ISRG Journal of Arts, Humanities and Social Sciences (ISRGJAHSS)

ISRG PUBLISHERS
Abbreviated Key Title: ISRG J Arts Humanit Soc Sci
ISSN: 2583-7672 (Online)
Journal homepage: https://isrgpublishers.com/isrgjahss
Volume – IV Issue - II (March – April) 2026
Frequency: Bimonthly

Students' Mathematical Readiness and Challenges Encountered in Calculus: Basis for Developing School-Based Intervention Program

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| **Received:** 05.04.2026 | **Accepted:** 12.04.2026 | **Published:** 22.04.2026

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Abstract

The purpose of this research was to determine the mathematical preparedness and difficulties of studying Calculus among Grade 12 students in four Camalaniugan and Lal-lo, Cagayan public senior high schools with an eventual goal to design a school-based interventional program. The subjects were largely 17-year-old males (65) with low-income families of 10,000 and below (45) with an average GWA of 91.12 and Calculus grade of 88.57. The results showed that students were right at Approaching Proficiency level in conceptual understanding (6.11) and problem solving (11.61) but were at a significant disadvantage in applying Calculus to engineering problems (1.87) with a Partial Credit level. On the other hand, they were rated high (3.47) in terms of their confidence, motivation and attitude. Nevertheless, students were subjected to challenges (2.79).

The one-way ANOVA and Pearson-r statistical results showed that mathematical readiness did significantly differ depending on age and academic grades in General Mathematics, Pre-Calculus and Calculus, but not sex and socio-economic status. Surprisingly, there were no considerable correlations between student description and the problems that they faced, which indicated that the problem with Calculus is a shared experience, independent of the demographic profile. Although academic performance had positive correlation with conceptual understanding and affective readiness, they did not have a positive correlation with problem-solving and application skills and pointed out a vital difference between theory and practical situations in the real world.

In order to fill this gap, the intervention program was created, project BRIDGE STEM (Bridging Readiness through Integrated Drills and Guided Engineering). This is with the intention of narrowing the divide between the high affective readiness of students with little capability to implement Calculus concepts to engineering problems, and the ultimate objective of the K-12 system in equipping STEM students with the tertiary engineering education.

Keywords: mathematical readiness, challenges encountered, Calculus, STEM students, school-based intervention program

DOI: 10.5281/zenodo.19691235

INTRODUCTION

Mathematical skill forms the foundation of the modern STEM workforce, where high-level reasoning is not only essential in academic settings but also a critical professional competency in the 21st century (World Economic Forum, 2020). Entry into fields such as engineering largely depends on proficiency in calculus, which in turn requires a strong conceptual understanding of algebra, functions, and limits developed during high school (Ceci & Williams, 2020). In response to these demands, the K–12 Basic Education Program under Republic Act No. 10533 introduced the STEM strand to better prepare learners for higher education and technical careers (DepEd, 2016). Despite this reform, gaps in student readiness persist, as many learners demonstrate procedural competence but struggle to apply mathematical concepts to real-world and engineering-related problems (Luna & Morales, 2018; PNU, 2022). These challenges are further compounded by limited access to instructional resources and socio-demographic constraints, particularly in municipalities such as Camalaniugan and Lal-lo, Cagayan, where localized data on students' mathematical preparedness remain scarce (Villanueva et al., 2021; Cordova, 2020).

Anchored on this context, and guided by the provisions of the ARAL Program Act (RA 12028), this study aims to assess the mathematical readiness of Grade 12 STEM students and identify the challenges they encounter in learning Calculus. It also examines the relationship between students' socio-demographic and academic profiles and their level of preparedness to inform the development of a localized, school-based intervention program. The study is grounded in Social Cognitive Theory by Albert Bandura, which emphasizes the role of self-efficacy in shaping learners' motivation and performance, and Cognitive Load Theory by John Sweller, which explains how limited prior knowledge can lead to mental overload when solving complex problems. Together, these theories suggest that gaps in readiness stem not from lack of ability but from insufficient foundational knowledge and reduced academic confidence. Guided by an IV–DV framework, the study considers student characteristics such as age, sex, socioeconomic status, and prior academic performance as predictors of mathematical readiness, measured across conceptual understanding, analytical problem-solving, application to engineering contexts, and motivation. Ultimately, this research supports national educational goals by providing evidence-based insights to strengthen transition pathways from secondary to tertiary education and to enhance support systems for future engineers in rural communities.

