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## Implementing a Technology-Integrated Problem-Based Learning (TIPBL) Strategy in a Higher Education Mathematics Classroom

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### Abstract

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This study examined the influence of Technology-Integrated Problem-Based Learning (TIPBL) on engagement, academic grit, mathematical mindset, and perceptions of technology among first-year Bachelor of Secondary Education major in Mathematics (BSEd-Mathematics) students at a state university in the Philippines. Using a collaborative action research design utilizing modified explanatory sequential mixed-methods approach, quantitative data were collected via validated scales (Academic Grit Scale, Mathematical Mindset Scale, and Perception of Technology in Teaching and Learning Scale), while qualitative insights were derived from post-intervention interviews. Results indicated high levels of academic grit and growth-oriented mathematical mindset, with technology perceived positively for teaching and learning. Qualitative themes highlighted collaborative learning, technology efficacy, and resilience, though concerns about over-reliance on technology and access disparities emerged. Further, the qualitative data revealed that students perceived TIPBL as engaging, collaborative, and motivating. They described increased participation, stronger perseverance, a more open mindset toward solving problems, and positive attitudes toward the integration of technology. The findings suggest TIPBL develops perseverance, mindset development, and critical thinking, but equitable implementation and balanced technology integration are essential. Recommendations include scaffolding self-regulation, addressing digital inequities, and promoting collaborative problem-solving. It is also recommended that educators incorporate TIPBL strategies in their instruction. This study contributes to literature on technology-enhanced pedagogies and their psychological impacts in teacher education.

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## Introduction

The integration of technology into mathematics education is a growing priority in 21st-century learning environments. Existing literature has highlighted that digital tools, when used alongside innovative pedagogies, can support both cognitive and non-cognitive learning outcomes in mathematics (Hwang et al., 2020; Bicer et al., 2021). While Problem-Based Learning (PBL) has been shown to enhance students' conceptual understanding and problem-solving abilities (Savery, 2015), the specific approach of Technology-Integrated Problem-Based Learning (TIPBL) remains underexplored, especially within teacher education programs in developing countries (Alakrash & Razak, 2021). This study aims to investigate the influence of TIPBL on pre-service mathematics teachers' engagement, academic grit, mathematical mindset, and perception toward technology in learning. Using a mixed-methods action research design, the study integrates technology-enhanced PBL activities into a mathematics education course and examines their effects through both quantitative and qualitative lenses.

Mathematics education faces persistent challenges, including high levels of student anxiety (Dowker et al., 2016) and declining engagement during transitional academic periods (Attard, 2018). These challenges are particularly acute in the Philippines, where recent international assessments revealed that 81% of Filipino students failed to reach minimum proficiency levels in mathematics (OECD, 2019). This crisis has prompted urgent calls for pedagogical reforms that address both the cognitive and affective domains of mathematics learning (Bernardo et al., 2022).

Recent scholarship has identified two critical psychological constructs that influence mathematics achievement: academic grit (Clark & Malecki, 2019) and mathematical mindset (Megawanti et al., 2024). Grit, defined as "perseverance and passion for long-term goals" (Duckworth et al., 2007, p. 1087), has been shown to predict academic success beyond measures of intelligence (Credé et al., 2017). Similarly, growth mathematical mindset—the belief that mathematical ability can be developed through effort (Dweck, 2006)—has been linked to greater resilience in facing mathematical challenges (Yeager et al., 2019).

The intersection of technology integration and these psychological factors remains underexplored in pre-service teacher education (Tourón et al., 2018). This study addresses this gap by examining how TIPBL influences academic grit, mathematical mindset, and perceptions of technology among future mathematics educators—a population critical to educational reform (Ball et al., 2008).

## Theoretical Framework

This study draws upon three interconnected theoretical perspectives that collectively inform the design and implementation of the Technology-Integrated Problem-Based Learning (TIPBL) intervention. First, Vygotsky's (1978) Constructivist Learning Theory provides the foundational understanding that knowledge is actively constructed through social interaction and authentic problem-solving experiences. The TIPBL approach operationalizes these constructivist principles by engaging students in collaborative, technology-mediated activities that mirror real-world mathematical challenges (Jonassen, 2011). This theoretical lens emphasizes the

importance of scaffolding within students' zones of proximal development, particularly when working with complex financial mathematics concepts like annuities.

Building upon this foundation, Dweck's (2006) Mindset Theory informs the intervention's approach to fostering students' beliefs about mathematical ability. The study incorporates research-documented practices for cultivating growth mindsets, including process-focused feedback and the normalization of productive struggle in mathematics learning (Boaler, 2016). Empirical evidence suggests that such mindset interventions can enhance mathematics achievement by approximately 0.15 standard deviations, with particularly strong effects for students facing academic challenges (Sisk et al., 2018). The current study extends this work by examining how technology-enhanced problem-solving environments might uniquely contribute to mindset development among pre-service mathematics teachers.

Finally, Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge (TPACK) framework guides the strategic integration of digital tools within the problem-based learning environment. This theoretical model helps avoid the "technocentrism" trap identified by Papert (1987), ensuring that technology serves clear pedagogical purposes rather than being used as an end in itself. Recent applications of TPACK in mathematics education demonstrate how carefully designed technology integration can enhance conceptual understanding while developing students' digital competencies (Geiger et al., 2020). The TIPBL intervention applies these insights by selecting technologies that specifically support the mathematical content (annuities) and pedagogical goals (collaborative problem-solving) of the curriculum.

Together, these theoretical frameworks create a robust foundation for examining how technology-integrated problem-solving experiences might simultaneously enhance pre-service teachers' mathematical understanding, pedagogical skills, and psychological dispositions toward teaching and learning mathematics. The conceptual model emerging from this theoretical integration suggests that when implemented with attention to constructivist principles, mindset development, and technological pedagogical knowledge, TIPBL has the potential to transform both cognitive and affective outcomes in mathematics teacher education.

### **Statement of the Problem**

While Problem-Based Learning with the integration of technology has gained recognition as an innovative pedagogical approach (Chen et al., 2020), critical gaps persist in understanding its comprehensive impact on pre-service mathematics teachers. First, there remains limited empirical evidence regarding how TIPBL influences academic grit, the perseverance and passion for long-term goals (Duckworth et al., 2007), particularly when students engage with challenging mathematical tasks (Eskreis-Winkler et al., 2016). Given that pre-service teachers often encounter complex mathematical concepts during their training, understanding how TIPBL fosters or hinders their perseverance is essential for designing effective teacher education programs.

Second, although growth mathematical mindset, the belief that mathematical ability can be developed through effort (Dweck, 2006), has been widely studied, its cultivation within technology-enhanced learning

environments remains underexplored (Claro et al., 2016). Prior research suggests that mindset interventions can improve achievement (Yeager et al., 2019), but it is unclear how digital tools and collaborative problem-solving influence these beliefs in pre-service teachers.

Third, the reciprocal relationship between students' perceptions of technology and their perseverance (grit) in mathematics remains poorly understood (Scherer et al., 2019). While some students may view technology as a motivational tool that enhances learning, others may perceive it as a barrier, particularly when technical difficulties arise. Understanding this dynamic is crucial for optimizing TIPBL implementations in real-world educational settings.

To address these gaps, this study sought to answer the following research questions:

1. What are the baseline levels of academic grit, mathematical mindset, and technology perceptions among first-year Bachelor of Secondary Education major in Mathematics (BSEd-Mathematics) students prior to TIPBL implementation?
2. How do participants describe their experiences with TIPBL in terms of engagement, mathematical mindset, academic grit, and perception of technology in teaching and learning?

By investigating these questions, this study aimed to provide a deeper understanding of the influence of TIPBL in both cognitive and non-cognitive aspects of learning, ultimately contributing to more effective teacher preparation in mathematics education.

### **Significance of the Study**

This research makes substantial contributions across theoretical, practical, and methodological domains, offering valuable insights for diverse stakeholders in mathematics education. The study advances contemporary educational theory by bridging several critical frameworks. First, it extends the Technological Pedagogical Content Knowledge (TPACK) model by investigating its intersection with psychological constructs such as grit and mindset (Chai et al., 2019). This integration addresses a significant gap in understanding how technology-enhanced pedagogies influence non-cognitive learning outcomes. Second, the research expands growth mindset theory (Dweck, 2006) into technology-mediated mathematics contexts, providing empirical evidence on how digital problem-solving environments can shape students' beliefs about mathematical ability (Yeager & Dweck, 2020). Finally, the study refines grit theory (Duckworth et al., 2007) through its domain-specific application in mathematics teacher education, offering nuanced insights into how perseverance develops in technology-rich learning settings (Credé, 2018).

