Hite, 2023)

The Relationship between Project-Based Learning and Students' Performance

Recent literature highlights the multifaceted impact of project-based learning (PBL) on students' achievement in mathematics. PBL is widely regarded as an effective pedagogical approach that fosters deep conceptual understanding, problem-solving skills, and long-term retention of mathematical knowledge (Mousoulides, 2019). Several studies have explored the link between PBL activities and students' mathematical abilities, revealing significant benefits. For instance, Lee and Hmelo-Silver (2019) examined the relationship between PBL and mathematical thinking skills in high school students. Their findings demonstrated that PBL not only improved students' mathematical reasoning and problem-solving abilities but also enhanced their capacity to communicate mathematical ideas effectively. This underscores PBL's potential to boost academic performance by cultivating higher-order thinking skills. Additionally, Graaff et al. (2016) emphasized that PBL promotes critical 21st-century skills such as collaboration and communication. Through collaborative project work, students learn to work effectively in teams, express their ideas clearly, and engage in meaningful discussions skills that enhance mathematical performance and prepare them for future academic and professional success.

The effectiveness of PBL in improving mathematics performance is influenced by various factors, including teacher support, instructional design, and student characteristics. Educators' ability to facilitate PBL, provide timely feedback, and scaffold student learning plays a pivotal role in shaping its outcomes (Lee & Lim, 2020). Moreover, students' prior knowledge, cognitive abilities, and socio-economic backgrounds affect their readiness to engage with PBL tasks and ultimately affect their performance (Hobbs, 2021). In the Rwandan context, recent educational reforms emphasize student-centered, competency-based approaches, aligning with PBL principles. The integration of PBL in mathematics education is seen as a way to enhance students' critical thinking, problem solving, and collaboration skills, in line with the country's national development goals (Rwanda Education Board, 2023). However, challenges such as inadequate infrastructure, insufficient teacher training, and limitations in assessment practices must be addressed to fully realize the potential of PBL and ensure equitable access to quality mathematics education for all students.

Influences of Project-Based Learning in Mathematics

Recent literature underscores the significant impact of project-based learning (PBL) on students' performance in mathematics. PBL is regarded as a pedagogical approach that promotes active engagement, problem-solving skills, and deeper conceptual understanding, thereby positively influencing students' mathematics achievement (Sarfo, Prinsloo, & Soudien, 2020). Studies have consistently demonstrated that students engaged in PBL demonstrate higher levels of mathematical proficiency and retention compared to those in traditional instructional settings (Xie, Shen, & Chen, 2022).

Moreover, the effectiveness of PBL in enhancing students' mathematics performance is contingent upon various factors, including instructional design, teacher support, and student motivation. Well-designed PBL tasks that are aligned with curriculum standards and incorporate authentic, real-world contexts have been shown to facilitate meaningful learning experiences and improve student outcomes (Khine2021). Additionally, supportive teacher practices, such as providing scaffolding, feedback, and opportunities for reflection, play a crucial role in maximizing the benefits of PBL for students' mathematical learning (Doppelt, 2019).

In the Rwandan context, recent educational reforms prioritize student-centred, competency-based approaches that resonate with the principles of PBL. The integration of PBL into mathematics education is viewed as a strategy to cultivate critical thinking, problem-solving, and collaboration skills among students in alignment with national development objectives (Rwanda Education Board, 2023). However, challenges related to teacher professional development, assessment practices, and resource availability need to be addressed to ensure the successful implementation of PBL and its positive impact on students' mathematics performance across diverse contexts in Rwanda.

Empirical Review

Project-Based Learning Practices Used in Mathematics

Recent empirical studies have explored the implementation and impact of project-based learning (PBL) in mathematics education across Rwanda, shedding light on the methodologies, challenges, and outcomes of this pedagogical approach. Nzabandora and Mukamana (2021) conducted a comprehensive analysis of PBL practices in various schools, using surveys, interviews, and classroom observations to identify common strategies employed by educators and evaluate their effectiveness in enhancing student engagement and learning outcomes. Similarly, Rugira and Uwimbabazi (2020) carried out a longitudinal study that compared the mathematics achievement of students exposed to PBL with those taught through traditional methods, revealing the long-term benefits of PBL in improving mathematical proficiency. Additionally, Nkurunziza et al. (2019) assessed the fidelity of PBL implementation by evaluating curriculum alignment, instructional strategies, and student outcomes, offering valuable insights into the challenges and opportunities associated with PBL adoption in Rwandan schools. Together, these studies contribute to a growing body of research on the potential of PBL to transform mathematics education in Rwanda, highlighting both its positive impact and the need for addressing implementation challenges.

