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Exploring Resilience Mechanisms in High School Mathematics: A Study on Problem-Solving Challenges and Self-Regulation

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Abstract

This study explored how students develop and demonstrate resilience when prompted with mathematical problems. Anchored on the Three-Dimensional Resilience Theory in Mathematical Problem Solving, a multiple case study was conducted on thirteen (13) purposively selected students from a public senior high school in Davao City, Philippines. The cross-case analysis revealed three emerging themes on their mechanisms in dealing with mathematics problems: (1) mathematics resilience and problem-solving independence; (2) learner regulation of "negative emotions" towards Math problems; and (3) self-regulation and matching of learner behavior of learning challenge. The findings show that although all learners encounter learning difficulties, high resilience enables them to push through the difficulty until they overcome their struggle, creating meaningful learning experiences that boost their self-esteem and confidence in the long run. Learners with lower levels of math resilience were found to feel trapped in their struggle and resolute at the prospect of failure implying disempowerment. The findings also underscore the need to foster mathematics resilience among learners to empower them to actively deal with and overcome learning challenges.

Introduction

Mathematics is a cornerstone of education, serving as a fundamental aspect of success in academic and professional pursuits. Mastery of mathematical problem-solving equips students with the cognitive tools necessary for navigating the complex challenges of everyday work and life (Szabo, et al., 2020; Olivares, Lupiáñez, & Segovia, 2021). Understanding and solving math problems is important for developing thinking skills, making it a hallmark of 21st Century Learning. However, despite its undeniable importance, many students encounter challenges in navigating the demands of mathematical problem-solving. These challenges can affect their overall confidence as learners and hinder their overall progress.

Students encounter challenges in mathematics when they need to convert information from one viewpoint to another and handle scientific, logical, philosophical, and social types of content. Even students with average math skills have been reported to encounter challenges understanding problems and struggle with generating detailed,

organized, and systematic solutions. Likewise, students with lower math skills face difficulties understanding problems and rely on trial-and-error methods to devise solutions. They also struggle with employing clear rules and strategies when solving problems (Puspitasari, In'am, & Syaifuddin, 2019). As they progress in their education and into their adulthood, the ability to independently assess and solve problems becomes increasingly vital. This makes "teaching students to think", helping inactive students' progress, decreasing reliance on teachers, and fostering independent students capable of managing the intricacies of decision-making and problem-solving has become a priority for educators all over the world (Rashidov, 2020).

Efforts to ensure mastery of mathematical skills are seen in initiatives of education agencies and national governments as well as global and independent studies. The Programme for International Student Assessment (PISA), worldwide research conducted by the Organization for Economic Co-operation and Development (OECD) every three years offers to evaluate the reading, mathematics, and science skills of 15-year-old students. It offers an understanding of how students from various nations tackle and resolve math problems through an examination to evaluate trends for a range of age cohorts within the involved educational systems (Demir, Kılıç, & Ünal, 2010). At local and national levels, standardized testing serves to measure the achievement of mathematical learning outcomes and has become a basis for school ranking and barometers of success for government initiatives. Increased government funding towards STEM education is also indicative of broad efforts to improve achievement in this area and belies the value placed on skills in mathematics.

Independent research highlights the value of employing diverse problem-solving strategies and scientific approaches in teaching mathematics purposely for the development of higher-order thinking skills (HOTS) (Siagian, Saragih, & Sinaga, 2019). Comparative studies reveal that problem-solving strategies may surpass scientific approaches in enhancing students' communication, creativity, and mathematical reasoning abilities (Tambunan, 2019). Problem-based learning has been shown to improve students' mathematical reasoning and problem-solving ability, with structured phases such as Orientation, Organizing, Mentoring, Developing, and Analysis (Mustafa & Sari, 2019). Similarly, incorporating local cultural elements into math instruction has been reported to enhance learning outcomes (Simamora, Saragih, & Hasratuddin, 2019). Approaches that involve profiling students based on their thinking attributes, forming diverse groups, and engaging them in group learning tasks where they collaboratively solve problems have been found to lead to improved student performance (Insorio and Librada, 2021). These studies show that there are many approaches to investigating mathematical problem-solving in students and varied ways that mastery can be achieved in the classroom to benefit students.