At the classroom level, this research provides educators with empirically validated TIPBL instructional modules for teaching annuities, complete with technology integration strategies and assessment tools (Hmelo-Silver, 2004). These resources are particularly valuable for teacher educators seeking to implement innovative pedagogies in their mathematics methods courses (Desimone, 2009). Beyond immediate classroom applications, the findings inform broader educational policy, particularly in the Philippine context where the Department of Education (DepEd) has prioritized technology integration in STEM curricula (SEAMEO INNOTECH, 2021). The

study's evidence-based recommendations can guide decision-makers in allocating resources for teacher professional development and technology infrastructure.

The research demonstrates an innovative mixed-methods action research design that combines quantitative assessments of psychological constructs with rich qualitative exploration of student experiences (Mertler, 2019). This approach serves as a model for studying short-term educational interventions while maintaining scientific rigor. The study also exemplifies best practices in instrument validation, employing both expert review and pilot testing to ensure the reliability and validity of measurement tools (Haynes et al., 1995). Furthermore, the detailed documentation of the 3-week TIPBL intervention provides a replicable template for future studies examining technology integration in teacher education programs (Plano Clark & Ivankova, 2016).

Collectively, these contributions position the study as both theoretically grounded and pragmatically useful, offering actionable insights for researchers, practitioners, and policymakers alike. The findings have particular relevance for institutions navigating the transition to technology-enhanced mathematics instruction, providing evidence-based guidance on effective implementation strategies and potential psychological impacts on learners.

## Methods

### Research Design

This study employed a collaborative action research design utilizing a mixed-methods approach. Specifically, it adopted a modified explanatory sequential mixed method to explore students' engagement, mathematical mindset, academic grit, and perception of technology in teaching and learning in the context of the implemented intervention. The approach was modified by replacing the traditional follow-up quantitative phase with qualitative interviews, due to the theoretical assumption that mindset and grit remain relatively stable in short-term interventions

In the first phase, quantitative data were collected using instruments that measured students' mathematical mindset, academic grit, and perception towards technology. This survey was conducted prior to the implementation of the TIPBL strategy to establish a baseline understanding of the respondents' dispositions. The intervention used in this study was the Technology-Integrated Problem-Based Learning (TIPBL) strategy, which aims to enhance student engagement and develop deeper learning through the integration of technology within a problem-based learning framework.

Following the intervention, the next phase involved the collection of qualitative data through interviews. These interviews focused on the same constructs, including student engagement, in order to gather rich, reflective insights on students' experiences with the TIPBL strategy. A post-intervention survey using the same instruments was not conducted, as constructs such as mindset and grit are generally not expected to exhibit significant change over a short period. Instead, the qualitative data served to capture any perceived changes, reflections, or enhanced awareness resulting from the intervention. By integrating both quantitative and qualitative data sources, this mixed methods approach provided a more comprehensive and contextualized understanding of the influence of the

TIPBL strategy, aligned with the cyclical and reflective nature of action research.

### **Research Respondents**

The respondents of the study were first-year Bachelor of Secondary Education major in Mathematics (BSEd-Mathematics) students from a state university in Naval, Biliran, Philippines, for the School Year 2024–2025. These students were considered the most appropriate respondents as they are in the foundational stage of their teacher education program, where attitudes toward academic perseverance, mathematical mindset, and the integration of technology in learning are being formed and developed. Their experiences and perspectives are crucial in understanding how early exposure to specific interventions can influence long-term engagement and learning behaviors. The study employed total enumeration sampling, involving the entire population of first-year BSEd-Mathematics students. This method ensures comprehensive coverage, minimizes sampling bias, and enhances the validity of the findings by reflecting the full range of experiences and responses within the target group.

During the post-implementation phase, qualitative data were collected through interviews with all student participants. These interviews focused on the same constructs assessed in the quantitative phase, to provide deeper, more reflective insights into students' experiences with the TIPBL strategy. By involving all respondents, the study aimed to capture a holistic and inclusive account of the intervention's influence, enriching the findings with a comprehensive range of perspectives.

In addition to the student respondents, four experts also participated in the study. These experts were involved in the validation of the researcher-made instrument measuring students' Perception of Technology in Teaching and Learning (PTTL), a 15-item scale designed to assess students' views on the role of technology in education. Furthermore, the same experts validated the instructional module titled Understanding Annuities – Annuity Due and Deferred Annuity (Technology-Integrated Problem-Based Learning Approach), which was developed by the researcher in collaboration with the course instructor. This module was implemented during the intervention phase and was subjected to a rigorous validation process using the institution's standard tool for evaluating learning materials, ensuring its quality, relevance, and instructional value.

### **Research Instrument**

The study utilized the Academic Grit Scale (AGS) by Clark & Malecki (2019), which consists of 10 items measuring academic grit level. The scale demonstrates excellent psychometric properties, including a reliable single-factor structure and high internal consistency (Cronbach's  $\alpha = 0.92$ ). It shows strong construct validity through correlations with general grit and incremental validity by uniquely predicting academic achievement, life satisfaction, and school satisfaction. Its domain-specific focus on determination, resilience, and focus within academics makes it a valuable tool for assessing and supporting student perseverance and success in educational settings. Respondents answered using a 5-point Likert scale.

Additionally, the Mathematical Mindset Scale (MMS) by Megawanti, et al. (2024) was used to assess students' mathematical mindset. The psychometric properties of the scale were established through rigorous development and validation processes. The scale underwent content validation with experts, achieving high content validity based on Aiken's index. Confirmatory Factor Analysis (CFA) was used to assess its structure, resulting in a model with 11 items across five dimensions: challenge, resilience, effort, learning from critics, and learning from mistakes, all with factor loadings above 0.5. The scale demonstrated excellent reliability, with a Construct Reliability (CR) of 0.984 and an Average Variance Extracted (AVE) of 0.925. Fit indices from CFA, such as RMSEA (0.065), CFI (0.95), and TLI (0.928), confirmed the model's goodness of fit, making it a robust instrument for assessing mathematical mindsets in education students. This 11-item scale requires students to rate items on a five-point Likert scale regarding level of agreement (1 = Strongly Disagree, 5 = Strongly Agree).

A researcher-made instrument was developed to measure students' Perception of Technology in Teaching and Learning (PTTL). This 15-item scale was designed to capture students' perception of technology in the educational process. To ensure its validity, the instrument underwent expert validation by four specialists in the field. It demonstrated excellent content validity, with relevance ratings yielding S-CVI/Ave = 0.97 and S-CVI/UA = 0.87, and clarity ratings of S-CVI/Ave = 0.98 and S-CVI/UA = 0.93. A pilot test was conducted to evaluate the internal consistency of the instrument, resulting in a high Cronbach's alpha coefficient of 0.95. The items were rated using a 5-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), and were designed to be clear, concise, and directly aligned with the constructs being measured.

In addition to the quantitative instruments, an interview consisting of nine (9) open-ended questions was conducted after the implementation of the intervention. These questions were designed to elicit deeper insights into students' experiences and reflections regarding their engagement, mathematical mindset, academic grit, and perception of technology in the context of teaching and learning. Specifically, the interview included three questions related to student engagement, two questions each focusing on mathematical mindset, academic grit, and perception of technology in teaching and learning. The qualitative data from these interviews provided a richer understanding of how the intervention influenced the participants beyond what could be captured through survey instruments alone.

### **Data Collection Procedure**

The data gathering procedure for this study was conducted in a systematic and ethical manner to ensure the credibility, reliability, and integrity of the collected data. The process began with securing a Letter of Approval signed by the Dean of the School of Teacher Education, which granted formal permission to conduct the study within the institution. This approval not only facilitated access to the intended participants but also ensured compliance with institutional protocols and reinforced the study's adherence to ethical research standards.

The data collection process was carried out in three key phases:

1. Pre-Implementation Phase: Before the intervention, quantitative data were collected using standardized and researcher-made instruments. These instruments measured students' mathematical mindset, academic grit, and

perception of technology in teaching and learning. The instruments were distributed through a Google Form, selected for its accessibility, ease of use, and ability to reach all participants efficiently. At the beginning of the form, a data consent section was included, clearly outlining the purpose of the study, the voluntary nature of participation, confidentiality measures, and the participants' right to withdraw at any time. Ensuring informed and voluntary consent was a critical aspect of maintaining ethical standards in the research process.

2. Implementation Phase: During this phase, the Technology-Integrated Problem-Based Learning (TIPBL) Strategy was implemented over a period of three weeks. A key component of this phase was a module titled Understanding Annuities – Annuity Due and Deferred Annuity (Technology-Integrated Problem-Based Learning Approach), which was developed by the researcher in collaboration with the instructor teaching the course. The module was designed to integrate real-world problem-solving tasks with technological tools, in alignment with the TIPBL approach. To ensure its quality and instructional value, the module underwent a rigorous validation process by four experts, utilizing the institution's standard validation tool for learning materials.

The validated module served a dual purpose: it acted as a comprehensive guide for the instructor in implementing the TIPBL strategy and also as a learning resource for the students, providing structure, context, and support as they explored the topic of annuities through technology-integrated problem-solving activities.

