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UNDERSTANDING STEM LEARNERS: ENGAGEMENT AND SUCCESS IN MATHEMATICS

Richard M. Aquino[1], Enrico J. Calantas[2], Marcelo T. Buen[2]
[1]Education Student, College of Education, [2]Faculty Members, College of Education

ABSTRACT

The purpose of this paper was to describe the level of students' behavioral, emotional, and cognitive indicators of engagement, and to explore their relationship to the math performance of Grade 11 STEM learners. The study employed descriptive correlational research, utilized stratified random sampling (n=200), and surveyed students enrolled in general mathematics during the first and second quarters of the school year 2023-2024. Weighted means were used to analyze student engagement indicators, descriptive statistics for test scores, and Spearman-Rho Correlation to show relationship between two variables. Results showed that there was a weak positive relationship between students' engagement and their performance in mathematics. In addition, students were 'highly engaged' in terms of cognitive engagement and 'engaged' in behavioral engagement, while 'neutral' based on their emotional engagement. This result suggested that students' emotions greatly affect behavior and self-regulated learning.

Keywords: mathematics, student engagement, behavioral engagement, emotional engagement, cognitive engagement

INTRODUCTION

In the Philippines, mathematics from K to 10 is a skills subject and provides a solid foundation for STEM (Science, Technology, Engineering, and Mathematics) learning areas in senior high school. The importance of learning mathematics extends beyond academic pursuits, equipping learners with essential problem-solving skills applicable throughout life (Li & Schoenfeld, 2019). Additionally, one of the objectives of STEM education is to foster engagement, which may inspire learners to pursue STEM majors in college (Idin, 2020; Sauder, 2023).
Student engagement has emerged as a key factor in understanding student success in mathematics. One common definition of student engagement is, learners attending classes and possessing active participation in learning tasks and activities (Liang et al, 2018; Cents-Boonstra et al., 2020). There must be a cyclical, two-way approach between a supportive, caring, and encouraging teacher and an enthusiastic, motivated, and 'hands-on' learner to have positive behavioral, cognitive, and emotional engagement. Thus, positive student engagement leads to better performance in class.

However, many students grappled with math, experiencing disengagement, and ultimately, lower academic performance. The Programme for International Student Assessment (PISA), a global benchmark for educational performance, has painted a concerning picture of mathematics learning in the Philippines. In the latest PISA 2022 results, only 16% of Filipino learners were at least able to understand and identify how a straightforward situation can be represented mathematically without explicit instruction, and almost no learners can choose, assess, and compare suitable approaches to problem-solving for complex situations as well as represent them numerically. (Education GPS, 2024). A concerning trend coincided with research highlighting low levels of student engagement which threaten performance in secondary mathematics classrooms (Schuetz et al., 2018). Students were passive recipients of information; lacking opportunities for active participation and inquiry-based learning (Tesfaye & Berhanu, 2015). Moreover, students relied on rote memorization and failed to see the relevance of mathematics in real-life situations, leading to a lack of interest and motivation and resulting in anxiety, and discouragement in exploring new concepts in Mathematics.
Previous research on the developmental paths of engagement were not entirely consistent. There were other factors affecting student engagement, and each region, country, or even community may have different experiences regarding student engagement. For instance, one study has shown that there is no correlation between learner engagement and their grades, even if the most participative and active learners show higher scores in tests (Floris et al., 2022). More recent longitudinal research (Hong et al., 2020) has reported that student engagement in mathematics learning has been generally stable

In a classroom devoid of engagement, the students passively absorb information while their minds are wandering elsewhere. In such an environment, learning becomes a chore, and achieving true understanding remains elusive. Understanding the engagement-performance link empowers educators to develop effective teaching strategies by creating a supportive and engaging learning environment, fostering deeper student involvement, promoting positive attitudes towards mathematics, and enhancing learning outcomes. The field of mathematics education has been constantly evolving, with researchers and educators exploring innovative approaches to address the challenges of student engagement. However, existing research often focuses on younger student populations. Learners taking STEM strand, for instance, faced educational factors crucial for their classroom performance. (Rogayan et al., 2021). Understanding the specific relationship between student engagement in math and the academic performance of STEM learners is therefore particularly relevant.

By examining the distinct contributions of behavioral, cognitive, and emotional engagement, this study sought to provide a nuanced understanding of the complex interplay between these factors and how they influence math performance of STEM learners. Moreover, this study can potentially develop a deeper understanding of how to nurture a love

for learning and equip senior high school students with the necessary mathematical skills to thrive in the 21st century.