Despite the extant work on the topic, there is also a vast body of research that focuses on continuing challenges experienced by students specifically in learning math and problem-solving. This means that although targeted teaching approaches are employed in classrooms all over the world, and complemented by interventions whenever necessary, students continue to face struggles in achieving mastery, resulting in long-term underperformance in mathematics (Nelson & Powell, 2018). Studies that address the continued problems in mathematics learning point out that experiences of mathematics learning vary among learners and that the variance in experiences depends on a complex interplay of cognitive, psychological, and social factors (Nabilah, Syamsuri & Pujiastuti, 2024; Mata, Monteiro & Peixoto, 2012). While struggling as part of the experience is a commonality among students'

experiences, the difference lies particularly in behaviors and characteristics manifested to overcome struggle (Okoro, 2018; Cabanalan, et al, 2020). Students who can find ways of coping are able to handle setbacks and frustration (Neumann, Jeschke & Heinze, 2021), mitigate academic stress and anxiety (Ragusa et al., 2023; Trigueros et al., 2020; Zanthy, Kusuma, & Soemarmo, 2019), and ultimately turn their negative experiences into positive ones and overcome their struggles (Wiguna, Candiasa, & Arnyana, 2024).

This study is primarily anchored on the Three-dimensional Resilience Theory in Mathematical Problem-solving. This theory states that students' resilience in solving problems in mathematics depends on the interplay of cognitive, psychological, and social factors (see Figure 1). This means that when students face difficult mathematics problems, they need these three aspects working together to navigate and overcome difficulties and succeed in solving math problems. The ability to think critically, solve issues, and maintain composure under pressure are all supported by critical thinking and problem-solving skills. Two essential psychological characteristics are a growth mindset and a lifetime love of learning. The last group of social factors that support resilience include supportive parents and peers, competent educators, and secure learning settings.

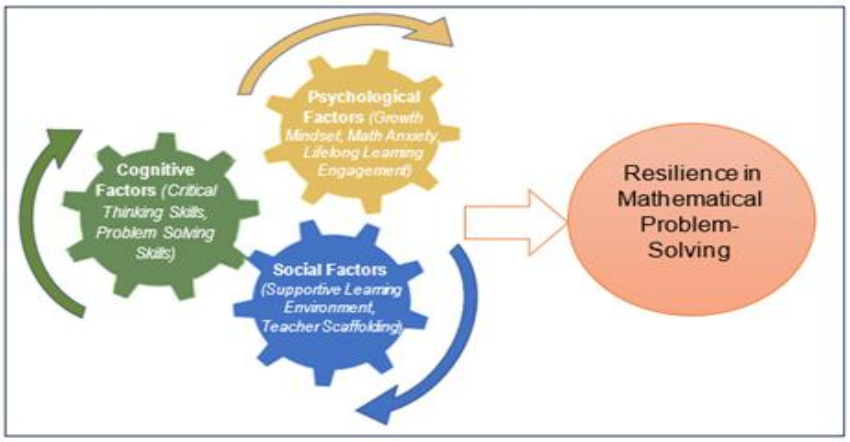

Figure 1. Framework of the Study

However, when any of these factors—cognitive, psychological, or social—are compromised, it can lead to increased levels of math anxiety. Recent research suggests that math anxiety is not a one-dimensional concept but rather a multifaceted issue, encompassing emotionality, such as fear and negative physical reactions, and concern, which includes negative expectations and self-deprecating thoughts. This anxiety can significantly hinder students' engagement with and overcoming mathematical challenges. By understanding and addressing these interconnected factors, teachers and parents can create an environment that mitigates anxiety and fosters mathematical resilience, enabling students to develop a confident, resilient approach to learning and problem-solving in mathematics.

This research explores the mechanisms that underlie students' varying approaches and experiences in dealing with mathematical problems, seeking a better comprehension of the elements that impact their success or difficulties in this domain.