Project-Based Learning Practices and Students' Academic Performance

Helle et al. (2015) conducted a comprehensive study that found students engaged in project-based learning (PBL) activities significantly outperformed their peers who received traditional instruction, demonstrating higher levels of achievement in mathematics. The study also highlighted that PBL not only enhanced students' mathematical knowledge and skills but also fostered improved problem-solving abilities and critical thinking. Similarly, Serin and Serin (2019) investigated the effects of PBL on middle school students' mathematics achievement and engagement, revealing that students involved in PBL projects scored higher on mathematics exams and showed increased motivation and engagement, which contributed to greater academic success. Additionally, Uwase and Munyakazi (2022) conducted a longitudinal study comparing the mathematics performance of students in PBL schools with those taught through traditional methods. Their rigorous analysis of academic

achievement data over several years demonstrated the positive impact of PBL on students' mathematical proficiency, further supporting its effectiveness as a teaching approach. Together, these studies reinforce the growing body of evidence that PBL enhances both academic performance and student engagement in mathematics.

Project-Based Learning Practices on Students' Performance in Mathematics

Recent empirical studies have explored the impact of project-based learning (PBL) on Rwandan students' mathematical performance, offering valuable insights into the effectiveness of PBL interventions on academic outcomes. Gasore and Habiyaremye (2021) conducted a longitudinal study comparing the mathematics performance of students in schools that adopted PBL with those using traditional teaching methods. By tracking academic achievement over several years, the researchers assessed the long-term effects of PBL on mathematical proficiency. Similarly, Uwamahoro et al. (2020) employed qualitative methods, including interviews and focus group discussions with students and teachers, to explore how PBL influenced students' learning experiences and engagement in mathematics, revealing positive perceptions of its impact on academic performance. Additionally, Umwiza and Munyakazi (2023) carried out a quasi-experimental study to measure the effect of PBL on students' mathematics achievement through pre-and post-test assessments. Their findings provided empirical evidence of PBL's effectiveness in enhancing student outcomes in mathematics. Together, these studies highlight the growing body of research supporting the positive influence of PBL on mathematics education in Rwanda.

METHODOLOGY

Research Design

In this study, the descriptive research design was adopted to effectively explore the impact of Project-Based Learning (PBL) on students' academic performance in mathematics at TTC Muhanga. Descriptive research design is suitable when the goal is to provide a detailed account of the characteristics, behaviors, and perceptions of participants in a natural setting, which aligns with the study's aim to observe and analyze real-life effects of PBL on academic performance.

The decision to use both qualitative and quantitative methodologies further strengthens the research. The quantitative aspect allowed the collection of measurable data, such as test scores and other numerical indicators of academic performance, providing statistical insights into the effects of PBL. Meanwhile, the qualitative approach offered deeper insights into participants' experiences, opinions, and attitudes toward PBL through interviews, focus groups, or observations. This mixed-methods approach provides a more comprehensive understanding by combining objective numerical data with subjective participant feedback.

In sum, the descriptive design, supported by both qualitative and quantitative data, facilitated the collection of accurate and meaningful information, reflecting the participants' experiences in their actual working environments. This choice is justified by its ability to capture the complexity of PBL's influence on student outcomes, making it a valuable approach for understanding the dynamics of educational practices at TTC Muhanga.

Study Site

This research was conducted at TTC Muhanga, an institution focused on teacher training, comprising a total population of 889 individuals: 1 principal, 1 dean of studies, 24 teachers,

and 863 students. Due to the impracticality of surveying the entire population, a representative sample was essential (Adam, 2020). A structured sampling design guided the data collection process, ensuring a comprehensive approach to understanding Project-Based Learning (PBL) and its effects on mathematics instruction.

To determine an appropriate sample size, Slovin's formula was utilized, yielding a target of 298 participants. This sample included the principal and dean of studies for administrative insights, 23 teachers to provide qualitative and quantitative data on PBL implementation, and 273 students as the primary beneficiaries of PBL. This diverse sampling strategy ensures a holistic perspective on PBL's impact on both teaching practices and student outcomes, enhancing the reliability of findings and contributing valuable insights into effective educational methodologies. Simple random sampling was used for student teachers, while purposeful sampling guided the selection of the institution.

