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Structural Equation Modeling of Students' Performance in Pre-Calculus: Basis for Intervention in Senior High School

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Abstract: Early intervention in education is vital to the progress and improvement of diverse learners that can significantly improve long-term educational outcomes and success in education like identifying and providing immediate intervention to students with learning difficulties, especially in mathematics subjects. Thus, this study aimed to develop Structural Equation Modeling, specifically the direct and indirect relationship among the students' demographic profile, cognitive support, learning environments, student engagements, and performance in the first quarter in Pre-Calculus among grade 11 STEM students of Notre Dame of Tacurong College and Tacurong National High School, to provide a foundation for intervention in senior high students. The research instrument used in this study was a validated survey questionnaire created by the researcher and grouped into five latent variables, which were composed of thirty-three observed variables. The data was examined using frequency, percentage, mean, standard deviation, causal path analysis, and structural equation modeling. The results revealed that the students are diverse in their demographic profile. The predictors of students' performance in pre-calculus (cognitive support, learning environment, and student engagement) need a very low to moderate intervention. Meanwhile, the level of the student performance was generally satisfactory. The demographic profile and student engagement have a direct connection with students' performance, whereas the cognitive support and learning environment have no association with students' performance. Thus, the link between cognitive support and learning environment has a direct impact on student engagement outcomes. Furthermore, the results revealed that student engagement mediates the relationship between cognitive support and student performance, demonstrating a substantial relationship. In contrast, there is no mediation effect between students' learning environment and their performance through student engagement. Furthermore, the structural equation modeling of five latent variables resulted in twenty-two indicators that indicate the reasonable level of convergent validity, discriminant validity, and significant relationship. Furthermore, the student engagement and student performance of the model indicate 35.6% and 9.3%, showing statistically significant support as a basis for intervention.

Keywords: *Structural Equation Modeling; Basis for Intervention; Demographic Profile; Cognitive Support; Learning Environment; Student Engagement; and Students Performance in Pre-Calculus.*

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I. INTRODUCTION

In education, student performance in mathematics has significant impact in the totality of development and improvement of their daily lives involving mathematical skills. Rahayuningsih et al. (2020) states that students solving math problems should thoroughly understand the problem, examine it from various viewpoints, and maintain flexible thinking when choosing a solution. Capuno et al. (2019) emphasized that math is among the most challenging and disliked subjects for students worldwide, including in the Philippines. Siaw et al. (2021) noted that students often find it difficult to grasp and master in the classroom. Acido et al. (2024) compared the Philippines' PISA results from 2018 and 2022, revealing a shift in math and reading outcomes, while science scores decreased slightly. These results give warning that there is a need to improve the students' performance in mathematics and create a like intervention to address the problem in dealing with mathematics. In the study conducted by PISA in the year 2022, it revealed a concerning disparity in math proficiency among Filipino 15-year-old students compared to their global peers. Thus, results in PISA 2022 Philippines ranked 76th out of 81 countries and economics when it comes to Mathematics.

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Early intervention plays a crucial role in preventing achievement gaps and preparing students for success. Effective early intervention programs offer significant developmental support and protection before challenges arise. The advantages of early intervention extend beyond just academic performance. Early intervention can also foster improvements in students' cognitive abilities, problem-solving skills, self-management, and social-emotional development, all of which are indicators of success both in school and in later life. In connection to this, several studies have been conducted on how to improve learning outcomes using large-scale data that come from different educational settings using mathematical modeling.

According to Prakash and Selvakumari (2021), mathematical modeling is the process of decoding issues using mathematical formulations for both theoretical and numerical analysis in order to provide appropriate solutions and assistance. According to Sun et al., (2023) it involves a cyclical process of problem identification, mathematical representation, solution and analysis, validation, and iteration. Creating a mathematical model to predict future student performance is significant to helping both the teacher and students with interventions and preventing low performance in education. Also, knowing the level of student engagement, cognitive support, and learning environment of the students before taking final exams helps students to identify what to improve and create an intervention to performance that prevents low performance in education.

In this research gap, the researcher formulated a Structural Equation Modeling (SEM) to student performance in mathematics as the basis for early intervention. Early interventions in student performance may provide data on what to prepare learning activities during the instructional process that may help to improve the students' performance in mathematics. Also, applying SEM in the study may contribute encouragement to the academe and other fields of stakeholders to explore more using SEM in conducting research. Furthermore, this study may contribute positive information among the student parents, teachers, administrators, and principals of the institution to strengthen the skills and improve the performance of students that need to be supported. The study focused on Grade 11 STEM (Science, Technology, Engineering, and Mathematics) students from Notre Dame of Tacurong College and Tacurong National High School as respondents. These students were identified because they are significantly exposed to mathematics subjects, such as Pre-Calculus, Basic Calculus, General Mathematics, and Statistics & Probability. Additionally, both schools implement cut-off grades for mathematics subjects and entrance exams, which students must meet to enroll in the STEM strand. Hence, the study aimed to formulate Structural Equation Modeling (SEM) among Demographic Profile of the Students (DPS), Student Cognitive Support in Learning Mathematics (SCSLM), Student Learning Environments in Mathematics (SLEM), Student Engagement in Learning Mathematics (SELM), and Student Performance in Pre-Calculus (SPPC) of grade 11 STEM students.

➢ *Statement of the Study*

Generally, the study aimed to formulate Structural Equation Modeling (SEM) among Demographic Profile of the Students, Student Cognitive Support in Learning Mathematics, Student Learning Environments in Mathematics, Student Engagement in Learning Mathematics, and Student Performance in Pre-Calculus of grade 11 STEM students of Notre Dame of Tacurong College - Senior High School Department and Tacurong National High School – Senior High School.