Method

Research Design

This study used the case study design which is most appropriate for achieving the study objectives. Case studies are recommended for investigations that seek to answer how and why questions, especially when the research aims to include relevant contextual factors (Yin, 2014). This approach is ideal in situations where the researcher has little control over the actions of the participants. Case study research involves an in-depth examination of a single unit, providing insights into a larger group of similar units within a specific timeframe. As a qualitative method, it allows for a comprehensive understanding of an individual, institution, or educational context, offering a detailed analysis of specific learning or teaching processes.

In this study, we used the multiple case study design, replicating procedures in three distinct cases. This approach follows the logic of replication for each case, to compare the outcomes and to also investigate variations within and between students with low, average, and high math resilience levels. By doing this, we were able to collect rich data that not only captures the experiences of high school seniors but also examines their varied responses to difficult math problems. This design was well-suited for capturing the nuances of how different levels of math resilience influence students' problem-solving approaches.

Participants

Thirteen students from public Senior High Schools (SHS) in the Division of Davao City participated in this study. These students were enrolled in the second semester of the 2023-2024 school year and were non-STEM students. A purposive sampling design was employed to select participants for this study. As outlined by Campbell et al. (2006), purposive or judgment sampling is used when the researcher identifies specific criteria for participant selection and seeks individuals who are particularly knowledgeable or experienced in interest. In this case, the thirteen students were purposely chosen based on their categorized levels of mathematical resilience, which was determined through an assessment of their problem-solving capabilities.

The selection aimed to provide both focus and variation within the sample, ensuring a range of mathematical resilience levels. Students who did not complete the assessment for mathematical resilience were excluded from the study. Specifically, five students were categorized under Case 1 (low resilience), with math resilience means ranging from 1.00 to 2.39; four students were categorized under Case 2 (average resilience), with means between 2.40 and 3.19; and four students were categorized under Case 3 (high resilience), with means ranging from 3.20 to 4.00.

Research Instrument

To better understand student mechanisms in dealing with math problems, we used a set of semi-structured interview guides developed specifically for this study. The interview guides underwent expert validation and revisions to appropriately capture the experiences of our participants. The intake interview form has three sections

that include a transmittal letter, semi-structured interview guide questions, and closing statements.

For case selection, we adapted Johnston- WIlder and Lee's (2010) Mathematics Resilience Scale. We asked five research experts to conduct a content validation review of the adapted research scale. After which, the pilot testing was done to establish its reliability for use in data collection. During the interview, we followed the interview guide designed for the study but also pursued significant sharing of the participants with follow-up questions when necessary.

Data Collection

We carried out data collection with the primary aim of securing valid data for analysis while protecting participant rights. Our protocol included exhaustive documentation and fail-safes. This included recordings with multiple devices both audio and video, and having backup files of the data. We worked primarily with copies of our original files so we had an original, untouched file we could access if necessary.

Each interview was scheduled for an hour. We gave our participants a full briefing before each interview and secured their consent to be recorded. During the interview code names were utilized with participant welfare checks being done at twenty-minute time intervals before proceeding. Participants were engaged in a casual conversation style to make them comfortable during the interview. After each interview files were checked and saved before proceeding to the next. After all the interviews we began the task of transcribing the recordings. We did verbatim transcriptions even if some responses were mixed English, Tagalog, and Binisaya. Once transcription was completed, we translated the responses to English using the forward-backward method for the accuracy of translations. We also did a final check of the data for analysis, ensuring that no identifying information remained on the data and that all our files were in order.

Data Analysis

We analyzed transcriptions from thirteen (13) interviews conducted with Senior High School Students enrolled in a public high school using the cross-case analysis method. Five of the participants were students with low Math Resilience Levels, four with average levels, and four with high levels of Math resilience. Initially, we independently reviewed the transcripts to familiarize ourselves with the responses. In subsequent rounds of reading, we focused on the specific objectives of the study, annotating the transcriptions to capture the essence of each response and identifying key phrases. We paid particular attention to the significant experiences of each participant, noting how they navigated challenges and how these experiences unfolded. This process allowed us to develop an individual profile for each participant's experience.

