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The Mediating Effect of Problem-based Learning on the Relationship between Technology Integration and Student Engagement in Mathematics

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This research aimed to determine whether problem-based learning significantly mediates the relationship between technology integration and the engagement of first-year college students. A quantitative approach with descriptive and correlational designs was employed. The respondents of the study were 133 first-year college students in three state colleges in the Division of Davao del Norte. They were chosen through stratified random sampling. Mean, Pearson-r, regression, and mediation analysis were used to analyze the data, which were obtained through the use of three adapted questionnaires. The findings revealed that technology integration is manifested in the students' learning. In mathematics, student engagement is observed, and problem- based learning is evident among the students. It is also found out that there is a significant relationship among technology integration, problem-based learning, and student engagement. Additionally, problem-

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based learning partially mediated the relationship between technology integration and student engagement. The findings suggested that CHED officials should encourage and support the integration of technology into the mathematics curriculum to foster increased student engagement. School administrators can work to maximize student engagement by focusing on the integration of technology and employing problem-based learning methods. Teachers may integrate technology into their lessons and incorporate problem-based learning, and college students may consider integrating technology into their learning environment. Future researchers should explore the effects of technology integration and problem-based learning on student engagement in mathematics.

Keywords: Mathematics education; problem-based learning; technology integration; student engagement; first-year college students; descriptive and correlational design; mean and mediation analysis; davao del norte; Philippines.

1. BACKGROUND

Low engagement of students is considered a challenge faced by the academe today. Student engagement is pivotal in providing meaningful and fair learning opportunities that require effective collaboration between teachers and students [1]. However, keeping students engaged in studying is a common difficulty, regardless of the learning context - remote, in-person, or hybrid [2]. Moreover, due to the constant demand for effective learning settings, the teaching-learning process has changed. In the field of mathematics, it is commonly shared that most students dislike the subject. It is one of the most difficult subjects to teach and learn. There are students in both secondary and tertiary levels who have a negative disposition toward math-related courses, which typically manifests as low student engagement [3].

In Hong Kong, some first year college students have shown weak engagement as they exhibit a lack of interest in mathematical topics and have difficulty engaging with others in their mathematics classes [4]. In Malaysia, there is a low manifestation of students' engagement in public universities. When considering ideas of student engagement like active learning and student-faculty interaction, disengagement among Malaysian college students appears to be a problem [5] Furthermore, in Nigeria, the result of a study showed that engagement in learning mathematics among college students has decreased and as a result, students are not attending their classes and did not pass assignments [6].

In the Philippines, students exhibit poor engagement in mathematics class. In one of the institutions in Cebu, some college students enrolled in mathematics-related programs are disengaged in their mathematics classes and have demonstrated a lack of motivation and enthusiasm in learning many course ideas [7]. Moreover, in Cotabato City, 49.58% of university students show low engagement in mathematics subject as a result of being preoccupied with their cell phones by scrolling on social media sites instead of studying their lessons [8].

At one of the public colleges in the province of Davao del Norte, the level of engagement among tertiary students has decreased by 40% since the start of the pandemic [9]. The author further observed that two (2) out of five (5) students were not participating in online classes and failed assessments and tasks in their modules in mathematics. Additionally, these students are unsuccessful in the submission of the requirements required in the course. Consequently, this problem of student engagement resulted in poor performance in mathematics subject.

The aforementioned problems above clearly emphasized the concern about students' engagement in mathematics and the factors it is being associated. This study focuses on the link between technological integration, problem-based learning, and student engagement. While several studies have tested and determined the relationship between technology integration and student engagement [10,11,12,13], problem-based learning and student engagement [14,15], and technology integration and problem-based learning [16,17,18], however, these studies have only been conducted in an international setting to investigate aspects associated to student engagement. Further, most of these studies mainly concentrated on the perspective of secondary students and the researcher did not find any research that directly correlates problem-based learning to the intermediary role between technology incorporation and student interest. Consequently, this study will be different in several aspects. The primary focus of this study will be to uncover and give substantial findings on the link between technology integration, problem-based learning, and students' engagement through the lens of tertiary-level students. Moreover, this study will also be conducted in the Philippine setting, especially in the post-COVID-19 educational setting in which may provide a different but important discussion on the problem of students' engagement in mathematics.

