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TECHNOLOGY INTEGRATION AND THE PERFORMANCE OF SENIOR HIGH SCHOOL LEARNERS IN GENERAL MATHEMATICS

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ABSTRACT

This study was conducted during the School Year 2025–2026 to examine the integration of technology in the teaching and learning of General Mathematics among Grade 11 STEM learners using the Technological Pedagogical Content Knowledge (TPACK) framework. Specifically, it determined the extent of technology integration in terms of Technological Knowledge, Technological Pedagogical Knowledge, and Technological Content Knowledge; assessed learners' academic performance; explored the experiences of teachers and learners; identified the challenges and opportunities in technology-integrated instruction; and developed a professional development program based on the findings. The study employed a Descriptive Sequential Mixed-Methods Design. Quantitative data were collected from 111 Grade 11 STEM learners through a validated TPACK-based survey questionnaire and analyzed using frequency, percentage, mean, and standard deviation. Qualitative data were gathered through semi-structured interviews with selected teachers and learners and analyzed using Braun and Clarke's thematic analysis. The findings revealed a high extent of technology integration across the three TPACK dimensions, with learners demonstrating satisfactory to very satisfactory academic performance. Technology enhanced learner engagement, participation, conceptual understanding, independent learning, and visualization of mathematical concepts, while challenges included unstable internet connectivity, limited ICT resources, unequal access to digital devices, and varying levels of digital readiness. Based on the findings, a professional development program entitled **Strategies for Mathematics Augmented with Responsive Technology for Teaching Effectiveness and Adaptive Classroom Habits (SMART for TEACH) was developed to strengthen teachers' TPACK competencies and support effective technology integration in General Mathematics instruction.

Keywords: *Technology Integration, TPACK Framework, General Mathematics, Academic Performance, STEM Learners*

INTRODUCTION

Mathematics remains one of the most challenging subjects for many learners because it requires abstract reasoning, problem-solving, and critical thinking skills. In response to these challenges, educational institutions have increasingly integrated technology into instruction through the use of digital tools, multimedia resources, graphing applications, and online learning platforms. Research has shown that technology can enhance learner engagement, conceptual understanding, and participation in Mathematics learning (Huang & Chen, 2023; Lee & Cheng, 2023). Likewise, the Department of Education (2023) continues to promote technology integration in public schools through various ICT-related initiatives designed to improve instructional delivery and digital accessibility.

The Philippines continues to raise questions about Filipinos' competence in Math. 15-year-old Filipinos have an average of 355 points in Mathematics in the 2022 Program for International Student Assessment (PISA), far below the OECD average of 472 points. Level 2 proficiency in Mathematics, or difficulty even reading an interpretable mathematical situation, is common among most learners. An ongoing challenge that reinforces the importance of originality, innovative pedagogical initiatives, and thoughtful technological adoption if we want to improve our Mathematics education in the country (Li et al., 2024).

However, just having technology does not lead to greater success, as successful integration will not come with more technology. The critical need is to understand how digital tools can be employed in depth to address learning gaps and facilitate deep conceptual understanding in Math. Therefore, teachers owe it to themselves to develop Technological Pedagogical Content Knowledge to facilitate the integration of technology into the conceptual construction of Mathematics (Rakes et al., 2022). In the educational research context, there is an alarming statistic on the Filipino learners emphasized the need to address systemic deficits in the mastery and use of Mathematics because of technological interventions, to be underperformers in TIMSS, and to be rated lower compared to other Asian countries - Singapore, South Korea, Hong Kong, Chinese Taipei, and Japan, in national and international Mathematics and science competency surveys.

Despite the growing emphasis on technology integration, several challenges remain, particularly in public schools located in rural and semi-urban communities. Limited ICT resources, unstable internet connectivity, unequal access to devices, and varying levels of digital readiness among teachers and learners continue to affect the effective implementation of technology-enhanced instruction (Leonardo & Cha, 2021; Dela Cruz et al., 2024). While previous studies have examined the benefits of technology integration in Mathematics education, many focused primarily on learner achievement or

teacher competencies. Few studies have explored both the quantitative and qualitative dimensions of technology integration using the TPACK framework while simultaneously examining the experiences of teachers and learners in public Senior High Schools.

This gap highlights the need for a more comprehensive investigation of technology integration in General Mathematics. The present study examined technology integration and the academic performance of Grade 11 STEM learners using the Technological Pedagogical Content Knowledge (TPACK) framework, focusing on Technological Knowledge, Technological Pedagogical Knowledge, and Technological Content Knowledge. The study is timely because schools continue to adopt technology-enhanced instruction while facing challenges related to accessibility and digital readiness. Furthermore, the study proposed an innovation through the development of the SMART for TEACH Professional Development Program, an evidence-based intervention designed to strengthen teachers' TPACK competencies and promote sustainable technology integration in General Mathematics instruction.

Research Questions

This study investigated the integration of technology in the teaching and learning of General Mathematics among Senior High School learners. Specifically, the study sought to answer the following research questions:

1. What is the extent of TPACK-based technology integration among Senior High School mathematics teachers in terms of:
    1.1. Technological Knowledge (TK);
    1.2. Technological Content Knowledge (TCK) and
    1.3. Technological Pedagogical Knowledge (TPK)?
2. What is the level of academic performance of Grade 11 STEM learners in General Mathematics?
3. How do Grade 11 STEM learners describe their experiences in learning General Mathematics with technology integration through the selected dimension of the TPACK framework?
4. How do mathematics teachers describe their strategies in integrating technology in teaching General Mathematics guided by the selected dimension of the TPACK framework?
5. What challenges and opportunities are encountered by teachers and Grade 11 STEM learners in the process of technology integration with the selected dimension of the TPACK framework?
6. Based on the findings of the study, what professional development program may be proposed?

METHODOLOGY

This study employed a Descriptive Sequential Mixed-Methods Design to examine technology integration and the academic performance of Grade 11 STEM learners in

General Mathematics. The study was conducted in public Senior High Schools offering the STEM strand in the First District of Oriental Mindoro. The quantitative participants consisted of 111 Grade 11 STEM learners selected through stratified random sampling, while selected learners and General Mathematics teachers participated in the qualitative phase through purposive sampling.