Having established individual profiles, we then grouped the data according to Math Resilience Level. This time we examined commonalities and differences between participants with the same level of Math Resilience and to see if there were any outlier cases in the data. This allowed us to get a composite experience of students belonging to low, average, and high levels of math resilience. When examining the individual experiences of students with

similar levels of math resilience, we did not have any predetermined classifications of keywords or themes. Instead, we grouped related responses and from there determined how to label them. We did this to allow the data to offer its own emerging patterns, themes, and concepts as individual cases. The same process was followed for other grouped transcripts until all of them had been properly exhausted of individual themes, and categories and grouping of similar codes into broader themes had been completed.

We then proceeded to compare data between and among groups of varying levels of Math Resilience, with attention being paid to extracting how the themes emerging from common participant experiences played to cognitive, social, and psychological factors laid out in the broad framework of the Three-Dimensional Resilience Theory in Mathematical Problem Solving. Outlier experiences were also considered aside from consistent patterns in the data and used to consider alternative interpretations.

Ethics Statement

This study underwent ethical review and clearance from Cebu Normal University with CNU ERC Code - 896/2024-02. Participant rights were given primary consideration through briefings, and welfare checks. We provided informed consent forms which detailed relevant information of the study which they were asked to sign and affix the date once they agreed to participate in the study. We maintained privacy and confidentiality by removing all identifying information from the data sets and replacing them with participant codes. Files of all communications, data sets, and documents relating to this study were stored electronically with file restrictions limited only to the researchers. Participants were furnished with copies of the completed data analysis to ensure fidelity of our interpretations of their responses.

Results

Overcoming challenges in math is a crucial aspect of academic success. This cross-case analysis explores the mechanisms utilized by students with low, average, and high math resilience to deal with math problems. Table 1 is the cross-case matrix which presents the participants' rephrased responses on their experiences in dealing with mathematical problems showing how students individually employ various mechanisms to tackle challenges. When grouped according to math resilience levels, we gain a picture of commonalities and differences in experience among students from low, average, and high math resilience shown in Table 2.

Table 1. Cross Case Matrix

P	Level of Math Resilience	Experiences in Solving Math Problems	Response to the Experience
8	Low	● Underwent academic difficulty. ● Faced lack of confidence ● Was confronted with retention problems	● Attempted to solve the problem. ● Employed a "read and re-read" strategy. ● Sought the help of others.
12	Low	● Lost focus easily ● Underwent academic difficulty	● Asked classmates for sample solutions to the problem, and followed the examples

P	Level of Math Resilience	Experiences in Solving Math Problems	Response to the Experience
		• Faced Low confidence	• Sought assistance from classmates and an older sibling
14	Low	• Underwent academic difficulty • Was exposed to the problem-solving approach	• Focused on listening to teachers' lectures • Sought help from classmates and teachers
13	Low	• Found difficulty in understanding the concept • Felt anxious when solving	• Sought slow and patient teaching which helped comprehension • Sought help from classmates and teacher • Watched video tutorials on YouTube
2	Low	• Experienced extreme difficulty in evaluating the formulas • Found dealing with signed numbers ambiguous • Did not feel confident in answers	• Asked questions, clarifications from the teacher • Searched YouTube on how to solve the problem • Employed a “read and re-read” strategy;
7	Average	• Belief in the inherent difficulty of Math; Could not grasp the concept • Felt low self-confidence; felt many negative emotions • Constantly struggled to maintain focus during discussions; Needed a slower pace of learning	• Did self-motivation to boost self-confidence • Paid attention during class and practiced solving questions • Requested teacher to slow down the pace to understand better
5	Average	• Was overwhelmed, perceived cognitive overload • Felt crippled by fear of failure	• Asked classmates • Did research (when no one was around to ask) • Took down notes
3	Average	• Felt lost due to lack of foundation in mathematics • Constantly struggled to focus during discussions. • Felt hesitation to ask for help	• Ensured understanding before solving • Depended largely on own understanding (Self-reliance)
11	Average	• Acknowledged lack of foundation in mathematics hampered understanding • Had difficulty in following discussions. • Burdened by Negative emotions • Attempted to connect new information to existing knowledge	• Sought help from close friends and classmates • Kept trying until correctly getting the answer (persistence)
1	High	• Experienced confidence and enjoyment • Had a strong foundation in mathematics • Thought that the experience would help them become better	• Proactively approached independent learning • Sought clarification; analyzed and tried to comprehend the problem • Focused on the problem, not the answer. • Tried thinking outside the box