This study aimed to provide an opportunity to improve the engagement of the students in the subject of mathematics. The researcher hopes to contribute to the advancement of mathematics curriculum and policies that are best suited to the new normal situation by giving new information emphasizing the relationship between technology integration and student engagement in mathematics mediated by problem-based learning. Teachers and other professionals may devise creative methods to engage learners in mathematics learning and use this research to address the demands and difficulties of modern education. Consequently, to the best of the researcher's knowledge, the conduct of the study is urgent since the modality and the delivery of teaching mathematics in the present times are constrained within the bounds of virtual interaction.

Furthermore, the researcher will disseminate the results of the study by attending research forums in the public and private sectors of educational institutions. This will be done in both online and offline academic presentations that concern mathematical research topics that involve tertiary-level students. Additionally, the researcher will give copies to the concerned stakeholders to contribute an additional body of knowledge on the different aspects of the relationship between technology integration and students' engagement in mathematics as mediated by problem-based learning. Moreover, the researcher is also planning to publish the entire results of the study in several online academic journals that may be applicable to further reach a wider scale of readers and other potential beneficiaries such as students, parents, mathematics teachers, and researchers in mathematics education.

1.1 Statement of the Problem

This research sought to investigate whether problem-based learning significantly mediate the relationship between technology integration and the engagement of first-year college students from Davao del Norte in the academic year 2022-2023,

This specifically sought responses to the following questions:

1. What is the level of technology integration on students?
2. What is the level of student engagement?
3. What is the level of problem-based learning of students?
4. Is there a significant relationship between:

   4.1 technology integration and student engagement?
   4.2 problem-based learning and student engagement?
   4.3 technology integration and problem-based learning?

5 Does problem-based learning significantly mediate the relationship between technology integration and student engagement?

1.2 Hypotheses

The following hypotheses were tested at 0.05 level of significance.

1. There is no significant relationship between technology integration and student engagement in mathematics.
2. There is no significant relationship between problem-based learning and student engagement in mathematics.
3. There is no significant relationship between technology integration and problem-based learning.
4. Problem-based learning does not significantly mediate the relationship between technology integration and student engagement in mathematics.

1.3 Theoretical and Conceptual Framework

This study is rooted in the belief that technology integration in teaching enhances student engagement by leveraging various instructional platforms, a concept supported by Bond and Bedenlier [19]. Recognizing the proven impact of technology integration on student engagement, particularly in fostering effective learning environments, has become a crucial aspect of