Theoretical Background

Theoretical Framework

The multidimensional model of student engagement by Frederick, Blumenfeld, and Paris (2004), which stressed behavioral, emotional, and cognitive aspects of school participation in addition to overall engagement, served as the foundation for student engagement. According to Fredricks and McColskey (2012), there are distinctions and relationships between the three engagement domains, and the association holds true for various facets of engagement, including cognitive engagement (deep processing of information, critical thinking, and problem-solving), behavioral engagement (active participation in learning activities), and emotional engagement (positive feelings towards the subject) (Skinner, Furrer, Marchand, & Kindermann, 2008).

The model posits that student engagement is not a singular construct, but rather a combination of cognitive, emotional, and behavioral dimensions. Cognitive engagement refers to the mental investment and effort students put into learning, which directly influences their ability to understand and solve mathematical problems. Emotional engagement reflects students' feelings of interest and enthusiasm, which can foster a positive attitude that enhances learning outcomes. Behavioral engagement, encompassing active participation and persistence in tasks, is connected to greater effort and better performance. Hence, the model suggests that when all three dimensions of engagement are high, students are more likely to perform better in mathematics due to increased motivation, focus, and persistence in their studies.

Literature Review

Student Engagement

Student engagement is the lifeblood of the teaching and learning process—a spark that ignites curiosity, drives motivation, and propels students towards deeper understanding and academic achievement. Often intertwined with motivation (Grootenboer & Marshman, 2016), a little involvement coming from a student can transform a learning landscape and can become an interactive journey. Learners become active participants rather than passive observers. Just like a fire that needs fuel to burn brightly, the learning process needs student engagement to flourish. Student engagement is a term on how interested and immersed the students and the degree of curiosity, motivation, optimism, willingness, and enthusiasm they employ inside the classroom setting (Bond & Bedenlier, 2019). Moreover, this is about how students devote themselves to academic and extracurricular activities, and how they utilize what the school or institution offers.

Student engagement is a complex connection between the learner and the learning environment, such as the curriculum, teachers, peers, and the school. Learners can be influenced by societal and cultural factors that play relevant roles in shaping student engagement, such as teacher's behavior in class and parents' expectations (Li & Lajoie, 2021; Wang et al, 2019). Hence, the more the students are inspired, empowered, and engaged in class, the more they will bring back the energy and in the learning process, leading to a more participative class.

According to Lee (2018), engagement is significantly related to student performance. Positive student engagement leads to higher rates of positive academic performance. However, lack of interest and motivation in learning has extremely grave implications that need to be addressed. A study by Vijayakumaran et al. (2023), said that when learners are well-engaged in their academic activities, it lowers the possibility of student dropout.

Student Engagement Indicators

Student engagement is a multifaceted concept that includes various unique but connected aspects, including behavioral, emotional, and cognitive engagement. Student's behavioral engagement is perceived as the level of students' attention, active participation in learning, adherence to rules, and task completion (Fredricks et al., 2004; Sinatra, Heddy, and Lombardi, 2015). Students' attitudes, the extent to which students believe they are capable of doing a task, and on how learners perceive social pressure all have an effect on their behavioral engagement (Gjicali and Lipnevich, 2021).

Student's emotional engagement is centered on assessing learning outcomes and responding positively or negatively to peers, instructors, and institutions. It includes interest, happiness, fear, and a sense of belonging and involves both positive and negative attitudes (Flores et al., 2021). Moreover, emotional engagement takes into account student's willingness to take on challenges and their sense of belonging (Zorn et al., 2022). Positive or negative emotions can affect student's cognitive processes and greatly influence memory, reasoning, and problem solving (Tyng et al., 2017; Fredericks et al., 2004).

Student cognitive engagement is centered on self-regulated learning (Zorn et al., 2022), and entails the notion of investment, an appreciation of the importance of learning, and a readiness to go above and beyond what is required of responsibilities. Among the three indicators, cognitive engagement is considered the stimulus or the driving force to learn (Hong et al, 2020). Students who engage in high levels of cognitive engagement tend to acquire more knowledge and skills, characterized by critical thinking, problem-solving, and deep processing of information, leading to better performance in mathematics (Dong et al., 2020).