P	Level of Math Resilience	Experiences in Solving Math Problems	Response to the Experience
6	High	● Felt deep self-doubt and less capable compared to others ● Had a strong foundation in mathematics; Experienced Confidence and enjoyment	● Sought external resources, Self-compassion ● Thought critically; exercise the problem, study, and repeat it over and over
10	High	● Felt confusion and not being able to automatically solve the problem ● Experienced some self-doubt and compared their abilities to others	● Studied all night, trying to remember each step; ● Value of teacher assistance ● Incorporate collaboration with peers (valued Importance of collaboration)
4	High	● Had self-doubt ● Felt comforted when given a problem within his understanding	● Identifying key information ● Analysis and comprehension ● Pushed to find answers (Growth mindset)

Table 2. Emerging Themes from Cross-Case Analysis

Themes		
Low	**Average**	**High**
Theme 1: Mathematics Resilience and Problem-Solving Independence		
● Predominantly seek outside help or assistance primarily from teachers and peers ● Dependent on the assistance of others	● Seek help from others but are not dependent on it ● Exhibit more willingness to find other sources of help such as the internet ● Manifest more effort in working and reworking the problem	● Seek help from others ● Exhibit a wide array of strategies to cope with their difficulty ● Manifest desire to work through the problem on their own terms through self-direction
Theme 2: Learner regulation of "negative emotions" towards Math problems		
● Exhibit deeply rooted, unresolved negative emotions associated with Math that leave them feeling stuck or resigned to the "difficulty" of Mathematics and their ability to do Math	● Have negative emotions associated with Math but can regulate these emotions to some extent but willing to work through these emotions to overcome the challenge but still tend to be burdened by their lack of confidence	● Have negative emotions of Math but do not let such emotions get in the way of working through the challenge ● They even seem to positively channel their negative emotions into motivation to find ways to succeed ● Do not focus on the negative emotions but actively (and independently) seek to remedy these emotions
Theme 3: Self-regulation and matching learner behavior to learning challenge		
● Attempt to solve the problem ● Use mimicking to solve	● Exhibit more efforts towards deeper understanding in class (asking questions, requesting a	● Exhibit the most proactive behaviors (help-seeking, collaboration with others, seeking clarification,

Themes		
Low	**Average**	**High**
problems instead of attempting true understanding ● Dependent on teachers and peers ● Limited to their notes and resources contrived from their immediate learning environment	slower pace to allow more time to digest teacher input) ● Show some self-reliance in working out the challenges by adding resources from sources other than their immediate learning environment	expanding on available resources) in an attempt at competence ● Strategize their learning (putting in the study time they need commensurate to the difficulty such as practice and repetition, mindful of making a note of what they need to remember and to pay attention to in the problem)

Discussion

From the cross-case matrix, three themes emerged from the study. The mechanisms in dealing with mathematics problems include (1) mathematics resilience and problem-solving independence; (2) learner regulation of "negative emotions" towards Math problems; and (3) self-regulation and matching of learner behavior to learning challenges. By examining themes, we can identify how students with different levels of resilience approach and overcome difficulties in math. This analysis aims to shed light on these diverse mechanisms and how they contribute to successful problem-solving in mathematics

Theme 1: Mathematics Resilience and Problem-Solving Independence

This theme emerges from variations in students' approaches to challenging math problems that differ based on their levels of math resilience. Students with high resilience levels demonstrate a tendency to persist in solving problems independently, rather than seeking external assistance. Moreover, they navigate challenges with ingenuity, utilizing a wide array of strategies to cope with difficulties. One participant's statement, "*Need to understand the problem first and try to solve it by believing in yourself"* (P3), exemplifies this independence. However, the freedom to learn independently does not imply a lack of structure or guidance. Instead, it suggests that learning is customized to the learner's interests and talents.