Data were gathered using a researcher-adapted TPACK-based survey questionnaire and semi-structured interview guides. The questionnaire measured Technological Knowledge (TK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK) using a four-point Likert scale. The instrument underwent content validation by experts and reliability testing using Cronbach's Alpha, which yielded acceptable reliability coefficients. Learners' academic performance was obtained from their General Mathematics grades. For the qualitative phase, semi-structured interviews were conducted to explore the experiences, challenges, and opportunities encountered by teachers and learners in technology-integrated instruction.

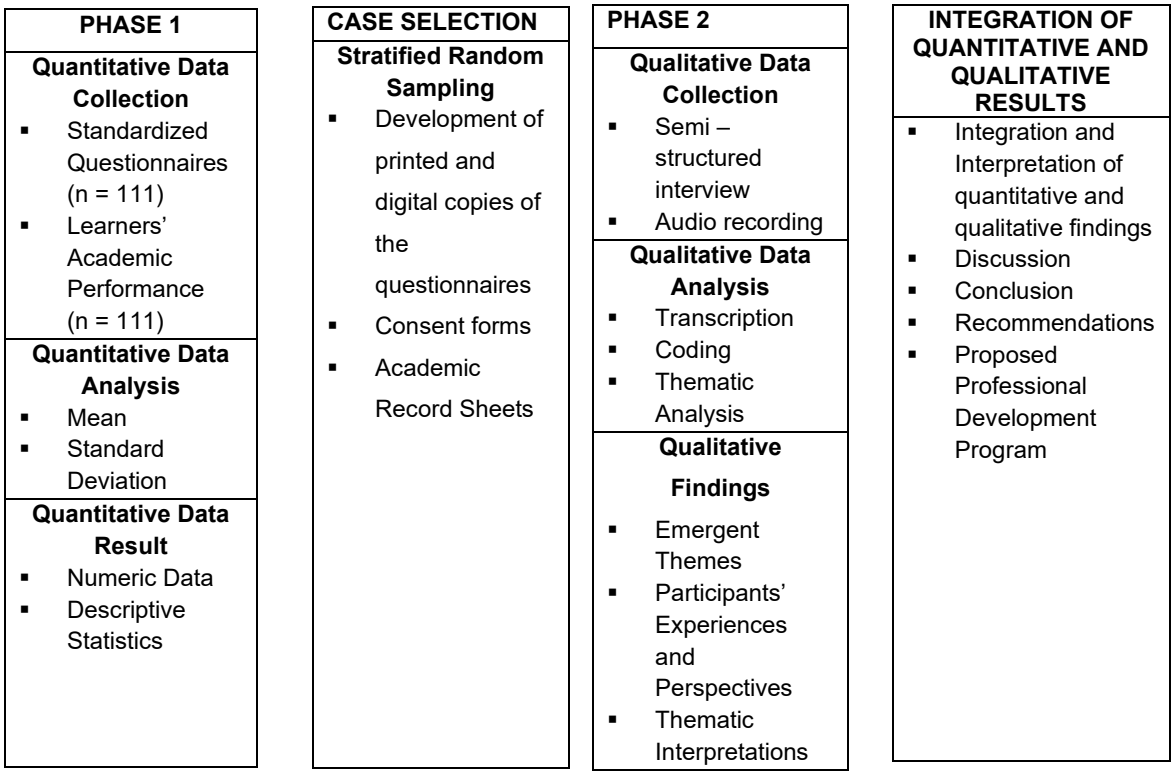

Figure 1.
A Visual Model of the Data Gathering Procedure for Descriptive Sequential Mixed-Methods Design (Adapted from Creswell, 2007)

Quantitative data were analyzed using frequency, percentage, mean, and standard deviation to determine the extent of technology integration and learners' academic performance. Qualitative data were analyzed using Braun and Clarke's (2006)

thematic analysis, which involved coding, categorizing, and identifying emerging themes from the interview transcripts. The study was limited to Grade 11 STEM learners and selected General Mathematics teachers from public Senior High Schools in the First District of Oriental Mindoro and focused only on the TPACK dimensions of TK, TPK, and TCK.

RESULTS

Quantitative Findings

1. Level of Extent of TPACK – Based Technology Integration in General Mathematics

1.1 Technological Knowledge (TK)

Table 1 presents the extent of Technological Knowledge (TK) of teachers in integrating digital tools and resources in teaching General Mathematics. It focused on teachers' ability to use technological devices, applications, and online platforms to support instruction.

As shown in table 1, teachers possess a high level of Technological Knowledge (TK) with an overall weighted mean value of 3.14, which means that the teachers have a high extent of TK. That means teachers can usually use the digital tools, applications, and devices in General Mathematics teaching. Among the factors, the one stating, "My teacher integrates digital tools and resources to update and enhance learning materials" in the statement number 11 had the highest mean of 3.28, indicating that teachers have a high use of technology to facilitate, improve and support learning.

The reduced average values on the use of online platforms and solution of technical problems suggest that teachers still struggle with the need to harness technology to achieve instructional goals. The results show that, despite the fact that the teachers demonstrated adequate levels of technological competencies, some of the areas were requiring improvement, particularly in the context of strategic and functional use of digital tools in the teaching of Mathematics. This supports Koehler et al. (2021), who stated that technological expertise is a crucial element of effective pedagogy and must be perpetually enhanced to facilitate meaningful technology integration in the classroom.

Table 1
Level of Extent of TPACK – Based Technology Integration in General Mathematics as Evaluated by the Student Respondents in Terms of Technological Knowledge (TK)

Statement	Mean	SD	Description	Rank
1. My teacher integrates digital tools and resources to update and enhance learning materials.	3.28	0.82	High Extent	1
2. My teacher uses online platforms effectively for math activities.	2.92	0.98	High Extent	5
3. My teacher confidently uses math-related applications and software.	3.15	0.84	High Extent	3
4. My teacher can troubleshoot basic technical problems during class.	3.09	0.82	High Extent	4
5. My teacher is skilled in using digital devices during math lessons.	3.26	0.86	High Extent	2
Weighted Mean: 3.14	**SD: 0.86**		**Description: High Extent**	

1.2 Technological Content Knowledge (TCK)

Table 2 presents the extent of Technological Content Knowledge (TCK) of teachers in General Mathematics. It focused on the use of digital tools to represent, explain, and visualize mathematical concepts.