➢ *Specifically, the Researcher sought to Answer the Following Questions:*

- What is the demographic profile of the students in terms of:

✓ Number of Hours Studying in a day;
✓ Number of Hours Sleeping in a day;
✓ Number of Classmates in a Classroom during JHS;
✓ General Weighted Average (GWA) in Mathematics 10; and
✓ General Average grade in Grade 10?

- What is the level of students' cognitive support in Mathematics?
- What is the level of students' learning environments in Mathematics?
- What is the level of students' engagement in learning mathematics?
- What is the students' performance in the first quarter in Pre-Calculus?
- Is there a significant relationship among students' demographic profile, cognitive support, learning environments, student engagement in learning mathematics, and student performance in the first quarter in Pre-Calculus?
- What structural equation modeling may be formulated in the predictors of student performance in Pre-Calculus?

II. METHODOLOGY

➢ *Research Design*

The research design of the study was descriptive-correlational. The descriptive design was used in this study to gather and interpret data based on the extent of predicators in student performance in mathematics and students' performance. The correlational design was used to interpret the indirect and direct relationship among the predicators of students' performance and student performance in the first quarter of pre-calculus.

➢ *Maintaining the Integrity of the Specifications*

The participants in this research were grade 11 STEM students from Notre Dame of Tacurong College Senior High School (NDTC-SHS) and Tacurong National High School (TNHS), who are now enrolled in the first semester of the 2024-2025 academic year. STEM students were chosen for this study because they are highly engaged in mathematics disciplines such as Pre-Calculus, Basic Calculus, General Mathematics, and Statistics & Probability. Additionally, it

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applies to a minimum 85 cut-off grades in mathematics to be qualified in the STEM strand and there is a good number of populations in the said school. The students were randomly grouped by the senior high school academic coordinator, without considering their final average grade from junior high school (Grade 10).

- *Sampling Techniques*

Based on the nature of the study, complete enumeration was employed. This decision was based on a priori sample size calculation for structural equation models. Considering the 33 observed variables, 5 latent variables, an anticipated effect size of 0.3, a significance level of 0.05, and a statistical power of 0.8 (Soper, 2021), the A-priori Sample Size Calculator for Structural Equation Models indicated a minimum sample size of 150 to detect the effect. Furthermore, it suggested a minimum sample size of 308 to properly support the model structure, leading to a recommended minimum of 308 respondents for this study. The complete number of respondents on this study was 426 grade 11 STEM students who provided the information comprehensively and analyzed the relationships of the variables in the study.

- *Instruments of the Study*

The research instrument that was used in the study was a researcher-made questionnaire that aligns with the study's objectives. Thus, validation and reliability questionnaires were validated by the five experts' evaluators before the conduct of the study. The feedback from these experts' content validity of test questions was highly positive, with a mean score of 4.85 rated as "Very Good". Meanwhile, to check the reliability of the questionnaire and to see if it would give consistent results, Cronbach alpha was used, and the results obtained an alpha of 0.852, suggesting that the test questionnaire was reliable and consistent enough to be used as a classroom-level survey questionnaire. The first part of the research questionnaire answers the distribution of the students' demographic profiles that may correlate with their performance in mathematics. The indicators in the demographic profile are five: the number of hours studying in a day, the number of hours sleeping in a day, the number of classmates in a classroom, general weighted average (GWA) grade in Mathematics 10, and general average grade in grade 10. The second part was a researcher-made survey questionnaire that answers the extent of latent variables of student performance in pre-calculus. The questionnaire is distributed into two latent variables and one mediator (Student Cognitive Support, Student Learning Environments, and Student Engagement) with nine indicators, each latent variable and mediator with a total of twenty-seven indicators. The indicators of latent variables focused on students' coping behavior, family involvement, instructional support, classroom environment, home environment, peer groups, exposure to technology, student readiness, and study habits; the three identified latent variables relate to the student performance in Pre-Calculus which completes the third part of the questionnaire. In total, there are 33 indicators in the research questionnaire, which were divided into five constructs in the study.

- *Procedure*

Once the completed questionnaires were collected, the researcher, with the assistance of the research adviser and a statistician, organized and tabulated the data. To gather additional information, a letter signed by the school principal was provided to both the Pre-Calculus teacher and the Senior High School Registrar, requesting access to the academic performance records of the participating students. Data analysis was then conducted using SPSS and AMOS. The results were interpreted with confidence, honesty, and a commitment to maintaining the confidentiality of the research data.

- *Data Analysis*

To analyze the variables and data collected in this study, descriptive statistics, including frequency, percentage, weighted mean, and standard deviation, were used to tabulate and interpret the student demographic profiles (number of hours of studying in a day, number of sleeping in a day, number of classmates in a classroom, general weighted average (GWA) grade in mathematics 10, and general average in grade 10), student engagement in learning mathematics (exposure to technology, student readiness, and study habits), student learning environments in learning mathematics (classroom environment, home environment, and peer groups), student cognitive support in learning mathematics (coping behavior, family Involvement, and instructional support), and first quarter grade of students in Pre-Calculus.

Causal Path Analysis was employed to examine the relationships between student demographic profiles, indicators of mathematics performance, and the first quarter grades in Pre-calculus. To perform the necessary calculations, the Statistical Package for the Social Sciences (SPSS) was utilized, aligning with the methodology outlined by Walberg (1981). Walberg's theory of educational productivity, initially introduced in 1981, incorporated SPSS to ensure the accuracy and reliability of results, thereby establishing a solid foundation for subsequent research in this area.