3. Post-Implementation Phase: After the intervention, qualitative data were collected through interviews with all student participants. These interviews focused on the same constructs assessed in the quantitative phase, including student engagement, mathematical mindset, academic grit, and perception of technology in teaching and learning, to provide deeper, more reflective insights into students' experiences with the TIPBL strategy. The interviews allowed participants to share personal observations, perceptions, and the influence of the intervention on their learning journey.

All data collected through the Google Form and interviews were securely stored in a protected digital format, with access limited to the researcher alone. Any identifying information was anonymized or excluded to uphold participant confidentiality and privacy. These steps ensured that the entire data collection process was aligned with ethical research practices and upheld the rights and dignity of all participants.

### **Data Analysis**

The quantitative data analysis was conducted using Jamovi (version 2.4.14) to examine students' mathematical mindset, academic grit, and perception of technology in teaching and learning. Descriptive statistics were applied to summarize students' profiles: frequency counts and percentages were used for categorical data such as sex, while the mean and standard deviation described continuous variables like age. The constructs of mathematical mindset, academic grit, and perception of technology were also analyzed using mean and standard deviation to highlight central tendencies and variability in students' responses.

For the qualitative data, thematic analysis was employed to interpret students' responses to nine questions about

their reflections and experiences with the Technology-Integrated Problem-Based Learning (TIPBL) strategy. This method enabled the identification of recurring themes and patterns across interview transcripts, providing in-depth insights into students' engagement, and perceived shifts in mathematical mindset, academic grit, and perception of technology in teaching and learning. Rather than serving solely to explain prior quantitative findings, the qualitative phase played a central role in exploring students' experiences and reflections on the intervention.

This approach aligns with the study's action research design, which emphasizes reflection, participation, and contextual understanding. The study employed a modified explanatory sequential mixed method approach, in which the qualitative phase followed the initial quantitative data collection. However, unlike traditional designs, a post-survey was not conducted, recognizing that constructs such as mindset and grit are unlikely to show measurable change over a short period. Instead, qualitative interviews were used to explore students' perceived changes and experiences in depth. This modification allowed the study to remain responsive and reflective, key principles of action research, while still benefiting from the structured insights of a mixed methods approach.

## Results and Discussion

This section presents the results and discussion of the study, highlighting both quantitative and qualitative findings. The data are organized around key constructs, mathematical mindset, academic grit, perception of technology in teaching and learning, and student engagement, reflecting the influence of the TIPBL strategy within the study's action research design utilizing modified explanatory sequential mixed methods approach.

Table 1 presents the demographic profile of the first-year BSEd-Mathematics students who participated in the study. Out of the 17 respondents, 10 were male (58.82%) and 7 were female (41.18%), indicating a higher representation of male students. The participants' ages ranged around a mean of 19.00 years ( $SD = 1.12$ ), suggesting that most of the respondents were in their late adolescence, a typical age range for first-year college students.

Table 1. Profile of the BSEd-Mathematics 1st Year Students

Variable	Frequency	Percent
Sex		
Male	10	58.82%
Female	7	41.18%
Total	17	100%
Age		
Mean = 19.00, Standard Deviation = 1.12		

The results indicate that BSEd-Math 1 students exhibit high levels of academic grit overall ( $M = 4.12$ ,  $SD = 0.60$ ), with individual item scores ranging from high to very high. This suggests that these students generally possess strong perseverance and passion for long-term academic goals, consistent with Duckworth et al.'s (2007) conceptualization of grit (see Table 2).

Table 2. Academic Grit of BSEd-Math 1 Students

	M	SD	Interpretation
1. I push myself to do my personal best in school.	3.94	0.75	High
2. I work toward my academic goals no matter how long they take to reach.	4.00	0.87	High
3. Even when I could do something more fun, I give schoolwork my best effort.	4.00	0.79	High
4. I complete my schoolwork no matter how difficult it is.	4.35	0.79	Very High
5. I am determined to give my best effort in schoolwork.	4.24	0.75	Very High
6. Once I set a goal in school, I try to overcome any challenges that arise.	3.88	0.70	High
7. I am able to balance working hard in school with my other hobbies and interests.	3.82	0.81	High
8. Even if I am struggling in school, I keep trying my best.	4.47	0.80	Very High
9. When it comes to completing work in school, I always try my hardest.	4.24	0.83	Very High
10. In school, I work hard to achieve challenging goals.	4.29	0.69	Very High
Overall	4.12	0.60	High

Several items stood out as demonstrating particularly strong grit characteristics. The highest-rated statement, "Even if I am struggling in school, I keep trying my best" ( $M = 4.47$ ,  $SD = 0.80$ ), along with other items regarding completing difficult schoolwork ( $M = 4.35$ ) and working toward challenging goals ( $M = 4.29$ ), all received very high ratings. These findings suggest that students maintain their effort and commitment even when facing academic challenges, a key component of academic success (Credé et al., 2017).

While all items were rated in the high to very high range, the relatively lower (though still high) scores on items like balancing schoolwork with hobbies ( $M = 3.82$ ) and setting goals while overcoming challenges ( $M = 3.88$ ) may indicate areas where students could benefit from additional support. These slightly lower scores might reflect the difficulties students face in managing multiple responsibilities or maintaining motivation over extended periods.

The findings align with previous research demonstrating the importance of grit in academic achievement, particularly in demanding programs like mathematics education (Duckworth & Quinn, 2009). Also, the results align with Tang et al. (2019), who identified the perseverance component of grit as a significant predictor of academic engagement, underscoring its importance in sustaining effort through obstacles. Similarly, Çınar-Tanrıverdi and Karabacak-Çelik (2022) highlighted grit's role in reducing academic stress, suggesting its protective effects in demanding academic environments. The high levels of self-reported grit among these students may contribute to their ability to persist through the challenges of their program. However, the presence of variability across items suggests that grit may manifest differently across various academic situations.

These results have important implications for educational practice. While students demonstrate strong persistence overall, the areas with relatively lower scores might represent opportunities for intervention. Programs designed to enhance time management skills or provide support for maintaining motivation during prolonged challenges could be particularly beneficial. Additionally, the findings support the value of developing grit as part of students' academic development, as it appears to be an important factor in their educational experiences.

The results demonstrate that BSEd-Math 1 students possess a strong growth mindset toward mathematics (Overall  $M = 4.17$ ,  $SD = 0.61$ ), with individual items ranging from high to very high levels of agreement. These findings suggest that future mathematics teachers in this sample maintain resilient, effort-based beliefs about mathematical ability, consistent with Dweck's (2006) mindset theory (see Table 3).

Table 3. Mathematical Mindset of BSEd-Math 1 Students

	M	SD	Interpretation
1. No matter how much math intelligence I have, I will be able to improve it.	4.18	0.64	High
2. If other people can master mathematics, then I can too.	4.24	0.75	Very High
3. I am aware that I do not have talent in mathematics, but I will do everything I can to become an expert in mathematics.	4.12	0.70	High
4. Even though the lecturer thinks my effort will be useless, I still want to prove that mathematics is a science that anyone can master.	4.24	0.83	Very High
5. I will keep asking anyone until I can really understand mathematics.	4.35	0.70	Very High
6. Even though my friends say that studying without having mathematical talent will be useless, I think otherwise.	3.59	1.06	High
7. Mastering mathematics is not an easy job, but there are opportunities to learn and understand it little by little.	4.53	0.72	Very High
8. Even though I've been told I'm not intelligent many times, I will keep asking questions until I finally understand mathematics.	4.24	0.75	Very High
9. The mathematics lecturer's criticism of me challenged me to prove that I could be better.	3.94	1.03	High
10. A bad grade in mathematics challenges me to continue to master it.	4.18	0.88	High
11. Even though my teacher said that I had no hope in mathematics, I wanted to keep trying.	4.24	0.66	Very High
Overall	4.17	0.61	High

Several particularly noteworthy findings emerged. The highest-rated item, "Mastering mathematics is not an easy job, but there are opportunities to learn and understand it little by little" ( $M = 4.53$ ,  $SD = 0.72$ ), along with other very high scoring items about persistence in asking questions ( $M = 4.35$ ) and belief in one's ability to improve ( $M = 4.24$ ), reveal a pattern of determined, incremental learning attitudes. This aligns with research showing that growth mindset predicts persistence in STEM fields (Yeager et al., 2019).

While all items scored in the high range, some interesting variations appear. The statement about peer influence ("Even though my friends say that studying without having mathematical talent will be useless...") received the lowest score ( $M = 3.59$ ,  $SD = 1.06$ ), suggesting social perceptions may present unique challenges to mindset maintenance. Similarly, responses to lecturer criticism ( $M = 3.94$ ) showed slightly more variability, indicating these situations may test students' mindset beliefs more than other academic challenges.