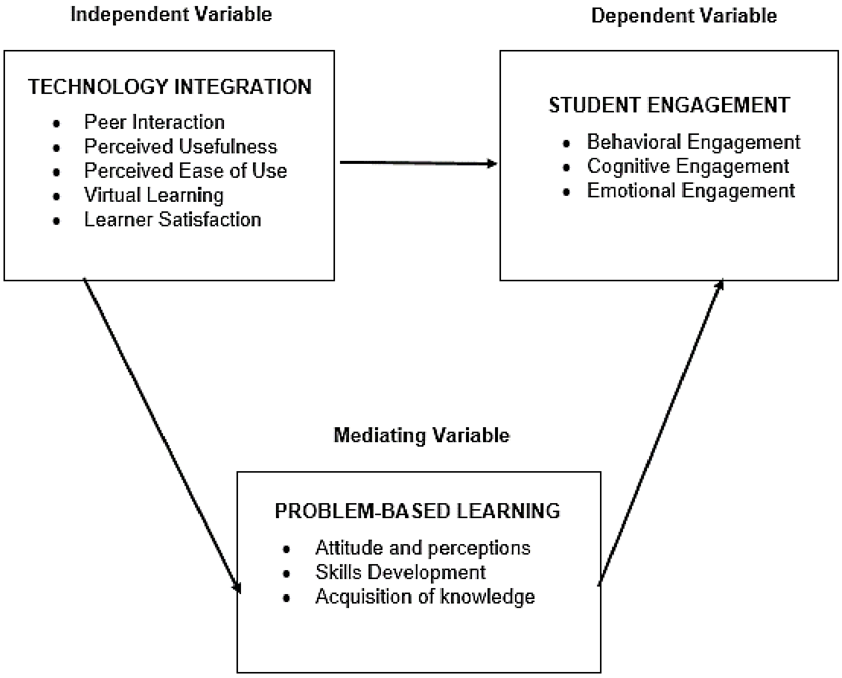


Fig. 1. The Conceptual Framework of the Study

education [20]. The significance of digital literacy and information and communications technology (ICT) abilities further solidify the role of technology integration in influencing student engagement and success [21,22]. Additionally, empirical findings affirm the positive correlation between technology use in the classroom, spanning traditional, online, and self-paced education, and improved student engagement [23]. Furthermore, the study draws inspiration from the works of Szabo et al. [24] and Condliffe et al. [25], highlighting how problem-based learning enhances student engagement by providing real-world problem-solving experiences and fostering a discovery-oriented attitude. Technology integration in problem-based learning is posited as a facilitator of interactivity, motivating learners to actively participate and engage in meaningful problem-solving [26,27,28]. The conceptual paradigm depicted in Fig. 1 outlines the study's independent variable—technology integration—and its five components, the mediating variable—problem-based learning—and its identified measures, and the dependent variable— student engagement—comprising behavioral, cognitive, and emotional indicators [29,30,31].

2. METHODS

In this chapter, the research methods and procedures employed by the researcher in this study are discussed. This covers the research design, the population studied, the research instrument employed, the data gathering process, the statistical treatment of data, and ethical considerations.

2.1 Research Design

In this research, a quantitative approach with a descriptive and correlational design was employed to investigate the phenomenon under study. Data was gathered through survey instruments and computational tools, either by conducting surveys or modifying existing statistical data. The research specifically targeted a sample population, measuring data to gain insights into the characteristics of the group. The descriptive approach was utilized to evaluate and quantify variables such as technology integration, student engagement, and problem-based learning. This involved the use of questionnaires to measure indicators of each variable, providing a comprehensive understanding of the population. Additionally, a correlational approach was adopted to statistically explain the variation among variables, addressing research questions about the significance of relationships between technology integration, student engagement, and problem-based learning. The researcher sought to determine whether problem-based learning influenced the connection between technology integration and student engagement, exploring potential alterations in this relationship within a classroom setting [32,33,34].

2.2 Research Respondents

The respondents of this research were first-year mathematics major college learners of the three (3) state colleges in the province of Davao Del Norte enrolled during the school year 2022-2023. Of the 202 students' population, 105, 65, and 32 students were coming from schools A, B, and C respectively. A total of 133 students were chosen to take part in the study, with the help of the Qualtrics online sample size calculator following a 95% confidence level (Z-Score=1.96) as well as a 5% margin of error. Additionally, stratified sampling technique was utilized to select 69 students from school A, 43 from school B, and 21 from school C.

Fig. 2. depicts the location of the colleges in Davao del Norte. The following places highlighted by the red line indicate the locations of the study's participating institutions.

2.3 Research Instruments

This research employed three adapted research instruments to assess problem-based learning, technology integration, and student engagement in mathematics. These research instruments were evaluated by experts and pilot-tested to a group of students from one college in Davao del Norte who were not involved in the research.

Technology-Adoption Model Questionnaire (TAMQ): To measure the level of technology integration, a questionnaire titled Technology Adoption Model Questionnaire (TAMQ) developed by Das et al. [29] was employed. This contains a 33-item survey questionnaire comprising the five dimensions of technology integration such as peer interaction (4 items), perceived usefulness (10 items), perceived ease of use (4 items), virtual learning (6 items), and learner satisfaction (9 items). The Cronbach Alpha values for the reliability of the whole questionnaire are as follows: peer interaction (0.835), perceived usefulness (0.923), perceived ease of use (0.940, virtual learning (0.849), and learner satisfaction (0.905). In addition, this questionnaire used a 5-point Likert scale to gauge responses: 5 (Strongly agree), 4 (Agree), 3 (Moderately Agree), 2 (Disagree), and 1 (Strongly Disagree).

The following parameter limits, descriptive equivalent, and interpretation were implemented to assess the degree of technology integration into mathematics education, each with their individual definition and significance.

Fig. 2. Map of the Philippines highlighting the public colleges of Davao del Norte

Range of Means	Descriptive Equivalent	Interpretation
4.20 - 5.00	Very High	This shows that technology integration is very much manifested.
3.40 - 4.19	High	This shows that technology integration is manifested.
2.60 – 3.39	Moderate	This shows that technology integration is moderately manifested.
1.80 - 2.59	Low	This shows that technology integration is less manifested.
1.0 -1.79	Very Low	This shows that technology integration is least manifested.