To address the research aims, Structural Equation Modeling (SEM) was employed to analyze and present correlational findings. SEM allows researchers to define hypothesized relationships between variables beforehand, which is crucial for evaluating the academic achievement model derived from the literature (Bhale & Bedi, 2023). Consequently, AMOS software was utilized to assess the SEM and explore potential links between various indicators of student performance in mathematics. All statistical tests were conducted with a significance level of 0.05.

- *Ethical Considerations*

To ensure the accuracy and impartiality of the collected data, the researcher distributed the questionnaire to the participants. The participants were thoroughly informed about the research objectives and assured that their responses would be kept confidential and used solely for academic purposes. They were also advised of their right to withdraw from the survey at any point without coercion.

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III. RESULTS AND DISCUSSION

Table 1 The Demographic Profile of the Grade 11 STEM Students.

Demographic Profile	Frequency (n=426)	Percentage (100%)
1.1 Number of Hours Studying in a Day		
4.1 hrs. – Above	14	3.29%
3.1 hrs. – 4 hrs.	38	8.92%
2.1 hrs. – 3 hrs.	117	27.46%
1.1 hrs. – 2 hrs.	172	40.38%
Below – 1 hr.	85	19.95%
1.2 Number of Hours Sleeping in a Day		
8.1 hrs. – Above	36	8.45%
6.1 hrs. – 8 hrs.	169	39.67%
4.1 hrs. – 6 hrs.	184	43.19%
Below – 4 hrs.	37	8.69%
1.3 Number of Classmates in a Classroom in JHS		
56 – Above	86	20.18%
46 – 55	52	12.21%
36 – 45	179	42.02%
Below – 35	109	25.59%
1.4 General Weighted Average (GWA) in Mathematics 10		
90 – 100	277	65.02%
85 – 89	126	29.58%
80 – 84	23	5.40%
75 – 79	0	0%
Below – 75	0	0%
1.5 General Average in Grade 10		
90 – 100	349	81.93%
85 – 89	72	16.90%
80 – 84	5	1.17%
75 – 79	0	%
Below – 75	0	%

The table results revealed that number of hours of studying in a day of the 426 grade 11 STEM students, 85 (19.95%) were 1 hr. – below, 172 (40.38%) were 1.1 hrs. – 2 hrs., 117 (27.46%) were 2.1 hrs. – 3 hrs., 38 (8.92%) were 3.1 hrs. – 4 hrs., and 14 (3.29%) were 4.1 hrs. - above. The number of hours of sleeping in a day of the 426 grade 11 STEM students, 37 (8.69%) students sleep at least below – 4 hrs., 184 (43.19%) were students sleep at least 4.1 hrs. – 6 hrs., 169 (39.67%) students sleep at least 6.1 hrs. – 8 hrs., and 36 (8.45%) of the students sleep at least 8.1 hrs. – above. Out of 426 grade 11 STEM students under number of classmates in a classroom, 109 (25.59%) were below – 35, 179 (42.02%) were 36 – 45 students inside the classroom, 52 (12.21%) of the students inside the classroom were 46 – 55, and 86 (20.18%) were 56 – above students inside the classroom. Also, demographic profile in terms of general weighted average grade (GWA) in 10 Mathematics, both below – 75 and 75 – 79 have 0% results, 23 (5.40%) grade 11 STEM students had 80 – 84 GWA, 126 (29.58%) with 85 – 89 GWA, and 277 (64.39%) of the grade 11 STEM students had a 90 – 100 GWA in 10 Mathematics. Furthermore, the demographic profile of the grade 11 STEM students in terms of their general average in grade 10, both below – 75 and 75 – 79 have 0% results, 5 (1.17%) students have a grade of 80 – 84, 72 (16.90%) have a grade of 85 – 89, and 349 (81.93%) of the grade 11 STEM students have a grade of 90 – 100.

Based on the results respondents of the study were dispersed in different indicators of student's demographic profile. Various demographic factors are known to be related to mathematics achievement. In the study of Lamsal (2024) it points out that a key challenge for mathematics teachers is employing fair and effective teaching methods when instructing diverse groups of students.

Table 2 The Level of Students Cognitive Support in Learning Mathematics

Indicators	Mean	SD	Interpretation
1. I practice solving review materials in mathematics that are available in the school library and the internet.	3.04	1.12	Moderate Intervention
2. I collect positive encouragement from my peers in dealing with mathematics.	3.51	1.03	Low Intervention
3. I reach out to my mathematics teacher when I don't understand the topic.	3.37	1.24	Moderate Intervention
4. My family helps me to answer and finish my assignment and projects in mathematics.	2.06	1.16	High Intervention
5. My family helps me to review my lessons in mathematics before examination.	1.82	1.11	High Intervention

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6. My family provides me learning materials to use in dealing with mathematics.	3.41	1.37	Low Intervention
7. My teacher applies varied teaching strategies and authentic methods of assessments in mathematics.	4.23	0.87	Very Low Intervention
8. There are available facilities to use to improve learning experience in the application of mathematics.	3.23	1.15	Moderate Intervention
9. In our school provides relevant programs that supports to enhance logical skills.	3.58	1.07	Low Intervention
Section Mean	3.14	0.61	Moderate Intervention

The findings revealed the students cognitive support gained the highest mean of 4.23, least dispersion of standard deviation of 0.87, and interpreted as “very low intervention.” This result implies that mathematics teachers always apply a varied teaching approach and authentic assessment method to support students learning mathematics, provide more reliable results in students’ academic performance, and accommodate diverse students learning styles in learning mathematics. Also, the result shows that the school of the students provides relevant programs that supports to enhance logical skills, which results to second highest mean of 3.58, standard deviation of 1.07, and interpreted as “low intervention.” Villamor & Vistro-Yu (2023) emphasize the importance of mathematics teachers creating learning experiences that connect mathematics to real-world applications while fostering active student participation. Acharya (2023) adds that students taught using diverse formative assessment methods demonstrate increased engagement and innovation in the classroom.