The findings show in table 2 indicated that teachers had a high level of Technological Content Knowledge (TCK), with a weighted mean of 3.21, interpreted as high extent. This suggested that teachers were capable of using technology to represent and explain mathematical concepts. The highest-rank statement was the use of graphing tools with a mean of 3.35, indicating that teachers used digital tools to support the visualization of mathematical concepts. Similarly, teachers were also able to demonstrate problem-solving processes and explain abstract concepts using digital tools. However, the relatively lower mean in visualizing concepts clearly in statement number 24 with a mean of 3.14 suggested that there was still room for improvement in maximizing technology for deeper conceptual understanding.

This finding supported Cîrneanu and Moldoveanu (2024), who stated that graphical and dynamic tools helped learners understand abstract mathematical

relationships. Moreover, Huang and Chen (2023) highlighted that the conceptual understanding was improved via several representations with the help of technology.

Table 2
Level of Extent of TPACK – Based Technology Integration in General Mathematics as Evaluated by the Student Respondents in Terms of Technological Content Knowledge (TCK)

Statement	Mean	SD	Description	Rank
6. My teacher uses graphing tools to explain General Mathematics concepts such as functions and equations.	3.35	0.76	High Extent	1
7. My teacher uses technology to help demonstrate step-by-step problem solving.	3.15	0.93	High Extent	3.5
8. My teacher uses digital examples to explain abstract math topics.	3.15	0.93	High Extent	3.5
9. My teacher uses digital tools or technology to visualize math concepts clearly.	3.14	0.98	High Extent	5
10. My teacher uses appropriate technology for math topics.	3.28	0.91	High Extent	2
Weighted Mean: 3.21	**SD: 0.90**		**Description: High Extent**	

1.2 Technological Pedagogical Knowledge (TPK)

Table 3 shows the level of Technological Pedagogical Knowledge (TPK) of teachers. It was interested in the use of technology by teachers to supplement and improve their teaching methods and classroom interaction.

Table 3 results reveal that teachers possessed high level of Technological Pedagogical Knowledge (TPK) with weighted mean of 3.09 which can be interpreted as a high level. This indicated that teachers were able to integrate technology into their teaching strategies. The top-ranked statement was statement number 30 with a mean of 3.16 in which the statement was “My teacher uses technology to make math lessons more engaging” Nevertheless, the lowest rank statement was the changing of teaching strategies with digital tools with a mean of 3.03 and this meant that teachers might have still been struggling to completely change pedagogy with technology. This implied that technology was in use but does not necessarily have been strategically matched with teaching strategies.

This result aligns with Huang and Chen (2023), who stressed that technology increased the engagement in the case of a successful integration with pedagogy. Moreover, Koehler et al. (2021) emphasized that the success of technology relied on the combination of technology and the teaching strategies. The implication of the result was that teachers were just starting to incorporate technology in teaching, but more integration was necessary before its potential effects on student learning could be harnessed.

Table 3
Level of Extent of TPACK – Based Technology Integration in General Mathematics as Evaluated by the Student Respondents in Terms of Technological Pedagogical Knowledge (TPK)

Statement	Mean	SD	Description	Rank
11. My teacher adjusts teaching strategies using digital tools.	3.03	0.77	High Extent	5
12. My teacher uses digital tools to support different learning activities.	3.05	0.91	High Extent	4
13. My teacher uses technology to explain lessons in multiple ways.	3.12	0.96	High Extent	2
14. My teacher uses technology to encourage collaboration among students.	3.07	0.89	High Extent	3
15. My teacher uses technology to make math lessons more engaging.	3.16	0.97	High Extent	1
Weighted Mean: 3.09	**SD: 0.9**		**Description: High Extent**	

The quantitative results indicated that teachers exhibited high to very high levels of technology integration regarding Technological Knowledge (TK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK). Teachers exhibited proficiency in choosing digital tools, employing multimedia presentations, integrating educational applications, and contextualizing technological resources in alignment with lesson objectives. The learner's scholastic achievement in General Mathematics was predominantly satisfactory to very satisfactory according to their official grades.

The results demonstrate that while technological integration facilitated engagement and instructional delivery, it did not inherently lead to substantial enhancements in academic performance.

2. Level of Academic Performance of Grade 11 STEM Learners in General Mathematics

Table 4 shows the frequency and percentage distribution of the academic performance level of Grade 11 Senior High School learners in General Mathematics who participated in the study. Overall, most of these learners performed great, suggesting that the subject had a rather high level of academic performance. Specifically, 72 learners (64.86%) received grades of 90 - 100 (Outstanding). On the other hand, 28 learners (25.23%) were in the Very Satisfactory level (85–89), 5 learners (4.5%) rated in the Satisfactory level (80–84), and 6 learners (5.41%) in the Fairly Satisfactory level (75–79). Of note, 0% of students were below 75 and all learners had met the minimum expectations in General Mathematics.

Table 4
Frequency and Percentage Distribution of the Level of Academic Performance in General Mathematics

Grading Scale	Frequency	Percentage	Descriptors
90 – 100	72	64.86%	Outstanding
85 – 89	28	25.23%	Very Satisfactory
80 – 84	5	4.5%	Satisfactory
75 – 79	6	5.41%	Fairly Satisfactory
Below 75	0	0%	Did Not Meet Expectations
Total	**111**	**100%**	

Qualitative Findings

3. Experiences of Grade 11 STEM Learners in Learning General Mathematics with technology integration through the selected dimension of the TPACK framework

Thematic analysis revealed several themes regarding learners' experiences in technology-integrated General Mathematics instruction.

Theme 1: Technology as a Cognitive and Instructional Support in Mathematics Learning

The learners' real-world experiences showed that technology acted as a cognitive and educational aid that improved their comprehension of mathematical ideas. Students linked technology to more confidence in learning general mathematics, better problem-solving, visual comprehension, and clearer explanations. Calculators, videos, online tutorials, graphs, and digital apps were viewed by participants as tools that made complex teachings easier to understand and made abstract mathematical ideas more approachable.