Student Engagement in Mathematics Questionnaire (SEMQ): To measure the level of student engagement, a questionnaire titled Student Engagement in Mathematics Questionnaire (SEMQ) by Flores et al. [31] was employed. This contains a 31-item questionnaire comprising the three (3) measures of student engagement such as behavioral engagement (9 items), emotional engagement (9 items), and cognitive engagement (13 items). The Cronbach Alpha values for the reliability of the whole questionnaire are as follows: behavioral engagement (0.830) items), emotional engagement (0.930), and cognitive engagement (0.885). In addition, this questionnaire used a 5-point Likert scale to gauge responses: 5 (Strongly agree), 4 (Agree), 3 (Moderately Agree), 2 (Disagree), and 1 (Strongly Disagree).

The following parameter limits, descriptive equivalent, and interpretation were implemented to assess the degree of student engagement into mathematics education, each with their individual definition and significance.

Range of Means	Descriptive Equivalent	Interpretation
4.20 - 5.00	Very High	This shows that student engagement is very much observed.
3.40 - 4.19	High	This shows that student engagement is observed.
2.60 – 3.39	Moderate	This shows that student engagement is moderately observed.
1.80 - 2.59	Low	This shows that student engagement is less observed.
1.0 -1.79	Very Low	This shows that student engagement is least observed.

Problem-Based Learning Survey (PBLS): To measure the level of problem-based learning, a questionnaire titled Problem-Based Learning Survey (PBLS) by Mossuto [30] was employed. This contains a 32-item questionnaire that comprises the three (3) components of problem-based learning such as attitude and perceptions (14 items), skills development (10 items), and acquisition of knowledge (8 items). The Cronbach Alpha values for the reliability of the whole questionnaire are as follows: attitude and perceptions (0.944) items), skills development (0.914), and acquisition of knowledge (0.932). In addition, this questionnaire used a 5-point Likert scale to gauge responses: 5 (Strongly agree), 4 (Agree), 3 (Moderately Agree), 2 (Disagree), and 1 (Strongly Disagree).

The following parameter limits, descriptive equivalent, and interpretation were implemented to assess the degree of problem-based learning into mathematics education, each with their individual definition and significance.

Range of Means	Descriptive Equivalent	Interpretation
4.20 - 5.00	Very High	This shows that problem-based learning is very much evident.
3.40 - 4.19	High	This shows that problem-based learning is evident.
2.60 – 3.39	Moderate	This shows that problem-based learning is moderately evident.
1.80 - 2.59	Low	This shows that problem-based learning is less evident.
1.0 -1.79	Very Low	This shows that problem-based learning is least evident.

2.4 Statistical Treatment of Data

The research employed various statistical tools to analyze and measure different aspects of the data. The mean was utilized to determine the average of data points, providing insights into the levels of technology integration, student engagement in mathematics, and the problem-based learning environment. This calculation was crucial in addressing research questions 1, 2, and 3. Standard Deviation played a role in assessing the spread of values in the dataset concerning their proximity to the mean, contributing to the precision of answers for the aforementioned research questions. The Pearson r, commonly known as Pearson correlation coefficient, was employed to quantify the relationships between technology integration, the problem-based learning environment, and student engagement in mathematics, addressing research question 4. Additionally, the Sobel z-test was utilized to examine the mediating effect of the problem-based learning environment on the connection between technology integration and student engagement in mathematics, offering insights into research question 5. These statistical tools collectively provided a robust framework for analyzing and interpreting the research data [32,33,34].

3. RESULTS AND DISCUSSION

This chapter presents the results and discussions of the study. In particular, the researcher discusses the data in tables and its corresponding descriptive interpretations. The researcher also tests the null hypotheses formulated in the study.

3.1 Summary on the Level of Technology Integration of the Students

Table 1 presents the summary on the level of technology integration of the students. It reveals that perceived usefulness had the highest mean of 3.89, as well as the highest level of technology integration among the students. Virtual learning and Learner satisfaction came in second, with a mean of 3.84, and perceived ease of use had the lowest mean of 3.78. All of these means were rated as high.

The students' level of technology integration is notably high, indicated by an overall mean of 3.84 with a corresponding descriptive equivalent of "high." The relatively low standard deviation of 0.809 suggests that responses are closely clustered around the mean, reflecting a consistent viewpoint among students with minimal variability. This indicates a strong manifestation of technology integration. The results underscore the students' positive perception of technology's usability and usefulness in learning mathematics, with high satisfaction levels and positive experiences reported. Notably, these findings align with a recent study by Meliksah University [35], which also observed students expressing a positive view of technology's usability and usefulness in learning mathematics, reporting high satisfaction and ease of use. Furthermore, a separate study conducted by Almagro and Edig [36] supports these observations, indicating that technology use in mathematics classes positively influences student engagement, motivation, and learning outcomes. Overall, the collective evidence suggests that students consistently view technology as beneficial and easy to use in the teaching-learning process for mathematics.