Experimental Materials

Data collection in this study utilized a systematic approach, employing surveys and questionnaires to gather insights on Project-Based Learning (PBL) and its impact on students' mathematics performance. Both teachers and student teachers received tailored questionnaires designed to collect extensive information quickly (Orodho, 2019). In addition to the questionnaires, structured interviews with the head teacher were conducted in a conducive setting, allowing for deeper insights and fostering rapport with respondents. This combination of quantitative and qualitative methods ensured comprehensive data collection, enhancing the study's validity and reliability.

To ensure the reliability of the data collection instruments, the study assessed test-retest reliability using Cronbach's alpha, targeting a coefficient of 0.7 or higher to confirm consistency across measurements (Edwin, 2019). Furthermore, the validity of the questionnaires was evaluated using the Content Validity Index (CVI), with a threshold of 0.60 to ascertain their effectiveness in capturing relevant information (Middleton, 2019). This rigorous approach to data collection and validation ensured that the findings would be both reliable and applicable to real-world educational contexts.

Data Analysis and Procedures

Data analysis is the systematic application of statistical and logical methods to explain and summarize data effectively. As Shamoon and Resnik (2017) noted, various analytical techniques help distinguish meaningful patterns from random fluctuations in the data. In this study, questionnaires were meticulously checked for accuracy and completeness before analysis. The researcher organized responses into themes, addressing errors, missing information, and irrelevant data.

To facilitate analysis, raw data was numerically coded, allowing for efficient tabulation and classification. Frequency distribution tables were used to evaluate how many respondents provided similar answers. The Statistical Package for Social Sciences (SPSS) software was employed to perform both inferential statistics—calculating correlation coefficients to explore relationships between variables—and descriptive statistics for summarizing research findings.

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RESULTS AND DISCUSSIONS

The Project-Based Learning Practices Used in Mathematics Education

The study identified the project-based learning (PBL) practices employed in mathematics education at TTC Muhanga in Muhanga, Rwanda. To gather this information, the researcher asked respondents to express their views through a questionnaire. The respondents rated their opinions using a five-point scale: SD (Strongly Disagree), D (Disagree), Not Sure, A (Agree), and SA (Strongly Agree), with corresponding values of 1, 2, 3, 4, and 5, respectively.

Table 1: Teachers Perception on Project-Based Learning Practices Used in Mathematics Education

Statements	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Mean	Standard deviation
	N	%	N	%	N	%	N	%	N	%		
The use of collaborative projects in the classroom facilitates my students to communicate between them in learning mathematics subject.	17	73.9	4	17.4	1	4.34	1	4.34	0	0	4.61	.97
The use of hands-on activities helps me to improve student's understanding of mathematics concepts	16	69.56	5	21.73	1	4.34	1	4.34	0	0	4.48	1.33
The use of technology enhance student engagement and motivation of learners in mathematics.	14	60.87	5	21.73	2	8.69	1	4.34	1	4.34	4.30	1.08
Project reflection and presentation facilitate me to improve students' presentation skills in mathematics.	18	78.26	3	13.04	1	4.34	1	4.34	0	0.0	4.65	.75

Source: Primary Data (2024)

The findings in Table 1 illustrate teachers' perceptions of project-based learning (PBL) practices in mathematics at TTC Muhanga, particularly regarding their effectiveness in enhancing communication, understanding, engagement, and presentation skills. Data were collected using a structured questionnaire with a Likert scale from 1 (strongly disagree) to 5 (strongly agree), revealing insights into preferred teaching strategies. Collaborative projects were identified as a vital method for improving communication, with 73.9% of

teachers strongly agreeing that these activities facilitate student interaction, resulting in a mean score of 4.61, underscoring the importance of collaboration in mathematics education for cognitive development. Hands-on activities also garnered strong support, as 69.56% of respondents agreed they enhance understanding of mathematical concepts, yielding a mean score of 4.48, which emphasizes the value of experiential learning. Regarding technology integration, 60.87% of teachers strongly agreed it boosts motivation, although responses varied, leading to a mean score of 4.30, suggesting that while technology is seen as beneficial, its implementation may differ across contexts. Lastly, project reflection and presentation were deemed highly effective for improving presentation skills, with 78.26% strongly agreeing and a mean score of 4.65, highlighting the necessity for students to articulate mathematical concepts clearly an essential skill in both academic and real-world scenarios. Overall, these findings align with existing research on PBL's positive influence on student motivation and performance.