In sharp contrast, students with low math resilience rely heavily on help from others, implying a sense of incapacity. Their responses often reveal deep-seated fears that can be crippling, leaving them unwilling to work on the problem without external support. When students overly depend on external help, they may miss opportunities to develop essential problem-solving skills. This suggests that students with low math resilience could be hindered in their development of self-reliance if they are excessively helped by others. Educators can foster more resilient, independent learners who are better equipped to tackle challenging math problems by motivating students instead of assisting them at the first signs that the students are having difficulty. The findings indicate that the "help" that students with low resilience require should be focused on guiding them to navigate challenges, alleviating their doubts and fears of failure, and empowering them to work through problems

independently. This approach enables students to gain a sense of achievement from overcoming challenges on their own.

Students with average math resilience seem to fall somewhere in the middle of these two extremes. They seek help when needed but do not use it as a crutch in their learning. Marsh et al. (2019) argue that students' motivation is significantly influenced by their sense of autonomy and competence, which resonates with how students with average resilience approach problem-solving. These students often consult additional resources to work through challenges, balancing their need for help with a degree of independence. Sethi and Scales (2020) emphasize the role of developmental interactions in achieving positive academic outcomes, as reflected in the statement, "*I'm going to ask someone how they understand the problem. Asking questions to people who can help them like professionals"* (P2). This suggests that while students with average resilience rely on help, they do so in a way that promotes learning rather than dependency.

Zanthy, Kusuma, and Soemarmo (2019) highlight that students who are aware of their strengths are better equipped to handle challenges without feeling overwhelmed. Those with high resilience manage their stress and navigate difficulties with confidence, further enhancing their problem-solving independence. Teachers and parents can play a crucial role in supporting students to build confidence and gradually reduce their dependence on others. By fostering a supportive learning environment that praises initiative and encourages problem-solving independence, students can be empowered to approach challenges with greater confidence and autonomy.

Theme 2: Learner regulation of "negative emotions" towards Math problems

This theme underscores the diverse strategies employed by learners in regulating negative emotions towards math problems, based on their levels of mathematical resilience. Learners with higher resilience demonstrate a remarkable ability to manage their negative emotions, channeling them into constructive actions such as intensifying focus, experimenting with various approaches, and innovating their strategies to solve problems. These students do not merely withstand challenges; they actively engage with them, viewing difficult problems as opportunities to grow. They seem to thrive under pressure, often deriving satisfaction from mastering challenges, embodying the notion of being "challenged by the challenge." This mindset is to use the difficulty as an opportunity for growth and success, showing their ability to persevere and remain self-reliant despite difficulties.

In sharp contrast, learners with lower resilience often appear resigned and defeated by their learning challenges, which significantly impedes their progress. These students struggle to regulate their negative emotions, which can become overwhelming and lead to a sense of futility. Their statements frequently belie a sense of disempowerment, as they express feeling stuck and overwhelmed by the difficulty of math problems. This mindset is reflected in comments such as, "*I am not confident, I am struggling"* (P8) and *"I lose focus easily and I don't feel comfortable with my answers"* (P12). These expressions of reluctance and discomfort stem from a belief that their efforts will ultimately be in vain, leading them to avoid fully engaging with the problem. This resignation to the difficulty exemplifies how a lack of resilience prevents students from seeing challenges as surmountable and

makes them overly reliant on external help.

The presence or absence of mathematical resilience differentiates students' responses to negative emotions. While all students experience negative emotions when faced with challenges, those with high resilience do not let these emotions get in the way of their determination to solve problems independently. They view challenges as surmountable and see their efforts as meaningful. In contrast, students with low resilience are often defeated by the challenge before they even begin, leading them to seek help from others. This reliance on external assistance further entrenches their sense of disempowerment, reinforcing the belief that they cannot overcome challenges on their own. As a result, their dependence on others becomes a barrier to developing the self-confidence and problem-solving skills that are crucial for academic success.