3.2 Summary on the Student Engagement in Mathematics

Table 2 summarizes the level of technology integration of the students. It reveals that, out of the three indicators of technology integration, the students had the highest mean for behavioral engagement, with a mean of 3.96, as well as a descriptive equivalent of high. Following this was emotional engagement, with a mean of 3.89 and a similar descriptive equivalent. Lastly, cognitive engagement had the lowest mean of 3.86, yet still being classified as high.

Table 1. Summary on the level of technology integration of the students

Indicators	Mean	SD	Descriptive Equivalent
Peer Interaction	3.83	0.807	High
Perceived Usefulness	3.89	0.880	High
Perceived Ease of Use	3.78	0.801	High
Virtual Learning	3.84	0.916	High
Learner Satisfaction	3.84	0.890	High
Overall	**3.84**	**0.809**	**High**

The level of student engagement has an overall mean of 3.90 with a descriptive equivalent of high. This means that student engagement is observed. The standard deviation of 0.82 indicates that the responses to the variable are spread out relative to the mean. This means that the majority of responses are close to the mean (3.90). This indicates that there is a relatively large range of responses within the dataset in this variable.

The study's results indicate that students displayed a high level of engagement in the teaching-learning process, encompassing behavioral, emotional, and cognitive dimensions. Notably, learners exhibited active participation with peers and teachers in a mathematics subject, demonstrating enhanced thinking strategies and problem-solving skills. The findings align with Li and Wang's [37] emphasis on the importance of student engagement in mathematics education, highlighting that students maintained a high level of attention and interest in the subject. Furthermore, positive emotions were observed during mathematics classes, with increased self-efficacy, task value, and enjoyment. The study's outcomes contribute to a growing body of research [38,39,40], which collectively reinforce the notion that students exhibit high levels of engagement across behavioral, emotional, and cognitive domains during their learning experiences. Garcia-Ros et al. [38] noted behavioral engagement tied to motivation in participating in activities, discussing with peers, and assuming responsibility. Similarly, emotional engagement linked to connections with peers, teachers, and the school community [39], while cognitive engagement associated with motivation to ask meaningful questions and critically analyze presented material [40].

3.3 Summary on the Problem-Based Learning of the Students

Table 3 presents the summary of the degree of problem-based learning of the students. It indicates that "acquisition of knowledge" had the highest mean of 3.83, making it the highest among the three indicators. Moreover, "skills development" was the second highest with a mean of 3.82, and "student attitude and perceptions" was the lowest with a mean of 3.79. Despite the slight difference in their means, all three had a descriptive equivalent of "high".

The level of problem-based learning of the students has an overall mean of 3.81 with a descriptive equivalent of high. This means that a problem based-learning is evident. The overall standard deviation of 0.832 in the overall mean indicates that the measures of variability of problem-based learning are close to the mean. Therefore, this shows that students have obtained close similarity of their responses in this variable.

The research findings indicate that students hold a positive perception of problem-based learning (PBL) as an effective approach to enhancing their learning experiences in mathematics. Students reported high views of PBL in terms of attitude and perceptions, skills development, and knowledge acquisition, particularly appreciating the real-world application of mathematical problems. The study underscores that PBL enhances students' abilities to understand, provide solutions, and implement techniques in solving mathematical problems. Additionally, recent research supports these findings, revealing that students enrolled in PBL courses exhibited significantly higher views of their problem-solving skills, attitudes toward mathematics, and the application of knowledge in real-world situations [41]. The study noted increased confidence, critical thinking, and enthusiasm for mathematics among these students. Furthermore, a study by Gülbahar et al. [42] further validates the positive student perspective on PBL, emphasizing its role in enhancing motivation, engagement, problem-solving skills, and the application of mathematical concepts to real-world problems. In summary, the accumulated evidence suggests that students highly value problem-based learning as an effective method for improving their understanding and skills in mathematics.