Statement of the Problem

This study aimed to determine the level of mathematical readiness and the challenges encountered in Calculus of Grade 12 STEM students from selected senior high schools. Specifically, it sought to answer the following questions:

1. What is the profile of the respondents in terms of the following variables?
   a. Socio-demographic Profile
      a.1. Age
      a.2. Sex
      a.3. Socio-economic status
   b. Academic Profile
      b.1. Grades in General Mathematics, Pre-Calculus, and Calculus
      b.2. Overall academic performance (GWA)
2. What is the level of mathematical readiness of respondents in terms of:
   a. Conceptual understanding of Calculus concepts
   b. Problem-solving and analytical skills in Calculus
   c. Application of calculus to introductory engineering scenarios
   d. Confidence, motivation and attitude toward learning Calculus
3. What are the challenges and strategies do Grade 12 SHS STEM students encounter in learning Calculus?
4. Is there a significant difference between the mathematical readiness of the STEM learners when grouped according to profile?
5. Is there a significant relationship between the profile of the SHS STEM learners and their;
   a. Challenges encountered in Calculus
   b. Mathematical readiness
6. What intervention program can be developed based in the identified weaknesses in mathematical readiness particularly in Calculus and the challenges encountered by the respondents?

METHODOLOGY

The following are the different methods, procedures and instrumentalities used in processing all data pertinent to this study.

Research Design

This study employed a quantitative, descriptive-comparative-correlational research design to describe the respondents, assess levels of mathematical readiness, examine group differences, and determine relationships among variables. The descriptive component presented the socio-demographic and academic profiles of Grade 12 STEM students and assessed their mathematical readiness across conceptual understanding, problem-solving and analytical skills, application of Calculus to engineering contexts, and affective factors such as confidence, motivation, and attitude. It also described the challenges encountered in learning Calculus. The comparative component determined significant differences in mathematical readiness when grouped according to profile variables. Meanwhile, the correlational component examined the degree and direction of relationships between respondents' profiles, their level of readiness, and the challenges they experienced, identifying both the strength and direction of these associations.

Locale of the Study

The research was conducted at Camalaniugan National Highschool (CNHS), situated at Dugo, Camalaniugan, Cagayan, Lal-lo National Highschool (LNHS), situated at Centro, Lal-lo, Cagayan, Magapit National High School (MNHS), situated at Magapit, Lallo, Cagayan, and Logac National High School (LoNHS), situated at Logac, Lallo, Cagayan. All schools are public–school institutions which nurtures well-rounded, values-driven, guided by national goals and locally encouraged student well-being. It offers various Senior High School Tracks such as STEM major in Engineering.

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The schools were chosen as the locale of the study due to its significant enrollment of students from its STEM strand and the expressed interest of the school administration and faculty in addressing pre-collegiate preparation concerns. A map may be inserted in this section to provide a visual representation of the study site and its geographical significance.

Respondents and Sampling Technique

The study respondents were Grade 12 students studying STEM and formally enrolled at the school year 20252026 and must pursue an engineering program at the tertiary level. The selection of this population was made due to the fact that it is the population of students whose mathematical readiness in Calculus can have the greatest consequence - students who are at the brink of leaving high school education and entering college engineering education.

The sample of respondents was selected based on purposive sampling. The technique is a non-probability sampling method used in those cases when the study aims demand participants of particular, clear-cut characteristics instead of a random, general sample (Etikan, Musa, and Alkassim, 2016). The rapport sampling technique was deliberate, leaving no chance of having irrelevant respondents as the respondents were as well directly pertinent to the aim of the study and the data generated will have a purposeful foundation in the development of the school-based intervention program proposed.

The following were inclusion criteria: (1) officially enrolled as a Grade 12 student taking STEM courses at one of the four schools identified as SY 20252026; (2) is or has taken Calculus as a course in the STEM strand curriculum; and (3) plans to take an engineering course upon graduation of Senior High School. Those students who failed to fulfill these requirements such as students in other strands, transferees, repeaters, and students with incomplete academic records were left out of the study.

The population and the respective sample size are as below:

SCHOOL	POPULATION	SAMPLE SIZE
CNHS	74	9
LNHS	177	35
MNHS	24	8
LoNHS	26	8

The researcher observes that the sample of CNHS, LoNHS, and MNHS is relatively small because of the small number of eligible Grade 12 STEM students in the schools. All the eligible students in these smaller schools were enrolled to make the most out of the available data. In the case of LNHS where the population to be sampled was significantly larger the sample was selected based on systematic sampling in the purposively identified pool of eligible respondents.