A number of people talked about how technology made it simpler and less stressful to solve mathematical difficulties. Student 1 shared, *"Mas madali po ang aking mga nasosolve po kapag gamit ang calculator." Similarly, Student 6 explained, "Mas madali po maintindihan ang isang lesson kapag gumagamit po ng technology kasi nga po mas naeexplain po ng ayos at may visual representation."*

These stories indicate that students found technology as a guide to learning that made mathematical processes easier to learn. The respondents seemed to relate visual representations and electronic explanations with clarity and understanding. Technology was regarded more as a support mechanism and not merely a calculation device. Student 11 highlighted that technology facilitated graphing and trigonometry by generating clearer, more precise, and visually comprehensible mathematical representations.

Theme 2: Technology as a Source of Engagement and Motivation

The participants said that technology makes learning more fun, participatory and interesting. Students associated increased motivation and classroom engagement with multimedia presentations, online games, movies, and digital activities. Implementation of technology appeared to transform the classroom setting that was characterized by passive learning into an active interaction and collaborative learning. According to student 11, *"Kapag gumagamit ang teacher namin ng technology sa klase, mas nagiging engaging po sya… may ppt, may illustration at explanation at nakakarelate po kami."* Student 14 echoed this, by saying, *"I believe that I am more engage when my teacher uses technology in teaching Mathematics like she is using online games…"*

These responses indicate that the students believed that technology helped to make the lessons more interactive and relatable. The students associated digital tools with increased attention, interest, and pleasure during the discussions in the classroom. Technology appeared to promote active learning, as opposed to passive listening. Also, Student 17 commented, *"Mas nagiging engaging and interactive po kapag gumagamit ang teacher namin ng technology. Mas nagiging cooperative at participative po ako…"* The participant narratives revealed that technology encouraged student participation and work. The interactive exercises and multimedia presentations appeared to make students less bored and make them more active in the classroom.

Theme 3: Negotiating Between Technology and Teacher Guidance

The experiences of the participants proved a continuing contradiction between the need to guide students in mathematics education by the teacher and use technology. Although students acknowledged benefits of technology, many participants still emphasized on the role of traditional instruction, step-by-step description, and direct interaction with the teachers.

Students appeared to view technology as an aid that could facilitate learning but not completely replace the need of an instructor. Student 5 explained, *"Mas okay po kung balance po para po may assistance pa din ng teacher."* Similarly, Student 3 said that,

"Mas okay din po na may teacher kasi mas naiipaliwanag po." these responses reveal that students found the teacher explanations helpful as they provided guidance, clarity and a better understanding of mathematical processes. In cases where the participants were confused, they appeared to recognize professors who had well-structured explanation and opportunities to pose questions.

The findings reflect constructivist perspectives that focus on the idea that meaningful learning occurs when one is guided and actively engages in the interaction and study of knowledge (Salmi and Järvela, 2024). The findings indicate that technology integration will be more effective in the context of TPACK in combination with appropriate pedagogical support and teacher facilitation.

Theme 4: Technology as a Pathway to Independent and Flexible Learning

Technology was cited by participants as a crucial tool for self-directed learning, especially in situations where direct help, books, or teachers were not available. Students linked digital technologies to flexibility in learning mathematics at their own speed, self-study, and information accessibility. Students seemed to be empowered by technology to investigate lessons on their own and look for different approaches to solve mathematical issues.

"Manonood lang po ako ng mga videos para maintindihan ko ang mga lessons," said student 1. Similarly, Student 3 said, *"Gumagamit po ako ng iba't-ibang application… lumalabas na po ang explanation and solution."* According to their answers, students saw technology as a learning aid that encouraged independent study. Participants were considered to be easily accessible resources offering timely instructions and explanations: YouTube, Google, ChatGPT, GauthMath, and others. Student 12 continued, adding, *"I can search on the Internet so that I can get a deeper insight into the topic."*

Theme 5: Experiencing Limitations and Inequalities in Technology Integration

Although the participants recognized the benefits of technology integration in the classroom, some students also discussed their experience of uneven technology usage in the classroom and limited access to digital materials. Students complained of relying on books, board work, and little use of technology due to lack of resources, poor internet connectivity, and limitations on the teachers.

Student 4 stated, *"Hindi po kami nagamit ng technology dahil kadalasan po ang gamit po namin ay libro…"* Similarly, Student 9 said, *"We don't technically use technology because we lack gadgets and we are only relying on books."* Such responses suggest that the number of students that had a chance to engage in technology-enhanced learning was limited. Participants felt that their educational experiences were not as good as they could have been due to the disproportionate access to devices and technical support.

The results corroborate those of Bernardo et al. (2022), who highlighted that access to technology resources, digital preparedness, and infrastructure constraints greatly impact how well technology is incorporated into education. Participants testimonies of the participants reveal that the opportunities and experiences of the learners in general mathematics education remains influenced by unequal access to technology.

4. Mathematics Teachers Strategies in Integrating Technology in Teaching General Mathematics Guided by the selected dimension of the TPACK framework

Theme 1: Technology as a Tool for Engagement and Meaningful Participation

Thus, according to the first-hand experiences given by the instructors, the process of incorporating technology into the general mathematics education was an extremely efficient method of increasing student involvement, engagement, and classroom interaction. Educators regarded mobile devices, games, digital tools and multimedia presentations as a means of transforming passive classroom into a more active and exciting learning experience. Teacher 2 further explained, *"I integrate technology through tools like graphing calculators, and Excel to help students visualize and understand concepts such as functions and business mathematics. These tools allow students to explore data and solve problems more effectively."* Technology would be viewed as a motivating tool that would encourage students to participate more in the classroom, and not as a teaching tool.

Theme 2: Technology as a Transformative and Visual Approach to Mathematics Instruction

According to teachers, technology was altering the teaching method, as well as the understanding of general mathematics classes. Respondents associated online resources with simpler explanations of abstract concepts in mathematics and improved recall, easier learning, as well as clearer images. Technology was found to change the approaches to instruction used by teachers and the way in which the teaching was received and digested by the pupils. Teacher 1 responded *"Feeling ko mas nauunawaan at mas naaalala ng bata ang lesson kapag gumagamit ako ng technology."* In the same way, Teacher 2 explained, *"Technology has made lessons more visual and interactive. Students can quickly generate graphs, solve problems efficiently, and see immediate results…"*

These responses indicate that educators believed that technology enhanced conceptual knowledge through immediate feedback and visuals. Specifically, among those classes that involved graphs, functions, and mathematical representations, participants associated digital tools with enhancing comprehension of difficult concepts by students.