Student Engagement and Math Performance

In recent years, the study of student engagement gathered great attention, as it is accepted as a sign of mathematics achievement (Petričević et al., 2022; Skilling et al., 2020). Studies have shown a significant relationship between student engagement and math performance. For instance, a study by Maamin et al (2021) revealed that emotional engagement, cognitive engagement, and behavioral engagement pose a significant relationship in the success of students' performance in mathematics. Moreover, emotional engagement has become a largest predictor of math performance.

Guinocor et al (2020) supported other findings, which revealed that Filipino learners with high student engagement through personal study orientation possessed high performance in mathematics tests. However, according to Mazumder et al (2020), results revealed a weak correlation between student engagement and math performance among mechanical engineering students. It is shown that classroom engagement is not a good indicator in assessing students' performance in mathematics, but students preferred grouped or independent study outside the classroom.

A study by Karademir (2019), revealed that there were variations on how students' performance in mathematics related to student engagement. Moreover, Grade 5 learners prefer reading their notebook and mathematics book, copying their notebook one by one, and learning by heart as a sign of their engagement which helped them to perform well in class. However, it has been shown that they were also aware of the trauma brought by group activity that pose positive and negative emotions towards the subject.

Based on a recent study, behavioral engagement and Filipino students' performance in mathematics appear to be somewhat positively correlated (Flores et al., 2021). A moderate, positive relationship between cognitive engagement and academic performance was shown, but academic performance poses no correlation with emotional engagement. Numerous studies have focused on cognitive engagement (Cevikbas & Kaiser, 2021), yet few studies have been conducted that concern the behavioral and emotional aspects of engagement in relation to performance in mathematics.

Based on these research gaps, the following hypotheses were set for the study:

H1: There is a significant relationship between students' behavioral engagement and their performance in mathematics.
H2: There is a significant relationship between student's emotional engagement and their performance in mathematics.
H3: There is a significant relationship between students' cognitive engagement and their performance in mathematics.
H4: There is a significant relationship between students' engagement and their performance in Mathematics.

Conceptual Framework

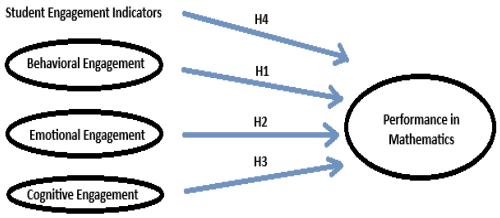

Figure 1. The Conceptual Framework

The framework sought to answer the research questions pertinent to the importance of the three student engagement indicators and their relationship to student performance in mathematics. Moreover, it highlights the interplay between students' engagement in general and their performance in mathematics, in terms of behavioral, emotional, and cognitive engagement.

METHODOLOGY

Research Design
This study employed a descriptive correlational method research design to explore the relationship between student's math engagement indicators and mathematics performance among Grade 11 senior high school students enrolled in General Mathematics subject. According to Devi et al (2023), a descriptive correlational design is utilized when the researcher seeks to describe a relationship among variables, without attempting to infer causal relationship.

Subjects
This study focused on 270 Grade 11 STEM students from Colegio de San Juan de Letran, 96 Grade 11 STEM students from City of Mandaluyong Science High School, and 34 Grade 11 STEM students from San Juan City Academic Senior High School (N=400) who took the General Mathematics subject and who are enrolled for the second quarter of school year 2023 – 2024. General Mathematics is the math subject that is offered during the first and second quarters. This study utilized a stratified random sampling technique using Slovin's Formula (n=200) to ensure the right number of respondents in every school.

Study site
This study was conducted at three different schools in three different cities in Metro Manila, namely: San Juan City Academic Senior High School in San Juan City, City of Mandaluyong Science High School in Mandaluyong City, and Colegio de San Juan de Letran in Manila. Permission to conduct research was granted by the principals of all participating schools. This selection provides a geographically diverse sample, encompassing public and private institutions, and catering to a range of socioeconomic backgrounds, thus, ensuring a well-rounded perspective for the study.

Instrumentation
A survey questionnaire by Flores et al. (2021), was adopted to assess student engagement and performance in mathematics. A 32-item, Likert-type scoring format is used for each of the subscales: behavioral (10 items), emotional (10 items), and cognitive engagement (12 items). On a five-point rating system, ranging from highly engaged (strongly agree) to highly not engaged (strongly disagree), students were asked to indicate how much they agreed with each statement.

It is to note that the instruments used to measure engagement and performance may not fully capture the complex nature of these constructs. The study focuses solely on the subject of mathematics, limiting the applicability of the findings to other academic domains.