However, students’ families help to review their lessons in mathematics before examination results to lowest mean 1.82, standard deviation of 1.11 and interpreted as “high intervention”. Moreover, second lowest mean of 2.06, standard deviation of 1.16, and interpreted as “high intervention” that family of the students rarely helps them to answer and finish their assignment and projects in mathematics. The result emphasized that the number of families of grade 11 STEM students rarely don’t have time and extend their time to help their children in academic concerns like doing assignments, finishing school projects, and reviewing mathematics lessons before examinations. This implies that in student cognitive support in learning mathematics there is need a parenting intervention since most of the family of the respondents don’t have time to connect with their children. According to Purnomo et al. (2020) it suggests that parental involvement significantly impacts a child's mathematics performance. Reinforcing this, Nobis & Caparroso's (2024) research indicates that parental involvement strengthens parent-child relationships, boosts student confidence, and cultivates a more favorable attitude toward mathematics.

The level of student cognitive support in learning mathematics was interpreted as "moderate intervention," with a mean score of 3.14 and a standard deviation of 0.61. This suggests that grade 11 STEM students sometimes experienced cognitive support in their mathematics practice. Thus, family involvement on student cognitive support in learning mathematics needs a high intervention to help students in their academic task and improve their learning experience. Also, the results highlighted that teachers of the grade 11 STEM students apply varied teaching strategies and authentic methods of assessments in mathematics.

Table 3 The Level of Students Learning Environment in Mathematics.

Indicators	**Mean**	**SD**	**Interpretation**
1. Our classroom is well arranged, during instruction in mathematics subject.	4.08	1.01	Low Intervention
2. The instructional materials of my teacher in mathematics are easily viewed by the entire class.	4.23	0.88	Very Low Intervention
3. I have enough space inside the classroom intended for group performance and assessment.	4.01	1.01	Low Intervention
4. There is enough space for studying and reviewing lessons in mathematics in our home.	4.18	1.07	Low Intervention
5. There is internet connection available in our home for online classes when classes are interrupted due to weather condition.	4.08	1.21	Low Intervention
6. There is family interaction when I need help to understand lessons in mathematics.	2.53	1.28	Moderate Intervention
7. I have a positive relationship with my peers to exchange ideas in learning mathematics.	4.10	0.99	Low Intervention
8. I have teamwork and collaborative efforts with my peers in learning mathematics.	4.00	0.96	Low Intervention
9. I have peers that help me understand better the concepts in mathematical lessons.	4.08	1.02	Low Intervention
Section Mean	3.92	0.57	Low Intervention

The findings reveal the highest mean of 4.23, with a standard deviation of 0.88, which was interpreted as "very low intervention.". Based on the results, the teachers in mathematics make sure that the learning environment in giving instructions were always practiced. Moreover, students often have enough space in their home for studying and reviewing lessons in mathematics, which results the second highest mean 4.18, standard deviation of 1.07, and interpreted “low intervention.” Based on the results, the family of grade 11 STEM students provides often enough space for the learning environment in their home which could help develop and improve their experience in learning

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mathematics. Thus, students' home is where the learning continues after classroom instructions.

On the other hand, students have moderate intervention of family interaction when students need help to understand their lessons in mathematics with lowest mean 2.53 and standard deviation of 1.28. Although this indicator received the lowest means reveals that students work their academic requirements independently and understand the limited time and ideas of their parents in learning mathematics. The results imply that the students' home environment needs some interventions when it comes to family interaction between the students in academic concerns which may contribute to improved learning mathematics. Also, the students have teamwork and collaborative efforts with their peers in learning mathematics that results second lowest mean 4.00, standard deviation of 0.96, and interpreted "low intervention." The results suggest that there is often an active learning environment among grade 11 STEM students since there is collaboration and teamwork in learning mathematics.

The students' learning environment in mathematics was interpreted as "low intervention," with a mean of 3.92 and a standard deviation of 0.57. This suggests that the learning environment for the grade 11 STEM students generally contributes positively to their academic performance and requires only minimal intervention. In the study of Widiyawanti's (2024) study underscores the importance of the classroom learning environment in maximizing the classroom's potential as a learning resource. Conversely, learning mathematics at home relies on parents following up with their children's engagement. Therefore, parental involvement is crucial in supporting children's mathematics education. According to Mokhtar ehighlights23) highlight that for special needs students, family involvement is crucial, significantly fostering their overall development and underscoring the importance of families participating in their special education.