This sense of futility is further compounded by feelings of shame and confusion, as noted by Nelson and Powell (2018), who found that many students continue to struggle with mathematics even without a diagnosed learning disability. Despite their efforts to pay attention and collaborate with peers, these students often find themselves unable to grasp the necessary concepts, leading to further erosion of their confidence. Ramirez et al. (2018) and Piccirilli et al. (2023) support this by highlighting how emotional distress, including low self-efficacy and math anxiety, can severely impact students' ability to engage with mathematical content. For example, one student expressed, *"In general, math is really a difficult subject"* (P7), while another noted the complexity of topics like trigonometry and algebra, admitting, *"I am not good at that"* (P7). This resignation to difficulty exemplifies how deeply entrenched negative emotions can prevent students from even attempting to engage with the material, perceiving any effort as futile.

In sharp contrast, students with high resilience are not only able to confront these negative emotions but also use them as fuel for persistence and problem-solving. These students exhibit a disciplined approach to learning, actively seeking out new methods to overcome obstacles and refusing to be deterred by setbacks. Kuncoro and Juandi (2023) suggest that this disciplined, autonomous approach is crucial for developing resilience, as it enables students to tackle challenges head-on, explore alternative strategies, and fully commit to their tasks. Unlike their low-resilience peers, these students do not view challenges as insurmountable barriers but as opportunities to demonstrate and enhance their competence and self-reliance. By transforming adversity into a source of motivation, they cultivate a mindset that views effort as a pathway to mastery rather than a futile endeavor.

For students with low resilience, again the help they need should address their underlying issues of being defeated by these negative emotions; it involves helping them see past the emotional discomfort and the feeling of the challenge being too difficult, nurturing their self-belief and empowering them to view challenges as surmountable. This support is crucial in helping them shift from a mindset of futility to one of possibility, enabling them to gradually reduce their reliance on others and develop the confidence to tackle problems independently. Zanthy, Kusuma, and Soemarmo (2019) emphasize that students who are aware of their strengths and do not rely excessively on others are better equipped to handle challenges without feeling overwhelmed, thus fostering resilience and independence.

By fostering such qualities in all students, educators can create a supportive learning environment that encourages problem-solving independence, reduces math anxiety, and ultimately empowers students to approach challenges with greater confidence and autonomy. Building mathematical resilience, therefore, is not just about teaching math skills but also about equipping students with the emotional and cognitive tools they need to persist in the face of difficulties, transforming their learning experience from one of fear and avoidance to one of engagement and growth.

Theme 3: Self-regulation and matching of learner behavior to learning challenges

This theme underscores the nuanced variations in self-regulation and behavioral alignment among learners, influenced by their levels of resilience. Learners with higher resilience demonstrate a keen awareness of the difficulty levels they face, exerting effort proportionate to the perceived challenge. They possess a discerning understanding of the essential elements required to surmount learning obstacles and conscientiously incorporate or enhance these elements in their approach. While all learners exhibit diligence in their studies, those with higher resilience showcase a propensity for strategic studying, optimizing their efforts for effectiveness rather than sheer intensity. This theme illuminates how resilience fosters adaptive self-regulation, enabling learners to navigate challenges with efficiency and efficacy in the pursuit of academic success.

Self-directed learning, characterized by individuals taking charge of their learning process, has gained prominence as a key approach to education. One self-directed learning strategy is repetition, which helps the new information be committed to memory and results in long-term retention (Agarwal & Bain, 2019). Participants shared that this was one way by which they coped with challenging math problems. Learners shared that they would work and rework the problem while noticing changes after each repetition to gauge their own progress. One participant shared *"I read it again and again if I didn't understand"* (P8) and *"I read the problem again then I would teach it to others so that I could learn"* (P8) while another said, "I will read it again and again until such time that I can answer" (P2). Another significant statement was "*(I would) draft my answers many times before coming up with a final answer"* (P2). These give insight to the ways in which repetition is employed to overcome learning difficulties. Davidson and Scripp (2021) propose that cognitive growth should be considered in the context and circumstances in which it occurs, rather than as an abstract, decontextualized construct, and that cognition happens inside a particular scenario. In this case, success in problem solving can be attained if students are willing to engage in multiple attempts so succeed and learning from each attempt. This echoes findings from other studies where mathematical understanding is significantly enhanced by repetition (Asfar & Asfar, 2019) and has been demonstrated to benefit students compared to traditional lecturing (Domingo et al., 2019).