Data Collection Procedure and Ethical Consideration
The study gathered data from a sample of Grade 11 STEM students enrolled in General Mathematics classes during the first and second quarter, school year 2023 – 2024. Quantitative data collection methods were employed, including surveys and second quarter examination scores of the respondents. Informed consent was sought from the respondents, and the consent holds assurance that individual results will be treated with confidentiality. It also guaranteed that no cost was incurred from them. Lastly, proper citations and references to the authors throughout the study were highly observed and recognized.

Data Analysis
Descriptive statistics were calculated to assess test scores. Weighted means were used to describe the student's engagement indicators. Inferential statistics were used to show statistically significant relationships between the variables. To examine the relationship between student engagement indicators and math performance, test the normality then a bivariate analysis was constructed through Spearman Rho with alpha level set at $p < .05$, which was used to determine the relationship between two variables, and the data gathered are ordinal and had outliers.

RESULTS

Student Engagement Indicators
Table 1 presents the weighted means of pupils' participation in General Mathematics class. It is revealed that the respondents are highly engaged in terms of their level of cognitive engagement in mathematics (Mean=4.263), based on their level of preparation for the mathematics subject, their level of attention to their teacher's lectures, and their desire to get good grades. Students' engagement based on their behavior (Mean=3.703) were rated "engaged" in terms of their perceived level of attention, active participation in class discussion, following teacher's directions, and eagerness to complete a task behavioral engagement. However, respondents were "neutral" with their emotional engagement (Mean=3.239). This implies that respondents were 'in between' emotionally engaged or not engaged, based on their interest, attitude, and feeling towards math, and their willingness to take all challenges during math discussions.

Table 1. Student Engagement Indicators

Student Engagement Indicators	Mean	Interpretation
Behavioral Engagement	3.703	Engaged
Emotional Engagement	3.239	Neutral
Cognitive Engagement	4.263	Highly Engaged

Legend: 1.00 – 1.80 - Highly not engaged; 1.81 – 2.60 – Not engaged; 2.61 – 3.40 – Neutral; 3.41 – 4.20 – Engaged; 4.21 – 5.00 – Highly engaged

Students' performance in General Mathematics

Table 2 revealed the mean performance of STEM students in Grade 11 under General Mathematics. The mean score of students was high with an average of 35.34, median of 37, and standard deviation of 8.65. The standard deviation implied an average dispersion of students' scores around the mean. The skewness of the level of students is -0.449. A distribution with a negative skewness has a longer left tail and a majority of values that are concentrated on the right side of the mean. The kurtosis of -0.883 implies that there is less extreme data in the distribution.

Table 2. Mean Performance of STEM Students

Statistics	Value	Interpretation
Mean	35.34	High
Median	37	
Standard Deviation	8.65137	
Skewness	-.449	
Kurtosis	-.883	

Relationship between Student Engagement and Performance in Mathematics

Table 3 shows Spearman-Rho correlation to evaluate the significant relationship between students' engagement (behavioral, emotional, cognitive) and the mathematics performance of Grade 11 STEM learners. Findings showed that there is a weak positive correlation between the two variables (ρ=.230). It also revealed that the p-values are less than the significant level, thus rejecting the null hypothesis.

Table 3. Correlation between Student Engagement and Test Scores

Variables		Spearman-Rho	P-Value	Decision	Conclusion
Student Engagement	**Test Scores**	.230	.001	Reject HO	Significant
Behavioral		.242			
Emotional		.115			
Cognitive		.279			

DISCUSSION

Student Engagement Indicators

The study discussed three student engagement indicators, namely: behavioral engagement, emotional engagement, and cognitive engagement. Gjicali and Lipnevich (2021) described behavioral engagement as the extent to which students believe they are capable of doing and completing a certain task, and on how learners perceive social stress. Tyng et al (2017) posited positive or negative emotions that can affect student's driving force to learn (Hong et al., 2020) and greatly affects critical thinking, problem solving, information processing, and eventually their performance in class (Dong et al., 2020).

The respondents were united in their decision on their level of interest and behavior in mathematics. The item, "I follow my teacher's directions in math class" ranked first with the interpretation 'highly engaged'. This resolves to the willingness of the learners to follow the teacher's instructions in solving math problems. Moreover, the item "Sometimes, I skip difficult math questions" ranked last and can be interpreted as 'not engaged'. This implies that several students are resolving to proceed to another problem, without asking for help from friends or teachers to solve a difficult math problem. This holds true to students who liked independent studying habits or having the tendency to disengage.