Theme 3: Purposeful and Contextualized Technology Integration

The experience of the teachers revealed that integration of technology was determined by conscious attempt to align technology with instructional goals, content in mathematics and needs of the learners other than mere availability of digital resources. To ensure that technology positively influenced the delivery of instruction, the respondents emphasized the importance of selecting, modifying, and situating digital materials illustrated with great care.

According to Teacher 1*, "Kapag applicable yung applications dun sa topic."* On the same note, Teacher 2 remarked *"I select tools based on the topic and learning objectives."* Teacher 5 also highlighted*, "I make sure that the visual aids that I am going to use are relevant and will address the lesson objectives."* The responses reveal that teachers merely believed that technology was helpful when purposefully connected with learning goals and content. Besides the application of technology, participants appeared to view themselves as instructional designers who happened to decide on the application of the digital tools that they found befitting the interest of the students and nature of mathematical concepts.

Theme 4: Interactive and Exploratory Learning Through Technology

Incorporation of technology, as suggested by teachers, provides opportunity to inquire, collaborate, and participate in mathematics education. Playing games, exercising, solving problems in a group, and the activity of exploring - all of these methods helped the participants to realize that technology could help the students approach the world of mathematics directly. Teacher 1 said, *"Hinahayaan ko po ang bata na gumamit para po ma-experience nila ang paggamit ng technology."*

Teacher 3 said the same, as well, as he said*, "Yung parang mag-eexplore ang mga bata sa problem solving."* Based on such narrations, the teachers felt that technology facilitated inquiry-based and experiential learning. Students appeared to appreciate opportunities in situations where they actively explored mathematical concepts rather than passively learning. Teacher 2 also clarified that *"I use interactive activities, and collaborative problem-solving, to engage students."* Teacher 4 also shared, *"May mga hands-on activities po."* Similarly, Teacher 5 and 6, explained about their use of games and classroom activities, saying, *"Minsan gumagamit po ako ng mga crossword puzzles at iba pang games."*

Theme 5: Negotiating the Limitations of Technology Integration

Even though teachers noted the positive side of the technology introduction, several challenges and limitations were also named by the participants in relation to the dependence of learners, unequal access to the technology, and the in-depth misunderstanding. Instructors recounted examples when students were exposed to graphics and games and could hardly solve mathematical tasks without technological

support. Teacher 4 commented, *"Minsan ang mga bata ay nalilito kasi kapag magsasagot na sila ay nakakalimutan agad nila ung process…"*

Similarly, Teacher 6 confessed, when asked about the Teachers, *"Kapag tinanong mo na sila at nagpa-solve ka na sa board, minsan ay hindi na nila alam ang gagawin."* Based on these responses, teachers believed that students will end up depending too much on technology. The respondents understood that despite the availability and involvement that emerged with the use of technology, excessive dependence on digital aid could lead to a decline of the ability of students to solve their problems independently and gain conceptual understanding. Instructors also saw variations in students' preparedness for integrating technology. Teacher 4 elaborated to explain *"Yung iba… mas gusto pa din nila yung traditional kasi gusto nila yung may kinokopya sa blackboard…"*

5. Challenges and Opportunities Encountered by Teachers and Grade 11 STEM Learners in the Process of Technology Integration of the Selected Dimension of the TPACK Framework

Theme 1: Negotiating Digital Readiness and Technological Limitations

The lived experience of teachers revealed that their digital preparedness and that of their students affected technology integration in general mathematics. Respondents shared examples when technological differences hampered the engagement of learners, classroom learning, and the effectiveness of activities conducted using technology. Teachers saw technology as a challenge when students or teachers lacked adequate digital abilities, as well as a potential for better learning. Teacher 1 said, *"Kapag ang bata ay hindi marunong gumamit ng laptop, tumatagal po ang lesson discussion."*

Similarly, Teacher 6 showed that she was not good at using technology without saying, by disclosing that *"Hindi din ako masyadong magaling sa paggamit ng technology so yung pinaka-basic lang talaga ang ginagamit ko."* Teacher 3 also shared, *"Maghanap ng free apps, time consuming din."* These experiences suggest that classroom dynamics and teaching process were highly influenced by the preparedness to technology. When students were not able to use digital tools, teachers needed to make certain changes and postponements to the classroom sessions and in some cases, teachers believed that they were not of the same technical capabilities as to take the best out of the technologies available to them.

Theme 2: Technology as Both an Opportunity and a Constraint in Mathematics Learning

The participants reported technological integration as offering an opportunity to understand better and complexity in terms of availability, internet connectivity, and reliance on learners. Although adopting a realistic perspective in regard to the constraints of lack of resources and unequal availability of digital technologies, educators and students viewed technology as a device that enhanced visualization, interaction and

independent learning. Teachers emphasized a number of advantages of integrating technology. Teacher 2 explained the numerous advantages of technology, such as the easier system of tracing the progress of students, faster feedback, and better understanding of the challenging concepts. *"Technology provides many advantages, such as clearer explanations of complex concepts, faster feedback… and easier tracking of student progress."*

Similarly, the students compared technology with enhanced conceptual understanding and visualization. Student 6 contributed, there was a student who said, *"Mas madali po maintindihan ang isang lesson kapag gumagamit po ng technology kasi nga po mas naeexplain po ng ayos at may visual representation."*

The experiences of the participants reveal that the process of incorporating technology in the classroom requires constant adjustment, technical skills, and synergistic support systems. The findings support the research that digital preparedness plays a significant role in the influence of the degree of classroom integration of technology (Voogt et al., 2023).