These findings have important implications for mathematics education. The generally high growth mindset scores are encouraging for teacher preparation programs, as teachers' mathematical mindsets influence their future pedagogical approaches (Boaler, 2016). The high growth mindset is consistent with research by Polirstok (2017), which emphasized that growth mindset enhances persistence and helps students overcome challenges, particularly in mathematics. Moreover, Wu et al. (2022) identified that students with high grit and growth mindset profiles consistently performed better in mathematics, supporting the interconnectedness of these traits in fostering success.

Table 4 presents the perceptions of BSEd-Mathematics 1 students regarding the use of technology in teaching and learning. The overall mean score of 4.05 ( $SD = 0.52$ ) indicates a high level of agreement, suggesting that students generally have a positive perception of technology integration in education.

Table 4. Perception of Technology in Teaching and Learning of BSEd-Math 1 Students

	M	SD	Interpretation
1. Technology enhances my learning experience.	4.24	0.66	Very Positive
2. I find it easy to use technology in classroom activities.	4.12	0.86	Positive
3. Technology makes lessons more engaging and interactive.	4.06	0.66	Positive
4. I feel confident using technology for learning purposes.	3.94	0.66	Positive
5. Technology helps me understand complex concepts better.	4.06	0.83	Positive
6. The use of technology in teaching motivates me to learn more.	3.94	0.66	Positive
7. Technology allows me to learn at my own pace.	4.06	0.83	Positive
8. I find technology useful in collaborating with classmates on tasks.	4.18	0.53	Positive
9. Technology provides access to additional learning resources that improve my understanding.	4.47	0.72	Very Positive
10. I feel that using technology makes lessons more enjoyable.	3.82	0.81	Positive
11. Technology improves my ability to retain knowledge.	3.71	0.69	Positive
12. I feel more connected with my teacher when technology is used in teaching.	3.88	0.78	Positive
13. Technology helps me organize and manage my learning tasks effectively.	3.71	0.69	Positive
14. I believe that technology plays a critical role in modern education.	4.24	0.83	Very Positive
15. The use of technology in teaching prepares me for future career opportunities.	4.35	0.70	Very Positive
Overall	4.05	0.52	Positive

Among the individual items, the highest-rated statement was “Technology provides access to additional learning resources that improve my understanding” with a mean of 4.47 (SD = 0.72), interpreted as very positive. This emphasizes the perceived value of technology in enriching learning through resource accessibility, consistent with studies highlighting the internet's role in expanding learners’ access to materials (Johnson et al., 2016).

Three other items also received very positive ratings: “Technology enhances my learning experience” (M = 4.24, SD = 0.66), “I believe that technology plays a critical role in modern education” (M = 4.24, SD = 0.83), and “The use of technology in teaching prepares me for future career opportunities” (M = 4.35, SD = 0.70). These responses reflect a strong recognition of technology’s relevance not only for current learning but also for future professional readiness, aligning with 21st-century skills frameworks (Trilling & Fadel, 2009).

The item with the lowest mean was “Technology improves my ability to retain knowledge” (M = 3.71, SD = 0.69), though still interpreted as positive. This may suggest that while students appreciate the utility of technology, its impact on long-term retention may be perceived as less direct, possibly due to varied learning strategies and cognitive preferences (Fleming, 2001).

The findings imply that BSEd-Math 1 students are receptive to the integration of technology in education and acknowledge its role in enhancing learning, engagement, collaboration, and future preparedness. These results underscore the importance of sustaining and improving technology-supported instructional practices in teacher education programs.

This study examined how students experienced engagement in mathematics through content, peer interaction, and teacher facilitation within a technology-integrated, problem-based learning environment. Thematic analysis of student responses surfaced three key themes: Technology-Enhanced Pedagogy, Collaborative Learning Dynamics, and Teacher-Led Engagement Strategies (see Table 5).

Table 5. Thematic Analysis of Student Engagement in Technology-integrated Problem-based Learning (TIPBL)

Strategy					
Theme (Frequency)	Theme Description	Sub-Theme (Frequency)	Sub-Theme Description	Code (Frequency)	Example Quotations (Student-Question)
Technology-Enhanced Pedagogy (23)	Examines how digital tools and technology-mediated instruction enhance engagement in mathematics learning.	Digital Tool Efficacy (13)	Focuses on technological applications that improve engagement through interactivity and efficiency.	Interactive Software (8)	"The app offered hints and instant feedback." (S3-Q1)
				Gamified Learning (5)	"Games made math fun." (S2-Q1)

<b>Theme (Frequency)</b>	<b>Theme Description</b>	<b>Sub-Theme (Frequency)</b>	<b>Sub-Theme Description</b>	<b>Code (Frequency)</b>	<b>Example Quotations (Student- Question)</b>
		Skill Transfer (7)	Highlights how technology facilitates real-world application of mathematical concepts.	Real-World Application (7)	"Modeling investments showed practical value." (S9-Q1)
		Accessibility Challenges (3)	Identifies barriers to implementing technology-enhanced learning.	Resource Barriers (3)	"Most lacked laptops, limiting participation." (S11-Q1)
Collaborative Learning Dynamics (22)	Encompasses peer interactions that enhance mathematical understanding and motivation through social learning processes.	Cognitive Synergy (14)	Focuses on intellectual benefits of peer collaboration.	Diverse Problem-Solving (6)	"Classmates explained concepts in new ways." (S2-Q2)
				Collective Knowledge Construction (8)	"Brainstorming led to optimal solutions." (S10-Q2)
		Affective Support (8)	Emotional and motivational aspects of peer interaction.	Motivational Peer Interactions (8)	"Group's encouragement boosted confidence." (S16-Q2)
		Role Specialization (3)	How students divide tasks during collaborative work.	Task Delegation (3)	"Some solved, others wrote the report." (S2-Q2)
Teacher-Led Engagement Strategies (16)	Covers instructional approaches that foster engagement through designed learning experiences.	Active Learning Design (16)	Hands-on, problem-centered instructional methods.	Problem-Based Instruction (9)	"Real-world tasks made math relevant." (S2-Q3)
				Hands-On	"Hands-on tasks

Theme (Frequency)	Theme Description	Sub-Theme (Frequency)	Sub-Theme Description	Code (Frequency)	Example Quotations (Student- Question)
				Activities (7)	aided understanding." (S2-Q3)
		Differentiated Instruction (5)	Adapting teaching to diverse learner needs.	Adaptive Scaffolding (5)	"Teacher adjusted pacing so no one fell behind." (S10-Q3)

Technology-Enhanced Pedagogy ( $n = 23$ ) was the most frequently cited theme, emphasizing how digital tools supported student engagement. Within this theme, Digital Tool Efficacy ( $n = 13$ ) illustrated how applications and gamified tools facilitated motivation and sustained attention. For example, one student shared, *"The app offered hints and instant feedback"* (S3-Q1), while another noted, *"Games made math fun"* (S2-Q1). These responses align with research demonstrating that interactive digital tools enhance motivation and reduce cognitive load (Mayer, 2014; Plass et al., 2015). The sub-theme Skill Transfer ( $n = 7$ ) further emphasized real-world connections, with a student remarking, *"Modeling investments showed practical value"* (S9-Q1), supporting findings that authentic problem-solving strengthens conceptual understanding (Jonassen, 2011). However, a smaller but crucial sub-theme, Accessibility Challenges ( $n = 3$ ), revealed issues of digital inequality: *"Most lacked laptops, limiting participation"* (S11-Q1), underscoring the importance of addressing resource gaps to ensure equitable engagement (Warschauer, 2004).

Collaborative Learning Dynamics ( $n = 22$ ) revealed the value of peer interaction in enhancing both understanding and motivation. The sub-theme Cognitive Synergy ( $n = 14$ ) encompassed how working with others led to improved problem-solving. One participant stated, *"Classmates explained concepts in new ways"* (S2-Q2), while another highlighted, *"Brainstorming led to optimal solutions"* (S10-Q2), consistent with social constructivist principles (Vygotsky, 1978) and cooperative learning frameworks (Johnson & Johnson, 2009). Emotional benefits also emerged under Affective Support ( $n = 8$ ), with one student expressing, *"Group's encouragement boosted confidence"* (S16-Q2), reflecting research on the social-emotional benefits of collaborative learning (Slavin, 2014). Additionally, Role Specialization ( $n = 3$ ) reflected structured collaboration where task delegation supported active participation: *"Some solved, others wrote the report"* (S2-Q2), aligning with studies on productive group roles (Cohen, 1994).

Teacher-Led Engagement Strategies ( $n = 16$ ) focused on instructional methods that promoted active participation. The dominant sub-theme Active Learning Design ( $n = 16$ ) included responses referencing both problem-based instruction and hands-on tasks. For instance, *"Real-world tasks made math relevant"* (S2-Q3) and *"Hands-on tasks aided understanding"* (S2-Q3) show how experiential and contextualized learning activities deepened comprehension and interest, reinforcing evidence on inquiry-based learning (Hmelo-Silver, 2004). The sub-

theme Differentiated Instruction ( $n = 5$ ) captured how adaptive teaching practices fostered inclusivity: “*Teacher adjusted pacing so no one fell behind*” (S10-Q3), supporting research on responsive pedagogy (Tomlinson, 2014).