The overall weighted mean of emotional engagement was in between emotionally engaged or not engaged in this subject. This implied that their performance in mathematics depends on their positive or negative feelings before and during the class discussion. Among questionnaire items, the "I am interested in learning new things in math" received the highest engagement. This means that the students have the drive to learn new lessons. On the contrary, the item "I like to study other subjects rather than math", and "I am excited about solving difficult math problems" received the lowest engagement among respondents. This implies that there are other factors affecting students' learning, making them feel bored and uninterested in class discussions.

The overall weighted mean for cognitive engagement is labeled as "highly engaged". Moreover, the item "I want to get a good grade in math class" ranked first. This means that the respondents were desiring for good grades by memorizing important facts, thinking of different ways to solve math problems, developing their own strategy, and asking themselves math questions ensuring that they truly understand the lesson.

Students' Performance in General Mathematics

Based on the results of the study, the mean score of the students (Mean=35.34) implied that they performed high in their second quarter examination in general mathematics, with few students getting low scores. Moreover, the median score (Median=37) is higher than the mean, indicating that the distribution of the test scores is skewed to the left, with few extremely low scores pulling the mean down. Therefore, the skewness of data indicates that median is better in describing the center of distribution than the mean. In addition, the standard deviation of 8.65137 suggested that the scores are varied. However, the kurtosis of -.883 implied that there are more scores above the mean.

The test results reflect how well students performed in their quarter examination in General Mathematics and revealed that several respondents attained the mastery of the competencies in General Mathematics. These findings are contrary to the recent PISA 2022 results, where almost none of the learners can solve problems for complex situations.

Relationship Between Student Engagement and Performance in Mathematics

The results show that student engagement posed a significant relationship with their performance in mathematics. This supported the fact that learners with high student engagement possess high performance in mathematics (Maamin et al., 2021; Guinocor, 2020). The learners exhibited a positive attitude and attention towards learning mathematics. However, high levels of behavioral and cognitive engagements were greatly affected by their emotional engagement. External factors, such as classroom environment, teacher and teacher's strategy, peers, trauma from group activities may pose positive and negative emotions towards the subject.

CONCLUSION

Theoretical Contributions

Since dearth studies have been conducted showing the relationship between student engagement and mathematics performance, the results of the study will be a great contribution to the field of mathematics education, as the findings can provide valuable insights into effective strategies for promoting student engagement in mathematics classrooms. Research results have shown that emotional engagement greatly affects student performance in mathematics, as it affects cognitive and behavioral engagements. This will help teachers fully understand that in

taking the full grasp of students' interest can help entice their attention, and to acquire knowledge and skills in mathematics in the long run. Findings of this study will contribute to further exploration of the body of knowledge in the area of student engagement in relation to mathematics performance. Lastly, this will aid possible researchers for further studies involving student engagement and math performance.

Practical Implications

This study gives a more sound understanding of the role of teachers in fostering student engagement in a mathematics class. The study could help identify students who are disengaged or struggling with mathematics. This early identification allows teachers to provide timely support and interventions to ensure these students are not left behind. Moreover, this will help teachers develop more interactive, stimulating, and student-centered learning environments that cater to diverse learner needs. The study can encourage dialogue and collaboration among teachers, enabling them to share best practices for promoting student engagement and learn from each other's experiences.

By fostering a culture of engagement among students, schools can witness significant improvements in academic performance, particularly in mathematics. This can lead to higher graduation rates and better preparedness for future education and careers. The study can guide schools in allocating resources effectively, focusing on initiatives that demonstrably enhance student engagement and promote a positive learning environment. The study can facilitate collaboration between schools and parents, fostering a shared understanding of the importance of student engagement and encouraging joint efforts to support students' learning.

Limitations

This study solely focuses on exploring students' behavioral, emotional, and cognitive indicators of engagement and its relationship with performance in mathematics specifically among Grade 11 STEM learners. Student engagement indicators other than those included in the literature review and instrument may also be covered, especially for future studies in the senior high school, collegiate, and graduate levels. Future research could benefit from employing a larger, more diverse sample, or by utilizing a mixed methods approach to gain a more understanding of the complex relationship between student engagement and mathematics performance.

Finally, the study confirmed the significant relationship between three engagement indicators affecting performance of students in mathematics. Little can be concluded about the correlation between student engagement and math performance. Therefore, it is essential to recommend the study of student engagement alongside other variables such as math attitude, math self-efficacy, and math burnout, and determine the relationships between and among the variables.

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