Theme 3: Technology as a Pathway to Independent and Self-Directed Learning

The results of the experiences of students demonstrated that technology promoted self-generated inquiry and independent learning during general mathematics. The respondents mentioned that technology enabled students to learn lesson individually, check out explanations on the internet and even experiment with novel methods towards solving mathematics problems, particularly when the teachers or materials were not available. Student 1 said that *"Manonood lang po ako ng mga videos para maintindihan ko ang mga lessons." Likewise, Student 3 elucidated, "Kapag modular kasi kailangan po ng guideline… gumagamit po sa ako ng iba-iba application..."*

Based on these reports, students perceived technology as a tool of learning that provided flexibility, accessibility and independence in learning mathematics. Participants perceived YouTube, Google, GauthMath, and ChatGPT, among other applications, as easily available educational tools that made them more likely to solve problems independently and self-learn. Student 12 added on, *"Technology helped me become more independent…"*

According to the comments, technology made students more proactive in looking for clarifications, going over lessons again, and coming up with different ways to comprehend mathematical ideas. The participants appeared to have an association between technology and increased confidence and adaptability in their learning.

Theme 4: Balancing Technology and Traditional Teacher Guidance

The real-life experience offered by the participants indicated that even though technology has made learning and teaching easy and beneficial, the students and educators still value the traditional mode of teaching such as elaborating and

interpersonal communication. Participants did not see technology as a replacement of instructor facilitation but rather believed it was a support tool. Student 8 demystified it by explaining read on*, "Mas madali pong maintindihan sana yung nagtuturo po yung teacher step by step…"*

In the same vein, Student 3 commented*, "Mas okay din po na may teacher kasi mas naiipaliwanag po…"* these testimonies reveal that students related traditional education to direction, clarity and a more profound understanding of concepts. Participants believed that teacher explanations were more believable and easier to comprehend in comparison with some internet materials and films. Teachers realized the importance of striking a balance between conventional way of teaching and inclusion of technology. Teacher 4 thought, *"Hindi lahat ay interesado although ang iba naman ay okay."*

Theme 5: Continuous Professional Development as a Foundation for Effective Technology Integration

Teachers replied that to become more proficient in integrating technology, it is essential to work on the level of professional development and continuing training. The participants stated that technology is evolving at a rapid pace and therefore to facilitate successful general mathematics learning; teachers need to continuously renew their knowledge in digital tools, techniques and skills. Teacher 2 emphasized, *"Teachers need professional development in using digital tools…"* Similarly, Teacher 4 stated, *"Yearly trainings sana para ma-update kami about the latest trends in technology."* Teacher 6 further shared*, "Trainings… lalo na yung hands-on para naman ma-maximize namin ang gamit ng technology…"*

These answers show that in order for teachers to successfully integrate technology, they constantly needed institutional assistance and skill improvement. Participants indicated that to become more confident and competent enough to grow in terms of instructional competency, they had to get access to updated professional development, workshops, and training. Teachers also underlined importance of practical, experience-based instruction. Felt ko like teacher 5: *"Feeling ko e nauuna pa ang bata sa amin lalo na pagdating sa paggamit ng mga apps."*

This means that there are teachers who felt underprivileged and pressurized to adapt with fast changing circumstances in technology and students who are conversant with technology. Participants also recognized the need to continue to upgrade professional development as a way of sustaining confidence and effectiveness in classroom instruction besides improving technology skill.

The outcomes indicate that having effective TPACK competencies and continuous professional development significantly boosts the efficacy of teachers to integrate technology (Kadluba & Obersteiner, 2024). The experience of the participants demonstrates that meaningful integration of technological elements into the classroom, long-term training, and institutional support must be provided in order to make the use of digital technologies in the classroom possible.

The study gave the Strategies for Mathematics Augmented with Responsive Technology to Teaching Effectiveness and Adaptive Classroom Habits (S.M.A.R.T. for T.E.A.C.H.) Professional Development Program in view of these findings. The suggested course will enhance teacher TPACK competencies, strengthen the teaching strategies, address the issues of technology adaptability, and offer more profound, student-focused, and technology-intensive General Mathematics teaching.

DISCUSSION

The research investigated the connection between technology integration and the academic performance of Grade 11 STEM learners in General Mathematics, utilizing certain elements of the Technological Pedagogical Content Knowledge (TPACK) paradigm. The results indicated that technology integration was extensively applied regarding Technological Knowledge (TK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK). Teachers exhibited proficiency in employing digital tools, incorporating multimedia presentations, contextualizing instructional resources, and implementing technology-enhanced practices in the classroom of General Mathematics.

The results indicate that teachers have become progressively adaptable to the escalating requirements of technology-integrated teaching. The use of graphing programs, movies, simulations, calculators, presentation software, and digital learning platforms enabled teachers to enhance course delivery and classroom engagement. Teachers regarded technology as a pedagogical support instrument that enhanced learner engagement, motivation, and classroom interaction. These findings support the research of Huang and Chen (2023), which highlighted that technology-mediated education improves student engagement and conceptual comprehension in Mathematics. The results indicated that technology integration enhanced learners' conceptual comprehension in General Mathematics. Learners articulated that graphing, trigonometry, algebra, annuities, functions, and problem-solving tasks were more comprehensible when employing digital tools and visual representations. Learners linked technology to enhanced clarity in explanations, visual precision, and improved accessibility to examples and tutorials. These findings confirm Constructivist Learning Theory, which posits that learners cultivate understanding through active inquiry, visualization, interaction, and structured learning experiences.

Technology-enhanced learning settings enabled learners to change mathematical representations, reread explanations, and autonomously access educational resources. Learners often highlighted the efficacy of YouTube videos, graphing programs, GeoGebra, calculators, PowerPoint presentations, and various internet tools in facilitating their comprehension of challenging mathematical subjects. The findings align with the research of Lee and Cheng (2023), which demonstrated that visual and interactive digital tools enhance conceptual comprehension and engagement in Mathematics instruction.
The findings suggest that technology alone may be inadequate for enhancing mathematics performance without effective pedagogical assistance, directed training,

learner preparedness, and significant classroom interaction. Teachers and learners consistently underscored the significance of teacher facilitation, continuous explanation, and directed problem-solving in comprehending mathematical procedures. This reinforces the TPACK framework, which emphasizes that technology is most successful when combined with pedagogical and subject expertise.

The results indicated that learners continued to depend significantly on instructor explanations, notwithstanding the presence of digital resources. Learners indicated that certain online explanations were unclear, inaccurate, or insufficient. Several participants indicated that technology proved beneficial solely when educators offered supplementary explanations and contextualized illustrations. This suggests that technology ought to enhance, rather than replace, teacher facilitation in Mathematics instruction. The qualitative findings additionally uncovered various contextual obstacles impacting technology integration in General Mathematics instruction. Teachers and learners recognized unreliable internet connectivity, inadequate ICT infrastructure, unequal device access, and different digital competencies as significant obstacles to the implementation of technology-based instruction. Learners from rural and semi-urban schools encountered restricted access to devices and internet resources, hindering their ability to engage comprehensively in technology-enhanced learning.