These findings reinforce the importance of a multi-dimensional engagement strategy in mathematics education. When technology is meaningfully integrated (Higgins et al., 2019), collaboration is encouraged (Webb et al., 2019), and instruction is thoughtfully designed (Hattie, 2009), students experience deeper engagement cognitively, socially, and emotionally. These insights align with constructivist theories of learning (Vygotsky, 1978) and research on technology-mediated and student-centered instruction (Boaler, 2016). Future research may explore how sustained exposure to such strategies influences long-term achievement, especially among diverse learner groups.

This study examined students’ academic grit in the context of mathematics learning, particularly how they persist through difficulties, stay motivated, and commit to long-term improvement. Thematic analysis of the qualitative responses revealed three major themes: Resilience in Learning ( $n = 38$ ), Motivational Foundations ( $n = 21$ ), and Cognitive & Emotional Strategies ( $n = 16$ ). These themes highlight the multidimensional nature of grit, encompassing behavioral, motivational, and psychological factors that support students’ perseverance in mathematics, consistent with contemporary frameworks of academic resilience (Martin, 2013) and self-regulated learning (Panadero, 2017) (see Table 6).

Table 6. Emergent Themes, Sub-themes, Codes, and Exemplary Quotations on Academic Grit in Mathematics Learning

Theme (Frequency)	Theme Description	Sub-Theme (Frequency)	Sub-Theme Description	Codes (Frequency)	Exemplary Quotations (Student-Question)
Resilience in Learning (38)	Students' capacity to endure challenges through persistence and adaptive strategies.	Persistence Through Challenges (22)	Sustained effort despite difficulties, demonstrating determination.	Perseverance (14)	"I kept trying different methods, like breaking the problem into smaller parts." (S2-Q1)
		Adaptive Problem-Solving (16)	Cognitive strategies to manage and overcome challenges.	Goal-Oriented Behavior (8)	"I set small goals, like mastering one concept at a time." (S3-Q2)
				Coping Strategies (16)	"Taking short breaks helped refresh my mind." (S3-Q1)
Motivational	Driving forces	Intrinsic Drivers	Motivation from	Motivational	"My love for

Theme (Frequency)	Theme Description	Sub-Theme (Frequency)	Sub-Theme Description	Codes (Frequency)	Exemplary Quotations (Student- Question)
Foundations (21)	behind persistence, including internal/external motivators and social support.	(7)	personal values, interests, or identity.	Drivers (Internal) (7)	mathematics helps me stay committed." (S4- Q2)
		Extrinsic Drivers (5)	External rewards or obligations that motivate effort.	Motivational Drivers (External) (5)	"I want to pay off my parents' sacrifices." (S1-Q2)
		Social Reinforcement (9)	Interpersonal support systems encouraging persistence.	Social Support (9)	"The support of my classmates motivated me." (S9-Q1)
Cognitive & Emotional Strategies (16)	Mental frameworks and self-regulation techniques to interpret challenges.	Growth Mindset (10)	Belief that abilities can develop through effort.	Mindset Shifts (10)	"Struggling is part of learning." (S2-Q1)
		Self-Regulation (6)	Emotional management and reward systems.	Coping Strategies (Emotional) (6)	"I give myself rewards for small accomplishments." (S15-Q1)

The most prominent theme, Resilience in Learning ( $n = 38$ ), reflects students' capacity to sustain effort and adapt when encountering difficult mathematical tasks. Within this theme, the sub-theme Persistence Through Challenges ( $n = 22$ ) captured students' unwavering determination to complete tasks despite obstacles. A student expressed, *"I kept trying different methods, like breaking the problem into smaller parts"* (S2-Q1), showcasing perseverance—a core component of grit as conceptualized by Duckworth et al. (2007). This aligns with research demonstrating that task decomposition improves problem-solving efficacy (Jonassen, 2011). Additionally, students exhibited Goal-Oriented Behavior ( $n = 8$ ), setting small, manageable objectives to stay focused, such as *"mastering one concept at a time"* (S3-Q2). These behaviors suggest an intentional and sustained approach to learning, aligning with findings by Eskreis-Winkler et al. (2014), who emphasize the importance of long-term goals in academic perseverance, as well as Locke and Latham's (2002) goal-setting theory.

Furthermore, the sub-theme Adaptive Problem-Solving ( $n = 16$ ) illustrated how students manage stress and confusion through practical coping strategies. One participant noted, *"Taking short breaks helped refresh my*

*mind*” (S3-Q1), highlighting the importance of self-awareness and cognitive flexibility in overcoming academic setbacks. These adaptive behaviors are essential for self-regulated learning and reflect a resilience-oriented mindset (Martin & Marsh, 2006), particularly the role of "academic buoyancy" in navigating daily challenges (Martin, 2013).

The second major theme, Motivational Foundations ( $n = 21$ ), encompassed the internal and external forces that sustain students' grit in mathematics. Intrinsic Drivers ( $n = 7$ ) included passion for the subject and personal fulfillment. For example, a student remarked, “*My love for mathematics helps me stay committed*” (S4-Q2), reflecting a deep-seated connection between identity and motivation. This aligns with research suggesting that intrinsic motivation enhances engagement and persistence (Ryan & Deci, 2000), particularly when students perceive mathematics as personally meaningful (Middleton et al., 2017).

In contrast, Extrinsic Drivers ( $n = 5$ ) focused on obligations or rewards, such as familial expectations. One student shared, “*I want to pay off my parents' sacrifices*” (S1-Q2), demonstrating how external motivators can foster academic effort, especially in collectivist cultures where family support plays a pivotal role (King & McInerney, 2016). Such findings resonate with the cross-cultural literature on achievement motivation (Bernardo et al., 2018).

Moreover, Social Reinforcement ( $n = 9$ ) highlighted the role of peer and teacher support in maintaining motivation. As one participant stated, “*The support of my classmates motivated me*” (S9-Q1). These findings support the view that academic grit is socially influenced and may be enhanced through positive educational environments (Credé et al., 2017), particularly via teacher-student relationships that foster belonging (Furrer & Skinner, 2003).

The final theme, Cognitive & Emotional Strategies ( $n = 16$ ), reflected students' mental models and emotional regulation during mathematical challenges. The sub-theme Growth Mindset ( $n = 10$ ) was evident in students who believed that effort leads to improvement. For instance, one student stated, “*Struggling is part of learning*” (S2-Q1), illustrating Dweck's (2006) assertion that growth-oriented beliefs foster resilience and motivation, particularly in STEM fields (Claro et al., 2016).

Additionally, Self-Regulation ( $n = 6$ ) encompassed emotional management strategies such as self-reward systems. One student shared, “*I give myself rewards for small accomplishments*” (S15-Q1), indicating a high level of metacognitive control. These behaviors support Zimmerman's (2002) model of self-regulated learning, in which emotional regulation and self-monitoring are essential components of persistence, as well as broader theories of volitional strategy use (Wolters, 2003).

This study also investigated students' mathematical mindsets and their strategies for handling challenging mathematical tasks. Thematic analysis of qualitative responses revealed three main themes: Problem-Solving Approaches ( $n = 31$ ), Mindset Toward Mathematics ( $n = 23$ ), and Metacognitive Reflections ( $n = 20$ ). These themes highlight the cognitive, affective, and reflective dimensions of students' engagement with mathematics, aligning with frameworks that emphasize self-regulated learning (Zimmerman, 2002) and sociocultural influences

(Vygotsky, 1978) (see Table 7).