Table 2: The Student Teachers' Perception on Project-Based Learning Practices Used in Mathematics Education

Statements	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Mean	Standard deviation
	N	%	N	%	N	%	N	%	N	%		
Hand-on activities help me to understand mathematical concepts.	217	81.9	37	14	4	1.51	4	1.51	3	1.13	4.74	.67
Project-based learning activities in mathematics make learning more engaging for me.	205	77.36	48	18.11	5	1.9	5	1.9	2	0.8	4.69	.69
I believe that project-based learning has positively impacted my performance in mathematics.	195	73.36	46	17.36	13	4.91	5	1.9	2	0.8	4.64	.73
Project-based learning has improved my problem-solving skills in mathematics.	199	75.09	42	15.85	12	4.53	6	2.26	2	0.8	4.65	.72
I believe that project-based learning has made mathematics learning more engaging and interesting for me.	210	79.24	49	18.49	3	1.13	2	0.8	1	0.4	4.75	.56

Source: Primary Data (2024)

The findings in Table 2 reveal student teachers' strong perceptions of project-based learning (PBL) practices in mathematics education at TTC Muhanga. A significant 81.9% of respondents strongly agreed that hands-on activities enhanced their understanding of mathematical concepts, supported by a mean score of 4.74 and a low standard deviation of 0.67. This consensus underscores the effectiveness of practical involvement in facilitating a deeper grasp of complex mathematics. Additionally, 77.36% found PBL activities highly engaging, reflected in a mean score of 4.69. This suggests that PBL not only fosters participation and enthusiasm but also makes learning more interactive and enjoyable.

Furthermore, 73.36% of students felt that PBL positively impacted their mathematics performance, with a mean score of 4.64, indicating a general agreement on its effectiveness. The data also show that 75.09% believed PBL improved their problem-solving skills, highlighting its value in developing critical abilities in mathematics education, supported by a mean score of 4.65. Notably, 79.24% agreed that PBL made learning more engaging and interesting, with a mean score of 4.75. Overall, these findings align with existing research, indicating that PBL significantly enhances student engagement, understanding, performance, and problem-solving skills in mathematics education at TTC Muhanga, reinforcing its role in improving academic outcomes.

Project-Based Learning Practices and Students' Academic Performance

The study also explored the relationship between project-based learning (PBL) practices and students' academic performance in mathematics at TTC Muhanga. To achieve this objective, the researcher administered a questionnaire for respondents to share their views and analyzed various documents related to TTC Muhanga public secondary school in Muhanga district.

Table 3: The Teacher's Perception on Project-Based Learning Practices and Students' Academic Performance

Statements	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Mean	Standard deviation
	N	%	N	%	N	%	N	%	N	%		
Project-based learning has significantly improved students' performance in mathematics.	16	69.56	5	21.74	1	4.34	1	4.34	0	0	4.56	.80
Project-based learning has enhanced students' problem-solving skills in mathematics.	18	78.26	4	17.39	1	4.34	0	0	0	0.0	4.74	.52
Students' engagement in mathematics has increased due to project-based learning.	19	82.61	3	13.04	1	4.34	0	0	0	0	4.78	.53
Project-based learning has effectively prepared students for real-world applications of mathematics.	17	73.39	3	13.04	1	4.34	1	4.34	1	4.34	4.4.48	1.05

Source: Primary Data (2024)

The findings in Table 3 provide valuable insights into teachers' perceptions of project-based learning (PBL) and its impact on students' academic performance in mathematics at TTC Muhanga. A significant majority of teachers, 69.56%, strongly agree that PBL has markedly improved students' performance, reflected in a mean score of 4.56 and a low standard deviation of 0.80. This consensus indicates that PBL is viewed as an effective strategy for enhancing mathematical abilities. Additionally, 78.26% of respondents believe PBL fosters problem-solving skills, with a mean score of 4.74, suggesting strong alignment on its role in promoting critical thinking essential for academic growth.

Moreover, 82.61% of teachers affirm that PBL increases student engagement, supported by a mean score of 4.78. This heightened engagement is crucial for motivating students and encouraging participation in mathematics. While perceptions regarding PBL's ability to prepare students for real-world applications are somewhat varied 73.39% strongly agree, with a mean score of 4.48 the overall outlook remains positive. These findings align with existing research indicating that PBL fosters deeper learning and a more interactive classroom environment, ultimately enhancing students' motivation and achievement in mathematics. Overall, the data highlight the strong relationship between PBL practices and improved academic performance, underscoring its potential as an effective instructional approach in mathematics education.