Teachers faced challenges in developing digital educational resources, identifying suitable programs, and managing students with differing levels of digital preparedness. Several teachers acknowledged their reliance on fundamental technological tools due to insufficient technical proficiency and a deficiency in advanced training. The findings support the research conducted by Leonardo and Cha (2021) and Dela Cruz et al. (2024), which identified inadequate ICT infrastructure and insufficient teacher preparedness as significant obstacles to technology integration in Philippine public schools.

Given these limitations, the research also disclosed potential generated by technological integration. Technology facilitated collaborative learning, provided flexible access to lessons, promoted student autonomy, and enabled exploratory learning activities. Teachers indicated that learners exhibited increased engagement and participation when interactive activities, digital games, and multimedia presentations were employed. Learners valued the opportunity to review explanations, replay educational videos, and independently access mathematical tutorials.

The results demonstrate that the integration of technology can enhance learner-centered and engaging Mathematics instruction when digital tools are suitably aligned with instructional objectives and classroom requirements. Teachers who meticulously selected, adapted, and contextualized digital resources demonstrated more efficacy in fostering learner engagement and comprehension. This corresponds with the principles of the TPACK framework, which underscores the necessity of harmonizing technology, pedagogy, and subject knowledge.

The findings underscore the significance of ongoing professional development for Mathematics teachers. Teachers underscored the necessity for supplementary training,

mentoring, workshops, and collaborative learning opportunities to enhance their TPACK competencies and instructional methodologies. The participants claimed that professional development programs ought to emphasize not only technology competencies but also pedagogical techniques, contextualized instructional planning, and learner-centered teaching methodologies.

The study's findings provided the foundation for the proposed Professional Development Program titled Strategies for Mathematics Augmented with Responsive Technology for Teaching Effectiveness and Adaptive Classroom Habits (S.M.A.R.T. for T.E.A.C.H.). The program initiative seeks to enhance educators' proficiency in TPACK-based technology integration through Learning Action Cell (LAC) sessions, workshops, mentoring programs, classroom demonstrations, and collaborative exchanges of best practices. The curriculum emphasizes the augmentation of teachers' technological proficiency, instructional design, digital resource creation, learner engagement methodologies, and contextualized technology integration in General Mathematics.

The proposed professional development program also integrates innovation within the program implementation. The innovation component emphasizes contextualized technology integration, low-tech and offline teaching alternatives, collaborative development of digital materials, and adaptable classroom methods tailored to rural and semi-urban educational environments. The program's innovation emphasizes sustainable and accessible methods for technology integration instead of reliance on advanced digital infrastructure.

The study's findings enhance the existing research on technology integration in Mathematics instruction, specifically within the setting of Philippine public schools. The research offers specific empirical facts concerning the experiences of teachers and learners in technology-enhanced General Mathematics instruction within rural and semi-urban educational environments.

Furthermore, the results underscore that significant technology integration necessitates not only access to digital resources but also proficient pedagogical facilitation, contextual adaptability, ongoing teacher development, and learner support systems. The results indicate that educational institutions and policymakers ought to enhance ICT infrastructure, augment digital accessibility, facilitate ongoing teacher training, and promote learner-centered instructional innovation.

The study concludes that technology integration enhances student engagement, conceptual understanding, involvement, and instructional delivery in General Mathematics instruction. The efficacy of technology integration mostly relies on teachers' capacity to effectively incorporate technology with pedagogy and topic understanding, while also addressing contextual constraints and learner requirements. The research highlights that significant technology integration in Mathematics education should be regarded as a pedagogical and contextual process, rather than only a technological intervention. Successful implementation necessitates coordination among pedagogical tactics, technological resources, learner preparedness, and classroom dynamics.

The proposed S.M.A.R.T. for T.E.A.C.H. Professional Development Program is an evidence-based intervention aimed at enhancing instructional quality, reinforcing TPACK competencies, and facilitating meaningful, contextualized, and learner-centered technology integration in General Mathematics instruction.

Conclusions

The study found that technology integration in General Mathematics was implemented to a high extent in terms of Technological Knowledge (TK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK), indicating that teachers were generally competent in integrating technology into instruction.

The academic performance of Grade 11 STEM learners in General Mathematics was generally satisfactory, suggesting that learners were able to meet the expected learning competencies in the subject.

The experiences of learners revealed that technology served as a cognitive and instructional support that enhanced engagement, motivation, independent learning, and conceptual understanding. However, learners emphasized that teacher guidance remained essential for meaningful learning and problem-solving.

The experiences of teachers showed that technology enhanced learner participation, visualization of mathematical concepts, exploratory learning, and instructional delivery. Teachers also demonstrated purposeful and contextualized integration of technology in General Mathematics instruction.

The study further revealed several challenges and opportunities associated with technology integration. Challenges included unstable internet connectivity, limited ICT resources, unequal access to devices, and varying levels of digital readiness. Opportunities included increased learner engagement, improved visualization, independent learning, and collaborative learning experiences.

Based on the findings, the SMART for TEACH (Strategies for Mathematics Augmented with Responsive Technology for Teaching Effectiveness and Adaptive Classroom Habits) Professional Development Program was developed to strengthen teachers' TPACK competencies and support effective, sustainable, and learner-centered technology integration in General Mathematics instruction.

Recommendations

Based on the findings and conclusions of the study, the SMART for TEACH (Strategies for Mathematics Augmented with Responsive Technology for Teaching Effectiveness and Adaptive Classroom Habits) Professional Development Program may be implemented to strengthen teachers' TPACK competencies and enhance technology integration in General Mathematics instruction.

School administrators and educational leaders may provide continuous TPACK-based professional development activities, including training, mentoring, coaching, and Learning Action Cell (LAC) sessions, to improve teachers' technological, pedagogical, and content knowledge. Likewise, efforts should be made to improve ICT infrastructure, internet connectivity, and access to digital resources to support effective technology-enhanced instruction, particularly in rural and semi-urban schools.