Table 2. Summary on the student engagement in mathematics

Indicators	Mean	SD	Descriptive Equivalent
Behavioral Engagement	3.96	0.838	High
Emotional Engagement	3.89	0.911	High
Cognitive Engagement	3.86	0.815	High
Overall Category Mean	**3.90**	**0.820**	**High**

Table 3. Summary on the problem-based learning of the students

Indicators	Mean	SD	Descriptive Equivalent
Student Attitude and Perceptions	3.79	0.856	High
Skills Development	3.82	0.859	High
Acquisition of Knowledge	3.83	0.844	High
Overall Category Mean	**3.81**	**0.832**	**High**

Table 4. Significance of the relationship between the variables

Variables Correlated	r	p-value	Decision on H_o	Decision on Relationship
Technology Integration & Student Engagement	0.782	0.000	Rejected	Significant
Problem-Based Learning & Student Engagement	0.843	0.000	Rejected	Significant
Technology Integration & Problem-Based Learning	0.797	0.000	Rejected	Significant

3.4 Significance of the Relationship among Technology Integration, Student Engagement, and Problem-Based Learning

Table 4 shows the relationship between Technology Integration and Student Engagement, Problem-Based Learning and Student Engagement, and Technology Integration to Problem-Based Learning. The degrees of correlation of technology integration, student engagement, and problem-based learning environment showed strong positive correlations between the variables ($p<0.05$). The p-values are at 0.05 level of significance which made the relationship of all variables significant. Therefore, the null hypotheses are rejected.

3.5 Relationship between Technology Integration and Student Engagement

The examination of the relationship between technology integration and student engagement in mathematics revealed a significant correlation ($p<0.05$), with a correlation coefficient of 0.782. This indicates a strong positive connection, with 61.15% of variability suggesting that students' perceptions of technology use in learning, including factors such as peer interaction, perceived usefulness, perceived ease of use, virtual learning, and learner satisfaction, are linked to their engagement and behavior in mathematics classes. The findings imply that an increase in technology integration is likely to enhance student engagement in mathematics. These results demonstrated that technology-enhanced instruction and virtual learning environments in mathematics classes contributed to increased student engagement, evident through heightened participation, increased interactions with peers, and improved satisfaction [43]. Similarly, students' perceived usefulness and ease of use of technology in mathematics classes correlated with increased engagement and enthusiasm [44]. Collectively, these studies suggest that augmenting technology integration in mathematics education positively influences student participation and engagement with the subject.

3.6 Relationship between Problem-Based Learning and Student Engagement

The examination of the relationship between problem-based learning and student engagement yielded a significant correlation ($p<0.05$), indicated by a correlation coefficient of 0.843. This substantial correlation underscores the strong positive connection between problem-based learning and students' engagement in mathematics, explaining 71.06% of the variability. The findings suggest that employing a learning approach involving real-world mathematical problems enhances students' attitudes, perceptions, skills development, and knowledge acquisition, influencing their participation and behavior with peers and teachers in the context of mathematics. Furthermore, the increase in problem-based learning is likely to contribute to heightened student engagement in the subject. These results emphasize how problem-based learning enhances students' motivation, engagement, and beliefs about the value of mathematics [45]. The approach provides real-world contexts for applying learned skills, fostering active student participation in the learning process.

Similarly, Kawuri et al. [46] highlighted that problem-based learning, by connecting learning to students' interests and experiences, makes mathematics more meaningful and relevant, deepening understanding and promoting positive beliefs. Another study corroborated the effectiveness of problem-based learning in increasing student engagement in mathematics, particularly among those with lower levels of math knowledge [47]. Problem-based learning stimulates critical thinking and problem-solving skills, affirming its effectiveness in boosting student engagement in mathematics [48].

3.7 Relationship between Technology Integration and Problem-Based Learning

The test examining the relationship between technology integration and problem-based learning in mathematics revealed a significant correlation ($p < 0.05$), with a correlation coefficient of 0.797. This indicates a strong positive correlation, with 63.52% of variability, emphasizing that students' perspectives on technology use in learning, encompassing peer interaction, perceived usefulness, ease of use, virtual learning, and learner satisfaction, are connected to their experience in problem-based learning. The integration of technology is associated with real-world mathematical problems, enhancing students' attitudes, perceptions, skills development, and knowledge acquisition. These findings align with Lee et al. [49], which demonstrated a connection between technology integration and students' problem-based learning in mathematics, strengthening learning experiences, attitudes, perceptions, and skills development. Similarly, a positive relationship between technology integration and problem-based learning, resulting in improved attitudes, perceptions, and skills development, with students citing increased peer interaction, perceived usefulness, virtual learning, and learner satisfaction [50]. Incorporating problem-based learning into the process significantly enhanced students' attitudes and perceptions of technology, leading to better understanding and engagement.