Table 4 The Level of Students Engagement in Learning Mathematics

Indicators	**Mean**	**SD**	**Interpretation**
1. I practice solving problems in mathematics online.	3.29	1.09	Moderate Intervention
2. I use online mathematical tools in learning mathematics.	3.13	1.12	Moderate Intervention
3. I give time to view video tutorials and read online materials in mathematics lessons.	3.51	1.06	Low Intervention
4. I practice solving problems in mathematics before the start of lesson.	2.89	1.12	Moderate Intervention
5. I study mathematics in advance using online materials.	2.82	1.09	Moderate Intervention
6. I prioritize tasks and use time efficiently in doing math activities.	3.50	1.02	Low Intervention
7. I study mathematics lessons before going to sleep.	2.94	1.05	Moderate Intervention
8. I actively use notetaking and video/audio recording in learning mathematics.	3.67	1.22	Low Intervention
9. I study mathematics lessons with my peers.	3.47	1.11	Low Intervention
Section Mean	3.25	0.66	Moderate Intervention

Table 4 shows that students actively use notetaking and video/audio recording to participate in mathematics learning, yielding the highest mean of 3.67 with a standard deviation of 1.22, which is interpreted as "low intervention." Based on the findings, grade 11 STEM students often commonly engage with technology to enhance their learning in mathematics. Also, students often dedicate their time to watch video tutorials and read online resources related to mathematics lessons to deepen their involvement in learning mathematics, which leads to a second highest mean of 3.51, also interpreted as "low intervention."

In the study of Tossavainen et al., (2020) found that students who watch videos and review lecture materials before class tend to participate more actively and that differences exist between groups based on traditional assessment methods. In the study conducts by Bircan & Akman (2023) suggested that information and technology literacy could predict academic performance in mathematics courses. Bubou & Job (2020) similarly found that students' readiness for online learning significantly impacts their ability to solve mathematics problems.

In contrast, students sometimes prepare for their mathematics lessons in advance by utilizing online resources, which resulted in the lowest mean score 2.82, and standard deviation of 1.09 that needs moderate intervention. Despite this indicator having the lowest mean, it still suggests that students are engaging in study habits while learning mathematics. Echoing Winarso's (2016) findings, which highlighted the beneficial effect of student readiness on engagement and academic performance, the rapid adoption of STEM education can further empower students and lead to better learning outcomes. In the study of Udabah et al. (2022) also emphasized that stronger study skills correlate with better performance in mathematics and that students with diverse study skills exhibit significant differences in their mathematical achievements. Moreover, students who practice solving mathematical problems prior to the commencement of the lesson received a slightly higher mean 2.89 and standard deviation of 1.12, which is also interpreted as "moderate intervention." Consequently, it is clear that the teachers of the grade 11 STEM students are punctual in their class attendance, given that students have limited time available to review and prepare for their next subject.

The extent of student engagement in learning mathematics was interpreted as "moderate intervention," mean 3.25, and standard deviation 0.66, indicating that engagement in mathematics does exist among students. Nevertheless, the indicators of student engagement need enhancement, as five out of nine indicators were rated as

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"sometimes" while only four were interpreted as "moderate intervention." The findings suggest that grade 11 STEM students in both public and private schools in Tacurong City often need an intervention program to enhance their engagement in learning mathematics. Enabling students to utilize technology for notetaking and for video/audio recording in mathematics can enhance their ability to learn and practice the subject at any time. Additionally, offering accessible links to online platforms that feature video tutorials and advanced reading materials can encourage students' involvement in understanding mathematics. The results supported by the study of Villamor & Vistro-Yu (2023) that mathematics teachers are encouraged to provide activities that help students connect with math problems and promote active engagement in mathematics learning within the classroom.

Table 5 The Students Performance in the First Quarter in Pre-Calculus

Student Performance	Frequency	Percentage	Descriptor
90 – 100	74	17.37%	Outstanding
85 – 89	164	38.50%	Strongly Satisfactory
80 – 84	170	39.91%	Satisfactory
75 – 79	18	4.30%	Fairly Satisfactory
Below – 75	0	0%	Did Not Meet Expectations
Total	426	100%	

Table 5 presents the results of student performance of grade 11 STEM students of NDTC and TNHS in first quarter grade in pre-calculus. Based on the result, 74 (17.37%) out of 426 grade 11 STEM students have a performance range to 90 – 100 and described as "outstanding." Thus, based on the given frequency of student performance in first quarter grade in pre-calculus, there were small difference between grades range from 85 – 89 (38.50%) and 80 – 84 (39.91%) which described as "strongly satisfactory" and satisfactory. Also, it reveals that there are no students got a grade of below – 75 and only 18 (4.30%) out of 426 students got performance which described as "fairly satisfactory." This implies that students were adjusting from their subjects in grade 11 specifically in dealing with pre-calculus.

The findings of the table presented support with DepEd Order No. 55 s. 2016, that students can enroll in STEM where the general average in Mathematics 10 and Science 10 should be at least 85. In the study of Udabah et al., (2022) stress that the higher the study skills of the students, the better their performance in mathematics and students who had of various study skills differed significantly in their performance in mathematics.