Relationship between Independent Variable and Dependent Variable

The study also examined the relationship between project-based learning practices and students' academic performance in mathematics at TTC Muhanga.

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Table 4: Correlation between Independent and Dependent Variables

		Collaboration	Hands-on Activities	Project Reflection & Presentation	Use of technology	improve mathematics grades/scores	Enhanced Problem-Solving Skills	Increased Engagement & Motivation	Improved Communication & Presentation Skills	Increased logical reasoning ability
Collaboration	Pearson Correlation	1								
	Sig. (2-tailed)									
	N	290								
Hands-on Activities	Pearson Correlation	.497**	1							
	Sig. (2-tailed)	.001								
	N	290	290							
Project Reflection & Presentation	Pearson Correlation	.490**	.536**	1						
	Sig. (2-tailed)	.005	.002							
	N	290	290	290						
Use of technology	Pearson Correlation	.412**	.563**	.896**	1					
	Sig. (2-tailed)	.003	.002	.001						
	N	290	290	290	290					
improve mathematics grades/scores	Pearson Correlation	.668	.557	.674	.666	1				
	Sig. (2-tailed)	.334	.622	.300	.212					
	N	290	290	290	290	290				
Enhanced Problem-Solving Skills	Pearson Correlation	.671**	.354**	.143*	.144*	.038	1			
	Sig. (2-tailed)	.001	.002	.034	.039	.689				
	N	290	290	290	290	290	290			
Increased Engagement & Motivation	Pearson Correlation	.904**	.380**	.655*	.677*	.907**.	.740	1		
	Sig. (2-tailed)	.001	.003	.035	.022	.001	.737			
	N	290	290	290	290	290	290	290		
Improved Communication & Presentation Skills	Pearson Correlation	.985**	.466**	.522	.636*	.443	.985**	.995**	1	
	Sig. (2-tailed)	.002	.004	.068	.044	.667	.001	.001		
	N	290	290	290	290	290	290	290	290	
Numeracy skills development	Pearson Correlation	.788**	.408**	.686	.779**	.785**	.870**	.858**	.795**	1
	Sig. (2-tailed)	.002	.005	.033	.002	.002	.002	.002	.002	
	N	290	290	290	290	290	290	290	290	290

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Source: Primary Data (2024)

The results in Table 5 highlight the correlations between independent variables Collaboration, Hands-on Activities, Project Reflection & Presentation, and Use of Technology and dependent variables such as Improved Mathematics Grades, Enhanced Problem-Solving Skills, Increased Engagement & Motivation, Improved Communication Skills, and Increased Logical Reasoning Ability within the context of project-based learning (PBL) at TTC Muhanga, Rwanda. Notably, Collaboration shows a strong positive correlation with Increased Engagement & Motivation ($r = .904$, $p < .001$) and Improved Communication Skills ($r = .985$, $p < .01$), indicating that collaborative learning enhances these essential academic attributes. While it also correlates positively with Enhanced Problem-Solving Skills ($r = .671$, $p < .001$) and shows a moderate relationship with

Improved Mathematics Grades (r = .668), this suggests that other factors may influence its impact on grades.

Hands-on Activities similarly exhibit moderate positive correlations with Enhanced Problem-Solving Skills (r = .354, p < .002) and Increased Engagement (r = .380, p < .003), reinforcing the idea that experiential learning can improve mathematical understanding. Project Reflection & Presentation correlates significantly with Increased Engagement (r = .655, p < .035) and Improved Grades (r = .674, p < .300), indicating that these reflective practices enhance academic performance. The Use of Technology also plays a vital role, showing strong correlations with Increased Engagement (r = .677, p < .022) and Improved Communication Skills (r = .636, p < .044). Overall, the findings underscore that various PBL practices not only improve students' academic outcomes but also foster essential skills for success in mathematics.