3.8 The mediating effect of Problem-Based Learning on Technology Integration and Student Engagement in Mathematics

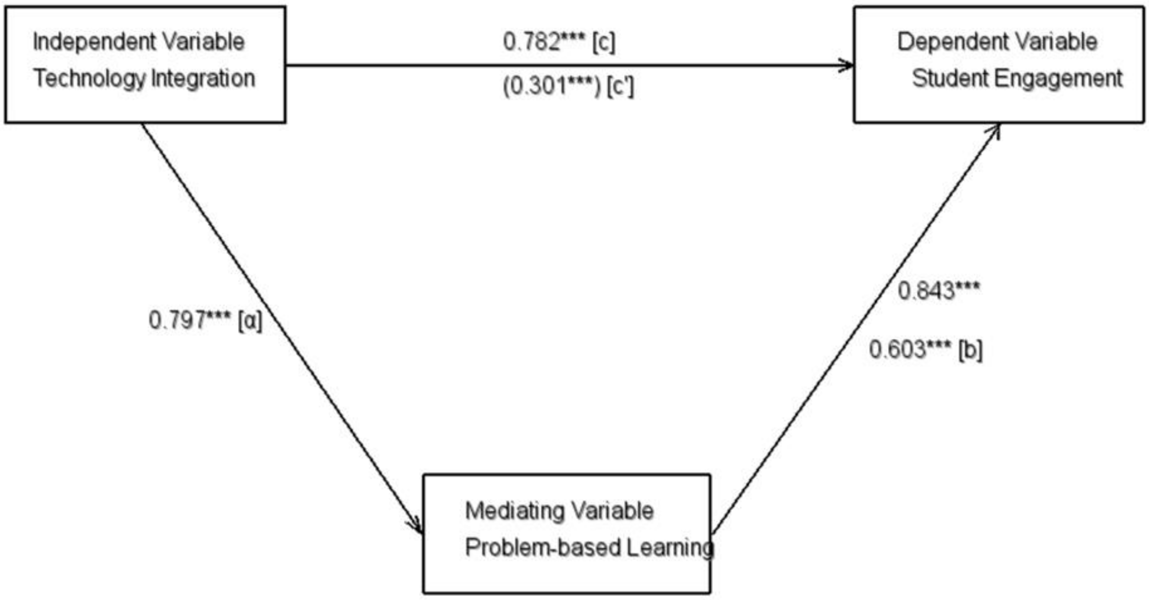
Table 5 illustrates the mediating influence of Problem-Based Learning (PBL) on the association between Technology Integration and Student Engagement in Mathematics. This study aimed to explore the impact of PBL on the relationship between these variables, conducting four regression analyses. The findings revealed a significant effect of Technology Integration on Student Engagement (p-value = 0.000), a significant effect of Problem-Based Learning on Student Engagement (p-value = 0.000), and a significant effect of Technology Integration on Problem-Based Learning (p-value = 0.000). The overall effect indicated a significant mediating role of Problem-Based Learning (Unstandardized Beta = 0.594), suggesting that incorporating PBL into a technology-integrated mathematics curriculum could enhance student engagement. Furthermore, Problem-Based Learning accounted for 36.4% of the effect of Technology Integration on Student Engagement, while Technology Integration had a direct effect (30.1%) not mediated by PBL. The Total R-squared of 0.744 demonstrated that Technology Integration and Problem-Based Learning explained 74.4% of the variance in Student Engagement. These results provide evidence supporting the significant mediating role of PBL in improving student engagement in mathematics through technology integration. Additionally, the Sobel z-test confirmed the significance of both the indirect and direct effects, highlighting that Problem-Based Learning partially mediated the relationship between technology integration and student engagement in mathematics. In summary, this study underscores the substantial mediating effect of Problem-Based Learning on the association between Technology Integration and Student Engagement in Mathematics, emphasizing the positive impact of integrating PBL into a technology-enhanced curriculum.