Table 6 Direct Effects Relationship among the Constructs

Constructs	Standardized path coefficient (β)	Sample Mean (M)	Standard Deviation (SD)	t statistic	p- value
Cognitive Support -> Students' Performance	0.007	0.005	0.064	0.110	0.912
Cognitive Support -> Student Engagement	0.526*	0.528	0.039	13.460	0.000
Demographic Profile -> Students' Performance	0.267 *	0.269	0.042	6.347	0.000
Learning Environment -> Students' Performance	-0.056	-0.053	0.060	0.933	0.351
Learning Environment -> Student Engagement	0.183*	0.186	0.051	3.616	0.000
Student Engagement -> Students' Performance	0.139 *	0.141	0.054	2.573	0.000

The table showed that relationship between cognitive support and students' performance was not significant ($\beta = 0.007$, $t = 0.110$, $p = 0.912$), indicating that cognitive supports have very weak positive relationship from students' performance. In contrast, cognitive support significantly and positively predicts Student Engagement ($\beta = 0.526*$, $t = 13.460$, $p < 0.001$), indicating that cognitive supports have moderate direct positive impact on student engagement. Demographic profile significantly predicts students' performance ($\beta = 0.267*$, $t = 6.347$, $p < 0.001$), suggesting that knowing demographic profile are essential contributors to students' academic outcomes. Alternatively, there was no significant direct relationship between the learning environment and student performance ($\beta = -0.056$, $t = 0.933$, $p = 0.933$), indicating that learning environment have very weak contributions to improved students' performance in Pre-Calculus. In contrast, learning environment was significantly and positively indicators of the outcome on student engagement ($\beta = 0.183*$, $t = 3.616$, $p < 0.001$), suggesting that students learning environments improved student engagement in learning mathematics. Also, student engagement was positively significant related to Students' Performance ($\beta = 0.139*$, $t = 2.573$, $p < 0.001$), suggesting that student engagement in learning mathematics was essential to predicts students' performance in Pre-Calculus.

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Table 7 Indirect Effects (Mediation) of Student Engagement among Cognitive Support, Learning Environment and Students Performance

Constructs	Standardized path coefficient (β)	Sample Mean (M)	Standard Deviation (SD)	t statistic	p- value
Cognitive Support -> Student Engagement -> Students' Performance	0.073*	0.071	0.030	2.340	0.019
Learning Environment -> Student Engagement -> Students' Performance	0.027	0.027	0.014	1.903	0.057

Table 7 presents the mediation impact of student engagement between cognitive support and students' performance, and between learning environment and students' performance. Based on results, there was significant indirect effect was observed, indicating that cognitive support positively influences academic performance through student engagement (β = 0.073*, t = 2.340, p < 0.019). This finding highlights the mediating role of student engagement between cognitive support and student performance in mathematics, which is essential for improving the performance of grade 11 STEM students in mathematics. This contrasts with earlier findings regarding a direct relationship between cognitive support and student performance.

In contrast, the indirect effect of the learning environment on student performance through student engagement was not significant (β = 0.027, t = 1.903, p = 0.057). This implies that student engagement does not mediate the relationship between the learning environment and student performance in mathematics. Therefore, further investigation, observation, and intervention are needed to explore the potential impact of the grade 11 STEM students' learning environment on their mathematics performance. These results also lend further support to the findings regarding the direct effect of the learning environment on student performance in mathematics.

Table 8 Total Effects Relationship among the Constructs

Constructs	Standardized path coefficient (β)	Sample Mean (M)	Standard Deviation (SD)	t statistic	p- value
Cognitive Support -> Students' Performance	0.081	0.081	0.059	1.374	0.169
Cognitive Support -> Student Engagement	0.480*	0.483	0.041	11.649	0.000
Demographic Profile -> Student Performance	0.271*	0.274	0.042	6.458	0.000
Learning Environment -> Student Performance	-0.062	-0.059	0.062	1.000	0.317
Learning Environment -> Student Engagement	0.183*	0.186	0.051	3.616	0.000
Student Engagement -> Students' Performance	0.145*	0.147	0.059	2.442	0.015

Table 8 shows that the total effect of cognitive support (β = 0.081, t = 1.374, p = 0.169) and learning environment (β = -0.062, t = 1.00, p = 0.317) on academic performance was not significant, suggesting that influence of cognitive support on students' performance in mathematics was primarily mediated through student engagement and learning environment, and have no substantial effect on students' performance in Pre-Calculus. On the other hand, cognitive supports (β = 0.480*, t = 11.649, p = 0.000) and learning environment (β = 0.183*, t = 3.616, p = 0.000) had a significant positive total effect on student engagement, emphasizing its direct impact on student engagement outcomes. Furthermore, grade 11 STEM demographic profile (β = 0.271*, t = 6.458, p = 0.000) and student engagement (β = 0.145*, t = 2.442, p = 0.015) also had significant positive total effect on students' performance, indicating that its direct impact on their performance in mathematics.

Table 9 R-square Value of Outcome Variables by Respective Predictors

Outcome Variables	Effect Size (R^2)	Sample Mean (M)	Standard Deviation (SD)	t statistic	p- value
Students' Performance	0.093*	0.102	0.024	3.849	0.000
Student Engagement	0.356*	0.302	0.036	8.103	0.000

Table 9 presents the measures how well the outcome variables in the model explain the variability of their respective predictors. For students' performance, the R-square value was R^2 = 0.093 with a standard deviation SD = 0.024, t = 3.849, p < .001. The results suggesting that predictors in the model account for approximately 9.3% of the variance in academic performance. Although it was statistically significant, it only represents a small effect size. For Student Engagement, the R-square value was R^2 = 0.356 with a standard deviation SD = 0.036, t = 8.103, p <

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.001. This finding suggests that the model explains 35.6% of the variance in student engagement, which is statistically significant and reflects a moderate effect size.