Table 7. Emergent Themes, Sub-themes, Codes, and Exemplars from Students' Responses about Mathematical Mindset

<b>Theme (Frequency)</b>	<b>Theme Description</b>	<b>Sub-Theme (Frequency)</b>	<b>Sub-Theme Description</b>	<b>Codes (Frequency)</b>	<b>Exemplar Quotations (Student- Question)</b>
Problem- Solving Approaches (31)	Strategies and behaviors students use to tackle challenging math problems.	Strategic Methods (13)	Structured, self-directed techniques for problem decomposition and resource use.	Systematic Breakdown (8)	S3-Q1: "Broke it down step-by-step." S9-Q1: "Persistence and step-by-step approach." S4-Q1: "Searched online." S13-Q1: "Used Excel tools."
		Collaborative Learning (9)	Reliance on social interactions to overcome challenges.	Peer/Instructor Support (9)	S5-Q1: "Asked teacher/classmates." S11-Q1: "Group study enhanced understanding."
		Adaptive Resilience (9)	Persistence and help-seeking behaviors in response to difficulty.	Persistence (7)	S10-Q1: "Never give up despite difficulties." S6-Q1: "Asked professor for clarification." S14-Q1: "Peer assistance."
Mindset Toward Mathematics (23)	Students' beliefs and emotional responses about math learning, especially toward mistakes.	Growth Orientation (23)	Viewing challenges and errors as opportunities for mastery.	Mistakes as Learning Tools (14)	S1-Q2: "Mistakes as an opportunity to grow." S7-Q2: "Invaluable tools for growth." S4-Q2: "Strengthens understanding."
				Self-Improvement	

Theme (Frequency)	Theme Description	Sub-Theme (Frequency)	Sub-Theme Description	Codes (Frequency)	Exemplar Quotations (Student- Question)
				(9)	S10-Q2: "Mistakes motivate progress."
		Emotional Trajectories (9)	Shifts in affective states during problem-solving.	Frustration → Motivation (6)	S8-Q2: "Discouraged at first, then motivated." S9-Q2: "Shift from failure to learning."
				Enjoyment Despite Difficulty (3)	S15-Q2: "Enjoy math even when hard."
Metacognitive Reflections (20)	Students' awareness and evaluation of their learning processes.	Learned Insights (12)	Key takeaways about conceptual clarity and process-oriented learning.	Conceptual Clarity (7)	S1-Q1: "Relearned from the start." S5-Q1: "Active listening matters." S5-Q2: "Errors are hurdles, not failures." S13-Q1: "Tools matter as much as math."
		Behavioral Adjustments (8)	Intentional changes to future strategies based on reflection.	Process Over Outcome (5) Strategy Refinement (8)	S2-Q2: "Checked steps to correct mistakes." S13-Q2: "Avoid repeating mistakes."

The most frequently occurring theme, Problem-Solving Approaches ( $n = 31$ ), encompassed the various strategies and behaviors students employed to address difficult math problems. Within this theme, Strategic Methods ( $n = 13$ ) emerged as a significant sub-theme, with students demonstrating structured and self-directed problem-solving techniques. For example, a student noted, "*I broke it down step-by-step*" (S3-Q1), reflecting a deliberate and organized approach consistent with Polya's (1945) heuristic model of problem-solving. The use of tools and resources was also prevalent, as seen in "*Used Excel tools*" (S13-Q1), showing students' inclination to utilize digital aids, which research suggests can enhance procedural fluency (Rittle-Johnson et al., 2015).

Another prominent sub-theme was Collaborative Learning ( $n = 9$ ), where students described engaging with peers or instructors to overcome mathematical challenges. Statements such as "*Group study enhanced understanding*" (S11-Q1) illustrate the social nature of learning and are supported by Vygotsky's (1978) emphasis on the role of social interaction in cognitive development, as well as more recent work on collaborative problem-solving (Hmelo-Silver et al., 2013).

Additionally, the sub-theme Adaptive Resilience ( $n = 9$ ) reflected students' persistence and help-seeking behaviors. "*Never give up despite difficulties*" (S10-Q1) was one such quote illustrating students' grit and adaptability. These findings are consistent with Duckworth et al.'s (2007) conceptualization of perseverance as a key contributor to academic success and Yeager and Dweck's (2012) research on resilience in academic contexts.

The second major theme, Mindset Toward Mathematics ( $n = 23$ ), captured students' beliefs and emotional orientations, especially in relation to mistakes. The dominant sub-theme here was Growth Orientation ( $n = 23$ ), with students viewing errors as stepping stones to improvement. One participant emphasized, "*Mistakes are an opportunity to grow*" (S1-Q2), reflecting Dweck's (2006) theory of a growth mindset, which has been linked to increased resilience and achievement in mathematics (Claro et al., 2016).

Within this growth-oriented perspective, students highlighted Mistakes as Learning Tools ( $n = 14$ ) and Self-Improvement ( $n = 9$ ). These responses suggest that students perceive errors not as failures but as valuable feedback mechanisms, a perspective supported by research on productive failure (Kapur, 2008). Another layer of this theme involved Emotional Trajectories ( $n = 9$ ), revealing the dynamic affective responses students experience. For instance, a student shared, "*Discouraged at first, then motivated*" (S8-Q2), demonstrating how emotional responses can evolve positively through persistence and reflection, a process aligned with Pekrun's (2006) control-value theory of achievement emotions. Interestingly, even in the face of difficulty, a minority of students reported Enjoyment Despite Difficulty ( $n = 3$ ), suggesting the presence of intrinsic motivation in learning mathematics (Boaler, 2016; Ryan & Deci, 2000).

The third major theme, Metacognitive Reflections ( $n = 20$ ), emphasized students' awareness of their own learning processes. The sub-theme Learned Insights ( $n = 12$ ) included reflections on conceptual clarity and the importance of understanding processes over merely obtaining correct answers. One student remarked, "*Relearned from the start*" (S1-Q1), signifying a reflective and conceptually grounded approach to learning, echoing Schoenfeld's (1992) work on metacognition in mathematics.

Another sub-theme, Behavioral Adjustments ( $n = 8$ ), revealed that students made intentional changes to their learning strategies based on past experiences. For example, "*Checked steps to correct mistakes*" (S2-Q2) demonstrates an evaluative mindset and aligns with Zimmerman's (2002) model of self-regulated learning and Winne and Hadwin's (1998) COPES framework. These behaviors are indicative of higher-order thinking and metacognitive engagement, which are crucial for sustained learning success (Veenman et al., 2006).

The thematic analysis, based on students' responses to questions about the role of technology in learning mathematics, revealed four central themes, supported by a total of 87 coded quotations. These themes reflect students' perceptions of both the benefits and drawbacks of integrating technology in mathematical problem-solving, aligning with contemporary frameworks of digital pedagogy (Selwyn, 2016) and equitable access (Warschauer, 2004). The identified themes include Enhanced Learning Efficiency ( $n = 37$ ), Interactive and Engaging Learning ( $n = 18$ ), Dependency and Critical Thinking Erosion ( $n = 26$ ), and Equity and Access Barriers ( $n = 6$ ), where  $n$  refers to the number of supporting quotations (see Table 8).

Table 8. Emergent Themes, Sub-themes, Codes, and Exemplary Quotations on Students' Perceptions of Technology in Teaching and Learning

<b>Theme (Frequency)</b>	<b>Theme Description</b>	<b>Sub-Theme (Frequency)</b>	<b>Sub-Theme Description</b>	<b>Codes (Frequency)</b>	<b>Exemplar Quotations (Student- Question)</b>
Enhanced Learning Efficiency (37)	Technology improves speed, accessibility, and effectiveness of math learning.	Accelerated	Tools that streamline mathematical processes and reduce manual effort.	Faster Solutions (16)	"Solving mathematical problems has become now so easy unlike the traditional one." (S6-Q1)
		Accessibility		(11)	"One can use a calculator in mobile devices... as I did not have any scientific calculator." (S5-Q1)
		Immediate Feedback (10)	Real-time corrections and learning reinforcement.	Real-Time Correction (10)	"Technology provides immediate feedback, helping me correct mistakes quickly." (S9-Q1)
		Resource Availability (8)	Diverse digital tools catering to varied learning needs.	Diverse Tools (8)	"Online tutorials and step-by-step video explanations help when I need extra practice." (S2-Q1)
Interactive and Engaging Learning (18)	Technology makes math dynamic through visual/gamified methods.	Visualization (10)	Tools that transform abstract concepts into tangible representations.	Visual Aids (10)	"Graphing calculators... help me visualize equations." (S2-Q1)
		Gamification (8)	Game-like elements increasing motivation and retention.	Interactive Methods (8)	"Online games and apps make practicing fun." (S13-Q1)
Dependency and Critical Thinking	Unintended consequences of over-reliance on technology.	Over-Reliance (21)	Dependence hindering independent	Reduced Critical Thinking (12)	"Students become too dependent on technology, always

Theme (Frequency)	Theme Description	Sub-Theme (Frequency)	Sub-Theme Description	Codes (Frequency)	Exemplar Quotations (Student- Question)
Erosion (26)			thinking.		relying on it." (S11-Q2)
				Skill Erosion (9)	"It can weaken my problem-solving skills." (S10-Q2)
		Distraction (5)	Technology diverting attention from deep learning.	Focus Loss (5)	"Sometimes technology can be distracting." (S13-Q2)
Equity and Access Barriers (6)	Systemic challenges in technology availability/reliability.	Inequity (6)	Disparities in access and technical limitations.	Access Disparities (3)	"Not everyone has access to technology, and that is a problem." (S11-Q1)
				Technical Issues (3)	"There are some misinformation in it." (S7-Q2)

Enhanced Learning Efficiency ( $n = 37$ ) emerged as the most frequent theme. Students commonly expressed that technology improved the speed, accessibility, and overall effectiveness of learning mathematics. The sub-theme of Accelerated Problem-Solving ( $n = 27$ ) was particularly dominant, with students appreciating the reduction in manual effort. For instance, one noted, "*Solving mathematical problems has become now so easy unlike the traditional one*" (S6-Q1), echoing research demonstrating how computational tools can streamline procedural tasks (Rittle-Johnson et al., 2015). Similarly, the Immediate Feedback sub-theme ( $n = 10$ ) highlighted technology's capacity to provide real-time error correction, reinforcing learning through instant responses—"*Technology provides immediate feedback, helping me correct mistakes quickly*" (S9-Q1). These responses affirm prior findings that emphasize the role of digital tools in scaffolding efficient and autonomous learning (Kay et al., 2017; Hattie & Timperley, 2007), particularly when feedback is timely and actionable (Shute, 2008).