The study underscores the significant influence of problem-based learning on the relationship between technology integration and student engagement in mathematics. The findings reveal a strong indication that technology integration positively affects student engagement when coupled with problem-based learning. Students who experienced problem-based learning with integrated technology demonstrated increased engagement and motivation in their learning. Notably, the use of technology for feedback enhanced students' confidence in understanding and applying information. These results that problem-based learning mediates the relationship between technology integration and student engagement in mathematics [51,52]. The combined use of technology and problem-based learning was found to have a more positive effect than either method used in isolation, suggesting an effective approach to boost student engagement. Further studies support the positive impact of problem-based learning and technology integration on student engagement and achievement in mathematics [53,54,55]. Additionally, Wu and Kao [56] highlight technology integration as a powerful tool for improving collaborative work and critical thinking in mathematics, reinforcing the notion that problem-based learning with technology integration is a potent strategy for enhancing student engagement in the subject.

Table 5. The mediating effect of problem-based learning on technology integration and student engagement in mathematics

Independent Variable	Technology Integration
Dependent Variable	Student Engagement
Mediating Variable	Problem-Based Learning
Step 1. Path C (IV and DV)	0.782
Unstandardized Beta (B)	0.793
Standard Error (e)	0.055
p-value	0.000
Step 2. Path B (MV and DV)	0.843
Unstandardized Beta (B)	0.830
Standard Error (e)	0.046
p-value	0.000
Step 3. Path A (IV and MV)	0.797
Unstandardized Beta (B)	0.821
Standard Error (e)	0.054
p-value	0.000
Step 4. Combined influence of IV and MV on DV	
Problem-Based Learning	
Unstandardized Beta (B)	0.594
Standard Error (e)	0.072
Standardized Beta	0.603
Part Correlation	0.364
Technology Integration	
Standardized Beta	0.301
Part Correlation	0.182
Total R-squared	0.744

Significance of Mediation			Significant
Sobel z-value		7.251228	p = < 0.000001
95% Symmetrical Confidence Interval			
	Lower	.35586	
	Upper	.61949	
Unstandardized indirect effect			
	a*b	.48767	
	se	.06725	
Effect size Measures			
	Standardized Coefficients		R^2 Measures (Variance)
	Total: .782		.611
	Direct: .301		.033
	Indirect: .481		.578
	Indirect to Total Ratio: .614		.946



4. SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter presents the summary of the major findings of the study, the conclusions, and proposed recommendations for possible implementations.

4.1 Summary of Findings

The major findings of the study are the following:

1. The level of technology integration of the students has an overall mean of 3.84 with a descriptive equivalent of high. It obtained an overall standard deviation of 0.809
2. The level of student engagement has an overall mean of 3.90 with a descriptive equivalent of high. It obtained an overall standard deviation of 0.82.
3. The level of problem-based learning of the students has an overall mean of 3.81 with a descriptive equivalent of high. It obtained an overall standard deviation of 0.832.
4. The degrees of correlation of technology integration, student engagement, and problem-based learning environment showed strong significant positive correlations between the variables ($p<0.05$). There is a significant positive relationship between technology integration and student engagement, technology integration and problem-based learning, and problem-based learning and student engagement.
5. The mediation analyses showed that there is a significant effect of Technology Integration on Student Engagement (p-value = 0.000), a significant effect of Problem-Based Learning on Student Engagement (p-value = 0.000), and a significant effect of Technology Integration on Problem-Based Learning (p-value = 0.000). There was a significant mediating effect of Technology Integration in the relationship between problem-based learning and Student engagement.

4.2 Conclusion

1. Technology integration is manifested in the students' learning.
2. Student engagement is observed in a mathematics subject.
3. A problem-based learning is evident among the students.
4. There is a significant relationship among technology integration, problem-based learning, and student engagement in mathematics. The higher the technology integration, the more the students are engaged in a mathematics classroom. The more the problem-based learning is evident, the more the students are engaged.
5. Problem-based learning partially mediated the relationship between technology integration and student engagement.

4.3 Recommendations

CHED officials should actively promote and support the integration of technology into the mathematics curriculum, creating an environment conducive to problem-based learning to enhance student engagement. School administrators can maximize student engagement by focusing on technology integration and implementing problem-based learning methods, including organizing seminars or workshops. Teachers should integrate technology and problem-based learning in mathematics lessons, incorporating stimulating activities to increase student engagement. College students are encouraged to integrate technology into their learning environment and attend relevant seminars and workshops. Future researchers should prioritize exploring the effects of technology integration and problem-based learning on student engagement in mathematics, considering their interplay in fostering a meaningful learning experience.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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