Table 10 The Construct Reliability and Validity of the Refined SEM

Constructs	**Reliability**			**Validity**
	Cronbach's alpha	***Composite Reliability (rho_a)***	***Composite Reliability (rho_c)***	***Average Variance Extracted (AVE)***
Demographic Profile	0.621	0.853	0.824	0.705
Cognitive Support	0.734	0.750	0.798	0.533
Learning Environment	0.720	0.805	0.827	0.549
Student Engagement	0.796	0.812	0.860	0.553

Table 10 presents the reliability measures of the refined constructs by examining their internal consistency using Cronbach's alpha and composite reliability. It also examines their construct validity by assessing convergent validity through the average variance extracted. Based on the results of the refined construct validity, cognitive support (0.734), learning environment (0.720), and student engagement (0.796) all have acceptable Cronbach's alpha values (above 0.70), indicating good internal consistency for these constructs. However, demographic profile (0.621) remains low Cronbach alpha, suggesting that moderate level of internal consistency among the items in measurement instrument.

After refining all constructs, both the rho_A and composite reliability values reached the acceptable threshold of 0.70. The resulting values for demographic profile (0.853), cognitive support (0.750), learning environment (0.805), and student engagement (0.812) were all above this level. Similar results were obtained for rho_C: demographic profile (0.824), cognitive support (0.798), learning environment (0.827), and student engagement (0.860). These results indicate consistent reliability after removing certain indicators from each construct in the structural equation modeling process (Hair et al., 2019). According to Nacion (2024) states that a composite reliability (CR) value of ≥0.6 is necessary for a latent construct to demonstrate internal consistency and composite reliability. A CR value ≥ 0.6 suggests that the items consistently measure their respective constructs.

Furthermore, all constructs meet the 0.50 threshold for average variance extracted (AVE). Demographic profile has the highest AVE (0.705), followed by student engagement (0.553), learning environment (0.549), and cognitive support (0.533), all of which also meet the minimum AVE threshold of 0.50. These AVE values indicate that the constructs have sufficient convergent validity. These results suggest that indicators in each construct are well-aligned with the intended construct (Hair et al., 2019).

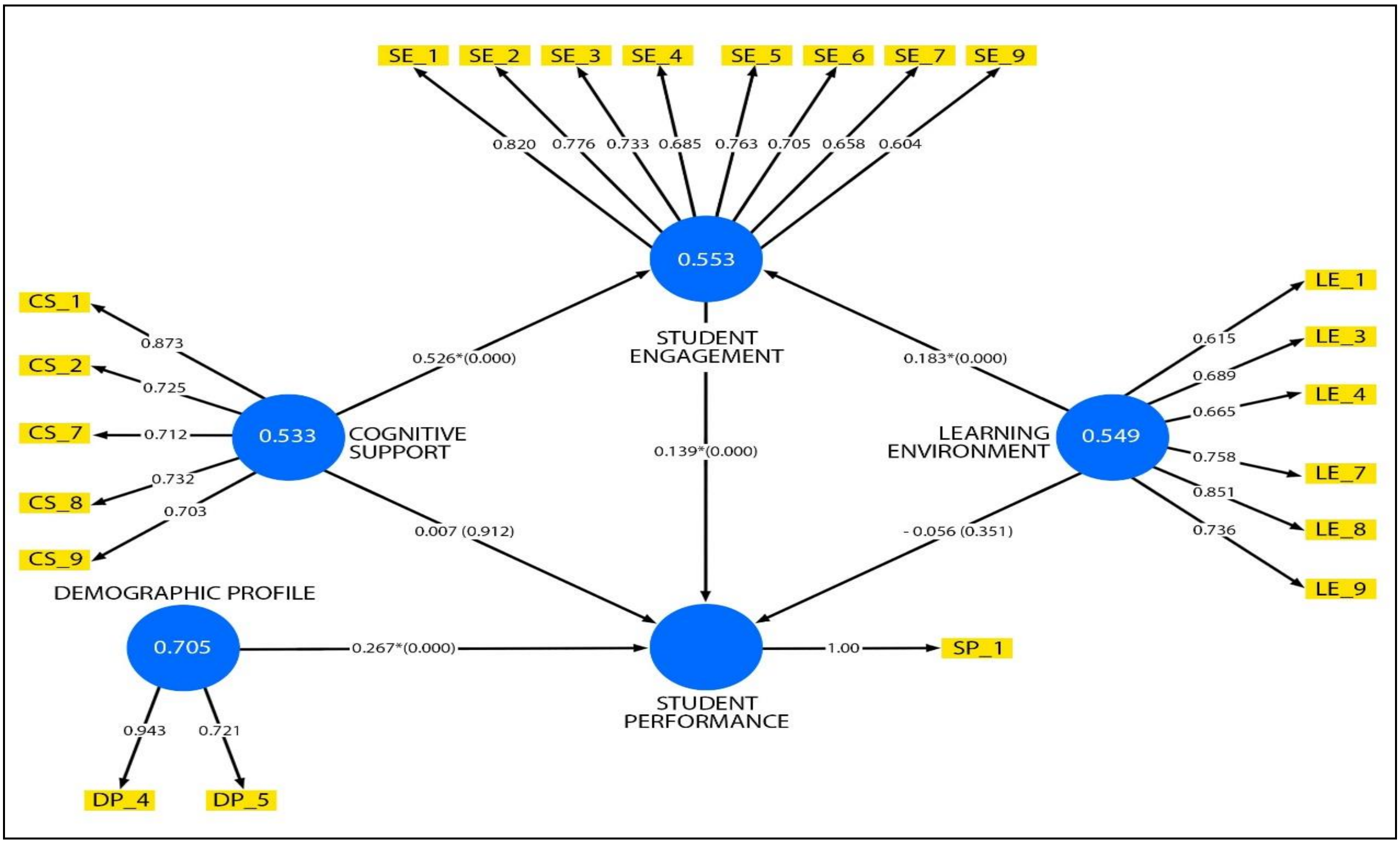

Fig 1 The Structural Equation Modeling of Predictors of Students Performance in Pre-Calculus.