The theme of Interactive and Engaging Learning ( $n = 18$ ) underscores how technology contributes to motivation and understanding through gamified and visual elements. The Visualization sub-theme ( $n = 10$ ) included references to tools like graphing calculators that aid in conceptual comprehension, as reflected in the quote, "*Graphing calculators... help me visualize equations*" (S2-Q1), supporting theories of embodied cognition (Abrahamson & Trninic, 2015). Gamification ( $n = 8$ ) was also evident, with one student stating, "*Online games and apps make practicing fun*" (S13-Q1). These insights support previous research showing that technology can enhance engagement and deepen understanding, especially when abstract concepts are made more tangible (Boaler, 2016; Papastergiou, 2009), and when game mechanics align with learning objectives (Plass et al., 2015).

Conversely, Dependency and Critical Thinking Erosion ( $n = 26$ ) captured students' concerns about over-reliance on technology. The sub-theme of Over-Reliance ( $n = 21$ ) included quotations suggesting that students may default to technological solutions without engaging in independent problem-solving—“*Students become too dependent on technology, always relying on it*” (S11-Q2), a phenomenon critiqued in studies of “cognitive offloading” (Risko & Gilbert, 2016). Similarly, Skill Erosion ( $n = 9$ ) and Reduced Critical Thinking ( $n = 12$ ) appeared in statements like, “*It can weaken my problem-solving skills*” (S10-Q2), resonating with warnings about the decline of manual computation skills (Pape & Tchoshanov, 2001). A smaller subset addressed Distraction ( $n = 5$ ), referring to the risk of diverted attention—“*Sometimes technology can be distracting*” (S13-Q2). These findings align with concerns in the literature about potential cognitive passivity resulting from excessive technology use (Heitin, 2016; Postman, 1992), particularly when tools are used uncritically (Carr, 2014).

Finally, the theme of Equity and Access Barriers ( $n = 6$ ) reflects broader systemic issues. Students cited limited access to devices and inconsistent digital infrastructure. The sub-theme of Inequity ( $n = 6$ ) was captured in remarks such as, “*Not everyone has access to technology, and that is a problem*” (S11-Q1), underscoring the persistent “second-level digital divide” in skills and usage (Van Deursen & Van Dijk, 2019). Technical Issues ( $n = 3$ ) included concerns over misinformation or functional limitations—“*There are some misinformation in it*” (S7-Q2), highlighting the need for digital literacy alongside access (Winegar & Abbott, 2022). These concerns emphasize the intersectional nature of the digital divide (Robinson et al., 2015) and its impact on learning equity (Van Dijk, 2020).

### **Integration of Findings in the Context of Technology-Integrated Problem-Based Learning (TIPBL) Strategy**

#### *Academic Grit*

Quantitative data revealed that students exhibit a high overall level of academic grit ( $M = 4.12$ ,  $SD = 0.60$ ), suggesting a strong general tendency to persevere and remain passionate about long-term academic goals. Particularly noteworthy were items reflecting persistence during difficulties (e.g., “*Even if I am struggling in school, I keep trying my best*” with  $M = 4.47$ ) and determination to complete schoolwork regardless of difficulty. These results suggest that students are highly committed to overcoming academic challenges, consistent with Duckworth et al.'s (2007) conceptualization of grit as sustained effort and interest over time.

However, some items received slightly lower (though still high) ratings, such as balancing schoolwork with personal interests ( $M = 3.82$ ) and maintaining motivation across prolonged challenges ( $M = 3.88$ ). These may represent potential areas for further support or intervention, especially in helping students sustain grit in contexts requiring long-term focus and task management.

To explain and expand on the quantitative results, qualitative data were gathered and analyzed, revealing three key themes: Resilience in Learning, Motivational Foundations, and Cognitive & Emotional Strategies. These themes provided nuanced insights into how grit manifests in students' day-to-day academic lives, particularly in mathematics.

The theme Resilience in Learning reflected students' determination and adaptability, often through persistence despite challenges and goal-directed behavior—mirroring the high scores in quantitative items on perseverance and hard work. One student illustrated this by stating, “I kept trying different methods, like breaking the problem into smaller parts,” reinforcing the behavioral aspects of grit observed in the survey.

The Motivational Foundations theme further clarified students' sources of persistence, revealing that both intrinsic (e.g., love for math) and extrinsic (e.g., family expectations) drivers sustain effort. This qualitative evidence complements the high self-ratings on items related to working toward goals, as it reveals the why behind the what—students' motivation is deeply personal, social, and culturally grounded.

Additionally, the theme Cognitive & Emotional Strategies uncovered how students regulate emotions and shift mindsets to maintain their effort, echoing items in the quantitative instrument related to perseverance during difficulties. Students emphasized growth mindset beliefs (e.g., “Struggling is part of learning”) and self-regulation tactics like rewarding themselves—both essential components for sustaining grit in mathematics learning, especially under the demands of rigorous coursework.

The findings collectively suggest that academic grit among BSEd-Math 1 students is not only high but also complex, multifaceted, and influenced by both personal and contextual factors. Students draw upon a mixture of determination, goal-setting, emotional regulation, and social reinforcement to persevere in mathematical learning. These insights align with Martin's (2013) model of academic resilience and Zimmerman's (2002) self-regulated learning theory, both of which view persistence as embedded in dynamic learning environments.

In the context of the Technology-Integrated Problem-Based Learning (TIPBL) intervention, the findings underscore the importance of designing learning environments that not only develop mathematical thinking but also nurture grit-related skills such as goal-setting, emotional regulation, and strategic help-seeking. The grit demonstrated by students suggests they are well-positioned to benefit from problem-based learning tasks that are complex and extended over time—especially when combined with supportive technologies that promote autonomy, feedback, and collaboration.

The relatively lower scores on balancing academics with personal life also suggest that TIPBL interventions should consider scaffolding time-management and self-regulation strategies, perhaps through features like digital planners, embedded reflections, or peer-support modules. These could help students maintain grit during long-term, open-ended problem-solving processes.

### *Mathematical Mindset*

The results from both the quantitative and qualitative strands of this study indicate that BSEd-Math 1 students hold a predominantly growth-oriented mathematical mindset, which played a crucial role in their engagement with the Technology-Integrated Problem-Based Learning (TIPBL) approach. The quantitative data show an overall high level of mathematical mindset ( $M = 4.17$ ,  $SD = 0.61$ ), with particularly strong agreement on items

related to effort, persistence, and belief in gradual improvement. These findings suggest that students are inclined to view mathematics as a domain where competence can be developed rather than fixed—a core tenet of Dweck's (2006) growth mindset theory.

The qualitative findings offered rich elaboration of these beliefs and illustrated how students enact and reflect on their mindsets in real learning situations. The most frequently cited theme, Problem-Solving Approaches, highlights the behavioral dimension of mindset—how students strategically approach challenges, seek support, and demonstrate persistence in mathematical problem-solving. For example, students reported "breaking problems down step-by-step" (S3-Q1) and using online tools or Excel (S13-Q1), behaviors aligned with Polya's (1945) heuristic model and modern conceptions of technologically supported problem-solving (Rittle-Johnson et al., 2015). This strategic behavior reinforces the idea that a growth mindset not only shapes beliefs but also guides effective learning behaviors.

The sub-theme of Collaborative Learning showed that students valued peer and instructor support—consistent with Vygotsky's (1978) sociocultural theory, which emphasizes the importance of social interactions in cognitive development. These interactions appeared to buffer against discouragement and reinforced students' commitment to learning, even when the mathematical content was challenging.

The second main theme, Mindset Toward Mathematics, provided insight into the emotional and cognitive orientations students held toward learning. Nearly all students expressed growth-oriented responses to mistakes, framing them as valuable learning tools rather than signs of failure. This finding directly supports quantitative results like the high agreement with the item, "Even though I've been told I'm not intelligent many times, I will keep asking questions until I finally understand mathematics" ( $M = 4.24$ ). Students shared quotes like, "Mistakes are an opportunity to grow" (S1-Q2), demonstrating the productive failure mindset described by Kapur (2008) and the resilience highlighted by Yeager and Dweck (2012).

Additionally, the sub-theme Emotional Trajectories revealed how students' affect shifted from frustration to motivation—indicating that the TIPBL environment may have served as a catalyst for transformative emotional experiences. For instance, one student noted, "Discouraged at first, then motivated" (S8-Q2), reflecting how persistence and a supportive learning structure can enhance emotional resilience (Pekrun, 2006).