It's worth noting that there are students with a natural aptitude and comfort level with mathematics. These students often grasp concepts quickly, enjoy the problem-solving process, and may even find it stimulating or like a game. Regardless of the specific area of strength, these students typically demonstrate a higher level of confidence when approaching mathematical problems. This comfort level can contribute to a more positive learning experience, allowing them to delve deeper into the subject and explore more complex concepts with greater ease. This concept was brought up by one of the participants during the interview saying, *"I'm good at math so I would try harder*

on learning how to do math and then I think that for myself. It's not really hard in a way." (P6).

Several students also view challenges as opportunities to grow rather than roadblocks. They understand that developing mathematical skills takes time and effort, and they are willing to persist through difficulties. This perseverance involves strategies like breaking down complex problems into smaller steps, seeking help from teachers or peers when needed, and learning from mistakes. The same concept was articulated during the interview. The participants mentioned, *"I need to push myself to learn more about it."* (P4); *"I'm good at math so I would try harder on learning how to do math and then I think that for myself." (P6); "The more I struggle, the more I will look for answers."* (S1).

This result was supported by the study of Lam and Zhou (2020) who posits perceived distress was significantly associated with perseverance of effort. The same is true in the study of Anderson (2020) which demonstrated that having a growth mindset is linked to perseverance and academic success to different extents. Also, metacognitive techniques improve students' academic performance, boost their self-esteem, and increase their self-awareness. This is evident in the statement, *"Every time I couldn't understand it, but my friends can, it makes me feel dumb so I'm studying."* (P6)

From the cross-case analysis, it becomes apparent that all three themes work together to create a cycle of persistence and effort in success in mathematical problem solving. When learners have a strong foundation and a wider range of strategies to help them deal with difficulties in solving math problems (Theme 1), students with high resilience are less likely to be discouraged by negative emotions (Theme 2) and can self-regulate their learning behavior (Theme 3) to keep working on the problem. This cycle fosters persistence and a strong effort towards solving challenging math problems. The cycle also serves to result in rewarding learning experiences or "success stories" for the students, boosting their self-esteem and confidence. The belief that they can find ways to surpass challenges they encounter brings about a stronger sense of self-efficacy that will serve them in learning in general. Resilience can thus be seen as an influence in the capacity for cognitive flexibility, adaptive problem solving and recognition of one's own cognitive processes and mindset.

The findings also imply that teachers and support systems ought to take the development of resilience into consideration when offering help to struggling students. Interventions that help learners increase their resilience can help equip students with the cognitive tools needed for academic success in mathematics. Helping them regulate their negative emotions, change negative mindsets and persist despite struggle by using or trying various strategies rather than directly helping them solve math problems would benefit them more in the long run.

Conclusion

Based on the three cross cutting themes from the cross-case analysis – problem solving independence, emotional regulation, and self-regulation work together to provide compelling evidence to support the proposition. Students with higher math resilience demonstrate greater persistence and effort by independently tackling challenges, managing their negative emotions and innovatively adapting their learning behaviors to overcome math

challenging problems.

Based on the findings, it is recommended that educators prioritize creating a supportive learning environment that acknowledges students' struggles in mathematics and offers early, differentiated interventions. Teachers should foster effective problem-solving skills through explicit instruction, promote self-directed and collaborative learning, and build students' understanding and confidence by focusing on conceptual learning, providing positive reinforcement, and cultivating a growth mindset that reframes challenges as learning opportunities.

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