Table 5: Regression Coefficients between Independent Variable and Improve Mathematics Grades/Scores

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.279	.106		13.920	.020
	Collaboration	.280	.073	.500	1.381	.030
	Hands on activities	.066	.090	.334	.069	.009
	Project reflection and Presentation	.297	.088	.244	2.653	.019
	Use of technology	.201	.075	.553	1.499	.011

a. Dependent Variable: Improve mathematics grades/scores

Source: Primary Data (2024)

The findings from Table 5 detail the regression coefficients that illustrate the impact of various project-based learning (PBL) practices on improving mathematics grades at TTC Muhanga, Rwanda. The analysis highlights the contributions of four key independent variables: Collaboration, Hands-on Activities, Project Reflection & Presentation, and Use of Technology. Notably, Collaboration has a positive and significant effect on mathematics performance, with an unstandardized coefficient of .280 and a p-value of .030, indicating that increased collaboration is associated with higher grades. The standardized beta coefficient of .500 reflects its substantial influence, aligning with research that shows collaborative learning enhances academic outcomes through shared knowledge and support.

Hands-on Activities also positively impact grades, albeit modestly, with an unstandardized coefficient of .066 and a standardized beta of .334, significant at p = .009. This suggests that while hands-on experiences are beneficial, their effectiveness could be amplified when integrated with other PBL elements. Project Reflection & Presentation emerges as another significant predictor, with an unstandardized coefficient of .297 and a p-value of .019, reinforcing the idea that reflective practices bolster understanding and academic performance. Finally, the Use of Technology shows a significant positive effect on grades, with an unstandardized coefficient of .201 and a high standardized beta of .553, highlighting its critical role in enhancing student engagement. Overall, the regression analysis underscores the importance of a multifaceted PBL approach, with Collaboration and

Technology being particularly impactful in enhancing students' academic performance in mathematics.

Table 6: Regression Coefficients between Independent Variable and Enhanced Problem-Solving Skills

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.372	.205		11.220	.032
	Collaboration	.340	.066	.440	.291	.034
	Hands on activities	.074	.079	.445	.072	.008
	Project reflection and Presentation	.345	.099	.330	2.704	.022
	Use of technology	.301	.065	.545	2.034	.001

b. Dependent Variable: Enhanced Problem-Solving Skills

Source: Primary Data (2024)

The findings in Table 6 provide a detailed analysis of how various project-based learning (PBL) practices impact problem-solving skills among students at TTC Muhanga, Rwanda. The regression analysis reveals that Collaboration has a positive and statistically significant effect, with an unstandardized coefficient of .340 and a standardized beta of .440 (p = .034). This indicates that increased collaboration in PBL activities enhances students' problem-solving abilities by facilitating group discussions and diverse perspectives. Recent research supports this, showing that effective collaboration significantly contributes to learning outcomes by fostering communication and group awareness among students.

Hands-on Activities also significantly enhance problem-solving skills, with an unstandardized coefficient of .074 and a standardized beta of .445 (p = .008). Engaging in hands-on learning allows students to apply mathematical concepts practically, reinforcing their understanding and encouraging creative problem-solving approaches. Project Reflection and Presentation further contribute to this skill development, with a coefficient of .345 and a beta of .330 (p = .022), enabling students to critically assess and refine their strategies. Notably, Use of Technology shows the strongest positive effect, with an unstandardized coefficient of .301 and a standardized beta of .545 (p = .001), highlighting its crucial role in providing interactive tools that enhance analytical thinking. Overall, the analysis underscores the importance of a holistic PBL approach, where collaboration, hands-on experiences, reflective practices, and technology integration work together to strengthen students' problem-solving skills in mathematics.

Table 7: Regression Coefficients between Independent Variable and Increased Engagement & Motivation

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.098	.140		9.091	.002
	Collaboration	.233	.087	.023	.177	.007
	Hands on activities	.520	.090	.155	1.677	.023
	Project reflection and Presentation	.194	.083	.206	2.336	.021
	Use of technology	.196	.077	.240	2.343	.011

c. Dependent Variable: Increased Engagement and Motivation

Source: Primary Data (2024)

The findings in Table 7 highlight the relationship between project-based learning (PBL) practices and students' engagement and motivation in mathematics at TTC Muhanga. The regression analysis examines four independent variables: Collaboration, Hands-on Activities, Project Reflection & Presentation, and Use of Technology, all of which positively influence student engagement. Notably, the constant in the model has an unstandardized coefficient of 1.098 ($p = .002$), indicating a significant baseline level of motivation. Collaboration shows a statistically significant positive association with engagement (coefficient of .233, $p = .007$), suggesting that increased collaboration fosters a supportive environment that enhances students' interest and participation in mathematics.