The third major theme, Metacognitive Reflections, added a reflective layer to students' mindsets. Sub-themes like Learned Insights and Behavioral Adjustments highlighted students' awareness of their own learning processes and their capacity to change ineffective strategies—an important marker of self-regulated learning (Zimmerman, 2002). For example, students mentioned "relearning from the start" (S1-Q1) and "checking steps to correct mistakes" (S2-Q2), showing not only a growth mindset but also metacognitive control and intentional learning regulation (Winne & Hadwin, 1998; Veenman et al., 2006).

These integrated findings suggest that the TIPBL approach not only fostered cognitive engagement but also created opportunities for students to develop more resilient, reflective, and socially supported mathematical

mindsets. The slight variation in quantitative responses—such as lower agreement on resisting peer discouragement ( $M = 3.59$ )—was illuminated by qualitative data emphasizing the importance of peer support and social influence in shaping mindset beliefs. This underscores the value of explanatory sequential mixed-methods in capturing the nuanced interplay between belief, behavior, and context.

### *Perception of Technology in Teaching and Learning*

The study also provides a comprehensive understanding of BSEd-Mathematics 1 students' perceptions of technology in teaching and learning, as influenced by the Technology-Integrated Problem-Based Learning (TIPBL) strategy. The quantitative results revealed an overall positive perception ( $M = 4.05$ ,  $SD = 0.52$ ), with the highest ratings attributed to technology's role in enhancing learning experiences, increasing access to resources, and preparing students for future careers. These findings were further explained and enriched by the qualitative phase, consistent with the modified explanatory sequential mixed-methods approach (Creswell & Plano Clark, 2018).

The theme of Enhanced Learning Efficiency, which emerged as the most prominent in the qualitative phase ( $n = 37$ ), provides insight into why students rated items related to resource availability and learning enhancement so highly. The highest-rated item in the survey—"Technology provides access to additional learning resources that improve my understanding" ( $M = 4.47$ )—is consistent with qualitative reports of improved speed, accessibility, and effectiveness. Sub-themes such as Accelerated Problem-Solving and Immediate Feedback reflect students' appreciation of digital tools that streamline complex computations and offer real-time correction, thereby reinforcing autonomous learning. These findings are consistent with the literature on digital scaffolding and feedback systems (Hattie & Timperley, 2007; Shute, 2008). Furthermore, students reported that technology facilitated individualized learning at their own pace ( $M = 4.06$ ), and improved conceptual understanding, aligning with prior studies on personalized learning through educational technology (Kay et al., 2017).

Quantitative results also showed strong agreement with statements such as "Technology makes lessons more engaging and interactive" ( $M = 4.06$ ). This is supported by the qualitative theme Interactive and Engaging Learning, which highlighted the use of visual tools and gamified applications. Sub-themes of Visualization and Gamification illustrated how technology transformed abstract mathematical concepts into more tangible and motivating experiences. For instance, students cited the usefulness of graphing calculators and educational games in enhancing their learning engagement. These findings align with theories of embodied cognition (Abrahamson & Trninic, 2015) and research showing increased motivation and retention through game-based learning (Papastergiou, 2009; Plass et al., 2015).

The alignment between the quantitative and qualitative phases affirms that the TIPBL strategy effectively fosters active and engaging learning environments—one of the core goals of technology integration in modern pedagogical frameworks (Boaler, 2016; Trilling & Fadel, 2009). While the quantitative results were generally positive, the qualitative theme Dependency and Critical Thinking Erosion offers a cautionary perspective. Students expressed concerns about over-reliance on technology, reporting reduced problem-solving and critical

thinking skills. Although confidence in using technology ( $M = 3.94$ ) and its effect on knowledge retention ( $M = 3.71$ ) were rated positively, the qualitative data reveal nuanced reservations. Statements such as “Students become too dependent on technology” and “It can weaken my problem-solving skills” point to the phenomenon of cognitive offloading, where learners defer too readily to technological tools (Risko & Gilbert, 2016).

These insights emphasize the importance of integrating technology in ways that still encourage independent reasoning and critical engagement—essential goals of the TIPBL framework. Without mindful use, technology may inadvertently hinder the development of deeper cognitive skills (Carr, 2014; Postman, 1992).

Although the item “I find it easy to use technology in classroom activities” ( $M = 4.12$ ) was positively rated, the qualitative theme Equity and Access Barriers revealed underlying disparities. Some students reported lacking access to reliable devices or internet connections, highlighting issues of digital inequality. The sub-themes Inequity and Technical Issues support the notion of a “second-level digital divide,” where students have unequal opportunities not only in access but also in meaningful usage of technology (Van Deursen & Van Dijk, 2019; Warschauer, 2004). These findings underscore the necessity of equitable implementation strategies, particularly in diverse learning contexts.

The divergence between quantitative and qualitative data in this theme exemplifies the value of explanatory sequential design, as the follow-up qualitative phase uncovered systemic issues masked by averaged numerical results. Aligned with the action research framework, the integrated findings provide actionable insights for improving the TIPBL strategy. First, technology-enhanced tools that promote individualized and engaging learning should be sustained and refined. Second, instructional practices should aim to balance technological support with opportunities for developing critical thinking. Finally, issues of access and equity must be addressed to ensure inclusive implementation of technology-integrated strategies.

## Conclusions

This study aimed to investigate the influence of Technology-Integrated Problem-Based Learning (TIPBL) on the engagement, academic grit, mathematical mindset, and perception of technology in teaching and learning among first-year BSEd-Mathematics students at Biliran Province State University. The findings demonstrate that students exhibited high levels of academic grit, characterized by perseverance and resilience, even in the face of academic challenges. Furthermore, students maintained a growth-oriented mathematical mindset, showing a strong belief in their ability to improve their mathematical competence through effort and persistence. The study also revealed that students held a generally positive perception of technology’s role in enhancing their learning experiences, although concerns about technology dependency and digital inequities emerged.

In line with these findings, TIPBL proved to be an effective strategy for developing engagement, supporting their academic resilience and development of critical thinking skills. The integration of technology in the learning process provided students with the tools to engage more deeply with mathematical content, while also enhancing their problem-solving abilities and access to learning resources. In addition to academic grit and mathematical

mindset, the study highlighted the students' positive perceptions of technology in teaching and learning, emphasizing how TIPBL effectively integrated technological tools to support learning and problem-solving.

The high levels of academic grit observed suggest that students are well-equipped to navigate the challenges of TIPBL environments, leveraging both intrinsic and extrinsic motivation. Similarly, students' growth-oriented mindset in mathematics played a significant role in their engagement with the TIPBL strategy, developing persistence and strategic problem-solving behaviors. However, despite positive perceptions of technology's role in enhancing learning experiences, concerns regarding over-reliance on technology and unequal access to resources point to areas that require further attention to ensure the equitable and effective implementation of TIPBL.

## Recommendations

Based on the findings of this study, several recommendations can be made to enhance the effectiveness of the Technology-Integrated Problem-Based Learning (TIPBL) strategy. These recommendations aim to build upon the strengths observed in students' academic grit, mathematical mindset, and perceptions of technology, while addressing areas that could benefit from further improvement:

1. *Enhance Technology Integration for Critical Thinking:* Although the technology proved beneficial in the TIPBL strategy, it's important to take it a step further by using digital tools that develop critical thinking and problem-solving skills. Instead of relying on technology for quick answers, educators can design tasks that encourage students to use technology in ways that promote deeper understanding and independent reasoning. For instance, digital tools can be used to guide students through problem-solving steps, while leaving room for them to make decisions and think through solutions on their own.
2. *Support Time Management and Self-Regulation:* Many students faced difficulties in balancing academic work with their personal lives. To help students maintain their focus and perseverance, TIPBL interventions should incorporate strategies for better time management and self-regulation.
3. *Address Digital Inequities:* The study revealed that some students struggled with access to reliable technology and the internet, which could limit their participation in TIPBL. To create a truly inclusive environment, it's essential that institutions provide students with access to the resources they need. This could include lending programs for devices or offering hybrid learning models where not all content relies on digital tools, ensuring that every student can fully engage in the learning process.
4. *Develop Collaborative Learning and Peer Support:* The study highlighted the importance of peer and instructor support in helping students develop a growth-oriented mindset toward mathematics. Moving forward, TIPBL should continue to provide opportunities for collaborative learning, where students can work together, share strategies, and encourage each other.
5. *Further Research on the Long-Term Impact of TIPBL:* Although this study showed promising results, further research is needed to explore the long-term effects of TIPBL on students' academic grit, mindset, and technology perceptions. Longitudinal studies can offer deeper insights into how these factors evolve as students' progress in their academic journeys. This could inform the refinement of TIPBL strategies to better support students as they advance through their educational careers.

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