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Figure 1 illustrates the refined structural equation model, showcasing the five constructs and their outer loadings, which represent the strength of the relationships between the observed indicators and their corresponding latent constructs. The figure also presents the average variance extracted (AVE) values, indicating the amount of variance captured by each construct relative to measurement error. The loadings were assessed to ensure they met a reliability threshold, typically around 0.70; however, loadings of at least 0.5 were also considered acceptable when the resulting AVE was 0.50 or higher (Hair et al., 2019).

Based on the results, only DP4_General Weighted Average in Mathematics 10 (0.943) and DP5_General Average in Grade 10 (0.721) within the demographic profile construct demonstrate a reasonable level of reliability, indicating the strength of the relationship between each indicator and its associated construct. The cognitive support construct revealed that indicators CS1_Solving Review Materials (0.873), CS2_Positive Encouragement (0.725), CS7_ Teaching Strategies and Authentic Assessment (0.712), CS8_ Facilities in Learning Mathematics (0.732), and CS9_Relevant School Programs (0.703) have moderate to strong loadings, indicating a reasonable level of reliability (Hair et al., 2020). Also, the indicators LE1_Well Arranged Classroom (0.615), LE3_Classroom Space for Group Performance (0.689), LE4_Home Space for Reviewing Lessons (0.665), LE7_Peer Relationship (0.758), LE8_Teamwork and Collaboration with Peers (0.851), and LE9_Peer Learning (0.736) fell the accepted threshold of at least 0.5 and above 0.7, indicating that six indicators of learning environment construct have a reasonable level of reliability. Furthermore, the results of student engagement construct eight indicators SE1_Practice Solving through Online (0.820), SE2_Online Mathematical Tools (0.776), SE3_Video Tutorials (0.733), SE4_Practice Solving Before the Start of Lessons (0.685), SE5_Study Lessons in Advance (0.765), SE6_Prioritize Task and used Time Efficiently (0.705), SE7_Study Lesson Before going Sleep (0.658), and SE9_Study Lessons with Peers (0.604) showed a reasonable level of reliability from moderate to strong loadings. Moreover, the indicator of student performance SP1_Students' Performance in Pre-Calculus (1.00) indicates a perfect loadings and reasonable level of reliability.

On the other hand, the average variance extracted (AVE) values for demographic profile (0.705), cognitive support (0.533), learning environment (0.549), and student engagement (0.553) all met the generally accepted threshold of 0.50. This indicates that the model exhibits convergent validity and that the constructs effectively capture their intended measurements after the removal of some weaker loadings (Hair et al., 2020). These results suggest that the refined structural equation model demonstrates acceptable reliability and discriminant validity, with most indicators showing a strong relationship to their associated constructs. Therefore, this five-construct structural equation model can serve as a basis for interventions aimed at improving the mathematics performance of grade 11 STEM students.

IV. CONCLUSION

The grade 11 STEM students from Notre Dame of Tacurong College and Tacurong National High School generally reported adequate study habits: they had a typical number of study hours per day, a normal sleep schedule, and their JHS classroom sizes met the standard. Additionally, their GWA in Mathematics 10 and general average in grade 10 were notably high. Assessments indicated that the students needed very little intervention regarding cognitive support in learning mathematics, low intervention for their learning environment, and moderate intervention to improve student engagement. However, the first quarter grades in pre-calculus for the 2024-2025 school year were only at a satisfactory level.

Demographic profile and student engagement directly correlate with student performance in the first quarter of Pre-Calculus, while cognitive support and learning environment do not show a direct relationship with this performance measure. However, cognitive support and learning environment do significantly influence student engagement. Moreover, student engagement mediates the relationship between cognitive support and student performance, indicating that cognitive support impacts performance through its influence on engagement. Conversely, student engagement does not mediate the relationship between learning environment and student performance.

The structural equation modeling of five construct (Demographic Profile, Cognitive Support, Learning Environment, Student Engagement, and Students Performance) resulted to twenty-two indicators (DP4_General Weighted Average in Mathematics 10, DP5_General Average in Grade 10, CS1_Solving Review Materials, CS2_Positive Encouragement, CS7_ Teaching Strategies and Authentic Assessment, CS8_ Facilities in Learning Mathematics, CS9_Relevant School Programs, LE1_Well Arranged Classroom, LE3_Classroom Space for Group Performance, LE4_Home Space for Reviewing Lessons, LE7_Peer Relationship, LE8_Teamwork and Collaboration with Peers, LE9_Peer Learning, SE1_Practice Solving through Online, SE2_Online Mathematical Tools, SE3_Video Tutorials, SE4_Practice Solving Before the Start of Lessons, SE5_Study Lessons in Advance, SE6_Prioritize Task and used Time Efficiently, SE7_Study Lesson Before going Sleep, SE9_Study Lessons with Peers, and SP1_Students' Performance in Pre-Calculus) indicates the reasonable level of reliability and relationship. Thus, the average variance extracted (AVE) values for demographic profile (0.705), cognitive support (0.533), learning environment (0.549), and student engagement (0.553) all exceeded the generally accepted threshold of 0.50, demonstrating convergent validity and indicating that the constructs effectively capture their intended measurements. The R-squared values for the outcome variables, Student Engagement (35.6%) and Student Performance (9.3%), indicate that the predictors in the model are statistically significant in explaining the variance in these outcomes.

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