Teachers are encouraged to utilize technology in ways that promote learner engagement, conceptual understanding, independent learning, and meaningful classroom interaction while ensuring that technology is complemented by appropriate pedagogical guidance.

Future researchers may conduct similar studies involving larger samples, different academic disciplines, or other educational settings to validate and extend the findings of the present study. Further investigations may also examine the long-term effectiveness of the SMART for TEACH Professional Development Program and explore additional factors influencing the successful integration of technology in Mathematics education.

SMART FOR TEACH: A PROPOSED PROFESSIONAL DEVELOPMENT PROGRAM MATRIX

Strategies for Mathematics Augmented with Responsive Technology for Teaching Effectiveness and Adaptive Classroom Habits
(S.M.A.R.T. for T.E.A.C.H.): A Professional Development Program on TPACK-Based Technology Integration in General Mathematics

Name of Proponent: Mary Joy C. Pelayo

Project/ Activity Title: Strategies for Mathematics Augmented with Responsive Technology for Teaching Effectiveness and Adaptive Classroom Habits (S.M.A.R.T. for T.E.A.C.H.): Professional Development Program in Technology Integration in Teaching General Mathematics

Project Time-frame: June 1, 2026 – April 8, 2027

Area of Concern (Based on Findings)	Training Objective(s)	Specific Strategies/Activities	Persons Involved	Resources/Materials Needed	Budget Allocation	Timeline/ Frequency	Expected Outcomes/Success Metrics
Teachers faced challenges in meaningful use of technology in teaching General Mathematics in terms	At the end of the Phase 1 program, teachers who take part will be able to demonstrate enhance	• Seminar on Positive Use of ICT and PPST Indicators • Sharing of challenges and least	Resource Speakers, SHS Mathematics Teachers, ICT Coordinators, Project Management Team	Laptop, projector, internet connection, printed handouts, training modules	₱4,000.00 (Honoraria and materials)	June 1, 2026	• During classroom observations, at least 80% of the participating teachers exhibit enhanced technology

of engaging learners and helping them to understand concepts.	d capabilities in the integration of technology based on TPACK in teaching General Mathematics.	mastered competencies • Demonstration teaching • Workshop on technology-integrated instructional strategies					integration practices. • Enhanced teacher confidence in the integration of technology into mathematics instruction.
Teachers needed to strengthen their use of appropriate digital instructional technologies in accordance with the competencies for General Mathematics.	At the end of the program teachers will be able to use the right digital and non-digital instructional tools in an effective and responsible way.	• Training on digital instructional materials • Presentation of instructional resources that are not digital • Workshop on the development of contextualized instructional materials • The exchange of best practices in the teaching of mathematics through the integration of technology	Resource Speakers, Mathematics Teachers, ICT Coordinators	Printed instructional materials, manipulatives, PowerPoint presentations, internet connection, projector	₱3,000.00	June 1 – 2, 2026	• Instructional materials that are contextualized and supported by technology are created by teachers. • Enhanced utilization of both digital and non-digital resources during the instructional process.
Unequal access to ICT resources and digital competence of learners impacted meaningful engagement in technology-integrated learning.	By the end of the monitoring period, teachers will be able to apply learner-centered and adaptable teaching strategies to encourage responsib	• Classroom monitoring • Peer mentoring • Reflection writing • Coaching sessions • LAC sessions and collaborative discussions	Mathematics Department, ICT Coordinators, Project Management Team	Monitoring forms, reflection journals, communication allowance, printed forms	₱3,000.00 (Monitoring and communication expenses)	June 8 – September 13, 2026	• Enhanced learner engagement and participation during classroom instruction. • Teachers exhibit enhanced strategies for technology integration and classroom management.

	le and independent use of technology by learners.						
Teachers expressed the need for continuous professional development and reinforcement training to sustain meaningful technology integration practices.	By the end of Phase 2 participating teachers will be able to develop instructional action plans to support continual progress in technology integrated teaching approaches.	• Reinforcement Training on Technology Integration Based on Monitoring Results • Sharing of best practices • Workshop on instructional improvement planning • Reflection and action planning activities	Resource Speakers, Mathematics Teachers, Project Management Team	Evaluation forms, action plan templates, laptops, projector, printed certificates	₱4,000.00	September 14, 2026	• Teachers develop instructional action plans for ongoing professional development. • Enhanced PPST ratings in the areas of instructional delivery and ICT integration.
The findings indicate a requirement for continuing collaborative professional learning and constant monitoring of technology-integrated teaching approaches in the teaching of General Mathematics.	The schools will maintain collaborative and technology-aided professional development practices that are aligned with the PPST criteria for School Year 2026-2027.	• Learning Action Cell (LAC) sessions • Peer coaching and mentoring • Classroom observations • Sharing of instructional materials and best practices • Monitoring and evaluation meetings	Mathematics Department, ICT Coordinators, Teachers	Classroom observation tools, lesson plans, reflection forms, digital repositories	Included in school-based MOOE / existing school resources	October 2026 – April 2027	• Sustainable implementation of instructional practices that are grounded on TPACK - based instructional practices. • Continuous enhancement of learner engagement and technology integration. • Fostered a more collaborative professional learning environment among teachers

Compliance with Ethical Standards

The researcher strictly adhered to ethical standards throughout the conduct of the study. Permission to conduct the research was obtained from the appropriate authorities prior to data collection. Informed consent was secured from all participants, and they were

informed of the purpose of the study, their voluntary participation, and their right to withdraw at any stage without penalty. The anonymity and confidentiality of the participants were maintained by ensuring that no personally identifiable information was disclosed in any report or publication. The study complied with the provisions of the Data Privacy Act of 2012 by safeguarding all collected data and using them solely for research purposes. The well-being, dignity, and rights of the participants were protected throughout the research process. The researcher declares that there was no conflict of interest in the conduct of the study and that all findings were reported honestly and objectively without bias or manipulation. Plagiarism was strictly avoided through proper acknowledgment and citation of all sources. The results of the study were utilized exclusively for academic and research purposes. Artificial Intelligence (AI) tools were utilized only to assist in language refinement, grammar checking, and organization of written content; however, all interpretations, analyses, conclusions, and final decisions remained the sole responsibility of the researcher.

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