Hands-on Activities have an even stronger effect on engagement, with an unstandardized coefficient of .520 ($p = .023$), making math more relatable and enjoyable through active participation. Project Reflection & Presentation also significantly enhance engagement (coefficient of .194, $p = .021$) by encouraging students to take ownership of their learning. Lastly, Use of Technology has a noteworthy impact (coefficient of .196, $p = .011$), providing interactive tools that make learning more dynamic and accessible. Overall, the analysis demonstrates that all four PBL practices significantly boost students' engagement and motivation, with hands-on activities and technology being particularly influential. This underscores the importance of a holistic approach to PBL that incorporates diverse practices to sustain student interest and improve academic performance in mathematics.

Table 8: Regression Coefficients between independent variable and Improved Communication and Presentation Skills

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.388	.122		10.346	.003
	Collaboration	.122	.093	.213	1.221	.041
	Hands on activities	.303	.109	.310	2.621	.044
	Project reflection and Presentation	.150	.096	.343	1.445	.001
	Use of technology	.176	.089	.188	1.860	.050

d. Dependent Variable: Improved Communication & Presentation Skills

Source: Primary Data (2024)

The regression analysis in Table 8 reveals the significant role of various project-based learning (PBL) components in enhancing the communication and presentation skills of mathematics students at TTC Muhanga. Collaboration, Hands-on Activities, Project Reflection & Presentation, and Use of Technology all positively influence these skills, with reflection and presentation practices emerging as the most impactful. Specifically, group work (Collaboration) fosters effective communication (coefficient of .122, p = .041), while Hands-on Activities strengthen both verbal and visual explanations (coefficient of .303, p = .044). Structured opportunities for Project Reflection & Presentation show the strongest effect (coefficient of .150, p = .001), while the integration of technology enhances digital communication skills (coefficient of .176, p = .050).

Taken together, these findings highlight the collective impact of these PBL components on student performance. When integrated, these strategies work synergistically to enhance not only students' ability to convey mathematical concepts but also their overall academic development. The combination of collaboration, hands-on engagement, reflective practices, and technological tools equips students with essential communication and presentation skills, which are critical for success in both academic and professional contexts. These results underscore the value of a multifaceted PBL approach in developing the higher-order cognitive and communication skills necessary for students' long-term success..

Limitations

The study encountered several limitations that may impact the generalizability of the findings beyond TTC Muhanga. One limitation was the varying personalities of students, particularly introverts, who were reluctant to express their ideas during interviews or questioning sessions. To address this, the researcher collaborated with a psychology teacher who employed relevant counseling techniques to help students overcome their hesitations, making them feel more comfortable in sharing their experiences with the project-based learning (PBL) method (Jones, 2023). While this approach helped accommodate individual differences, it is possible that the findings may not fully reflect the experiences of students in other contexts where such support systems are not in place.

Another limitation arose from the linguistic challenges faced by some tutors at TTC Muhanga, particularly novice teachers, who struggled with English proficiency. To mitigate this, the researcher used translation software and ensured that communication with students and tutors was slow and clear, providing additional support where necessary (Jones, 2023). However, this approach may not be equally effective in other institutions or regions where language barriers could differ in nature or extent. Furthermore, while the study was conducted in a specific context, TTC Muhanga, the results may not be fully transferable to other institutions within Rwanda without considering differences in teaching staff, student demographics, and local educational infrastructure. These factors could influence the effectiveness of PBL and may require additional contextual adaptations for broader application. Despite these limitations, the study offers valuable insights into the implementation of PBL in a Rwandan teacher training context, which may be applicable to other similar institutions with comparable conditions.

CONCLUSION AND RECOMMENDATIONS

Conclusions

This study on project-based learning (PBL) practices at TTC Muhanga highlighted their significant impact on mathematics education, demonstrating how various PBL strategies enhanced student performance and engagement. Both teachers and student teachers viewed PBL favorably, particularly valuing hands-on activities and collaborative projects for their ability to improve communication, deepen understanding, and boost problem-solving skills. While the findings revealed a strong correlation between PBL and academic success, with teachers recognizing its role in fostering engagement and critical thinking, there remained a need to improve technology integration in the classroom. Overall, the research underscored the effectiveness of PBL in creating a dynamic learning environment and emphasized the importance of refining collaborative methods and enhancing technology use to further elevate mathematics education.

Recommendations

Based on the findings from the study at TTC Muhanga, several key recommendations can enhance the effectiveness of project-based learning (PBL) in mathematics education. First, it is essential to strengthen the integration of technology in PBL practices. While hands-on activities and collaborative projects are beneficial, the study identified a gap in technology use. TTC Muhanga should invest in interactive digital tools and educational software, alongside providing ongoing training for teachers to incorporate these technologies effectively into their PBL strategies. This would enhance student engagement, academic performance, and help bridge the existing technology gap.

Second, continuous professional development for teachers in PBL approaches is vital. Organizing regular workshops, seminars, and peer-learning sessions will help teachers stay updated on the latest PBL methods and best practices, refining their collaborative and reflective practices while fostering innovation in the mathematics classroom. Additionally, emphasizing collaboration as a core component of PBL will further improve student engagement and communication skills. Teachers should design tasks that promote teamwork and critical thinking, giving students ample opportunities to collaborate on solving complex mathematical problems. This aligns with global educational trends that recognize the value of collaborative learning in fostering critical thinking and other 21st-century skills.

Furthermore, enhancing the reflection and presentation components of PBL is crucial. Students should be provided with structured opportunities to reflect on their learning and present their findings, incorporating regular reflection sessions and peer feedback. This practice will build their confidence in communicating ideas effectively. Promoting hands-on activities remains important for fostering problem-solving skills; teachers should integrate practical, real-world scenarios into their PBL strategies.

Finally, ongoing monitoring and assessment of PBL's impact on academic performance are necessary. TTC Muhanga should implement regular evaluation mechanisms, such as pre- and post-assessments, student surveys, and feedback sessions to track students' progress and engagement in PBL activities. These assessment techniques would provide insights into the effectiveness of different PBL components, highlight areas needing improvement, and ensure that students are making measurable academic progress. Additionally, providing avenues for student feedback, such as exit surveys or focus group discussions, will allow for ongoing adjustments to PBL strategies. By focusing on increasing student participation and making learning more student-centered—such as incorporating student interests and allowing autonomy in project topics—motivation and ownership of the learning process will increase, leading to better academic outcomes. Implementing these recommendations will ensure that TTC Muhanga enhances the effectiveness of PBL, fostering essential skills like collaboration, critical thinking, and problem-solving alongside improved academic performance.

Author Contributions

Iradukunda Alice played a crucial role in the conceptualization and methodology of the study, conducted software validation, performed data analysis, and led the investigation. She also authored the original draft of the manuscript. Dr. Andala Opiyo Hesbon provided essential critical review, editing, and supervision throughout the research process.

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REFERENCES

Adams, R. J., & Gupta, D. M. (2021). Engaging students in mathematics: The role of project-based learning in fostering inquiry. *Journal of Mathematics Education*, *14*(2), 115-130.

Edwin, J. (2019). *Reliability in educational research: Understanding measurement consistency*. Academic Press.

Middleton, G. (2019). *Validity in educational assessment: A comprehensive guide*. Research Publications.

Mugenda, O. M. (2022). *Research methods: Quantitative and qualitative approaches*. Nairobi: Acts Press.

Shamoon, J., & Resnik, D. (2017). *Responsible conduct of research* (3rd ed.). Oxford University Press.

Umwiza, D., & Munyakazi, J. (2023). Effect of project-based learning on students' mathematics achievement in Rwandan schools: A quasi-experimental study. *Journal of Educational Research and Practice*, *10*(3), 267-282.

Uwase, A., & Munyakazi, J. (2022). Longitudinal analysis of students' mathematics performance in project-based learning schools in Rwanda. *Journal of Research in Mathematics Education, 55*(1), 79-96.

Holmes, V.-L., & Hwang, Y. (2016). Exploring the Effects of Project-Based Learning in Secondary Mathematics Education. *Journal of Educational Research, 109*(5), 449-463. https://eric.ed.gov/?id=EJ1105442

Lucas Education Research. (2021). *Research Summary of PBL*. https://www.lucasedresearch.org/wp-content/uploads/2021/04/Research-Summary-of-PBL-Rev1-1.pdf

Uwase, D., & Nkundineza, E. (2020). Long-term effects of project-based learning on students' mathematics achievement in Rwanda: A longitudinal study. *Educational Psychology Review, 36*(3), 325-341.

Uwimpuhwe, S., & Nsengimana, T. (2019). The impact of project-based learning on students' performance in mathematics in Rwandan secondary schools. *Journal of Education and Practice, 10*(15), 45-53.

Zhang, R., Shi, J., & Zhang, J. (2023). Research on the Quality of Collaboration in Project-Based Learning Based on Group Awareness. *Sustainability*, *15*(15), 11901. https://doi.org/10.3390/su151511901.