Research Instruments

The study utilized a researcher-constructed instrument composed of four components, developed through content specification, item construction, expert validation, pilot testing, and reliability estimation following established educational measurement standards (Fraenkel et al., 2019). Part I gathered respondents' socio-demographic and academic profiles, including age, sex, income, grades, GWA, and engineering interest. Part II was a Calculus Achievement Test with 58 multiple-choice and 5 open-ended items assessing conceptual knowledge, problem-solving, and application to engineering contexts, with scoring based on NCTM (2014) rubrics. Part III, a 30-item Mathematical Readiness Affective Scale, measured confidence, motivation, and attitude using a 5-point Likert scale with reverse-coded items. Part IV was a 25-item Calculus Challenges Checklist covering conceptual, procedural, application, affective, and instructional challenges rated on a 4-point scale. Content validity was ensured by expert review, and pilot testing refined the tool. Reliability was established using Cronbach's alpha with a target coefficient of 0.80 or higher.

Data Gathering Procedure

The data collection process was conducted so as to have been carried out in a systematic and ethically sound manner. Bureaucratic permission was granted to the researcher by the administration of CNHS, LNHS, MNHS and LoNHS to do the study. When the approval was obtained, the respondents were oriented on the purpose, the fact that the participation is voluntary, the rights of the participants, right to confidentiality and right to withdraw at any time. Informed consent form was handed out and signed prior to the involvement.

The researcher was in charge of administering the instrument at regular class time with the approval of the subject teachers. Part II (Calculus Achievement Test) was given sixty (60) minutes work time and Parts I, III and IV given within a different thirty (30) minutes duration. The questionnaire was completed and the retrieved questionnaires were verified to be complete on the same day before being encoded.

All the answers were immediately retrieved when they were completed and each form was looked through by the researcher. In case of unclear or missing answers, the respondent was clarified on the spot. The information was systematized, coded, and placed in a database to analyze it. To understand the various levels of data collection process, a flowchart will be added.

Data Analysis

Data were then analyzed using descriptive and inferential statistics after collection in accordance with the research questions and hypotheses of the study. In Research Question 1, which involved investigating about on profiling the respondents, frequencies and percentages were implemented on categorical variables, whereas means and standard deviations were calculated on continuous variables.

In the case of Part II (Calculus Achievement Test), the level of mathematical preparedness of respondents was established by the means and classification of the score range of each content dimension. The average score on every item was calculated by subtracting the total number of points that were earned by all respondents on a given item divided by the overall number of respondents (N = 60). In order to analyse at subscale level, the respondents were clustered together into a range of scores and frequency distribution was created. The descriptive levels and their corresponding score ranges for each dimension were established as follows:

Table A. Score Range Interpretation for Section A: Conceptual Understanding of Calculus Concepts (Max = 10 points)

Score Range	Descriptive Level	Interpretation

DOI: 10.5281/zenodo.19691235

Score Range	Descriptive Level	Interpretation
9 – 10	Excellent	The respondent demonstrates a thorough and accurate understanding of limits, continuity, and related theorems.
7 – 8	Proficient	The respondent demonstrates a solid understanding of most concepts with only minor gaps.
5 – 6	Approaching Proficiency	The respondent demonstrates partial understanding of Calculus concepts but with notable gaps.
3 – 4	Basic	The respondent demonstrates limited understanding and requires substantial remediation.
0 – 2	Below Basic	The respondent demonstrates little to no understanding of foundational Calculus concepts.

Table B. Score Range Interpretation for Section B: Problem-Solving and Analytical Skills in Calculus (Max = 20 points)

Score Range	Descriptive Level	Interpretation
18 – 20	Excellent	The respondent demonstrates mastery of differentiation and integration techniques and analytical reasoning.
14 – 17	Proficient	The respondent demonstrates competence in most problem-solving procedures with minor errors.
10 – 13	Approaching Proficiency	The respondent demonstrates partial competence with consistent procedural or conceptual errors.
5 – 9	Basic	The respondent demonstrates limited problem-solving ability and requires targeted intervention.
0 – 4	Below Basic	The respondent demonstrates serious deficiencies in analytical and procedural skills.

The level of mathematical readiness in terms of application of Calculus to introductory engineering scenarios (Part II, Section D, Items 41–45) was determined using the weighted mean and standard deviation of the rubric scores assigned to each problem-solving item. Each item was scored using a five-level analytic rubric with score values of 0, 1, 2, 3, and 4 for four-point items (Items 41–43) and 0, 1, 2, and 3 for three-point items (Items 44–45), corresponding to No Credit, Minimal Credit, Partial Credit (Major Error), Partial Credit (Minor Error), and Full Credit, respectively. The weighted mean per item was computed as: $WM = \Sigma(f \cdot x) / N$ where WM is the weighted mean rubric score, f is the frequency of respondents who received each rubric score, x is the rubric score value (0–4 or 0–3), and N = 60.

The descriptive level of each item was determined by computing the proportion of the weighted mean to the item's maximum rubric score (WM ÷ max), and interpreting this proportion against the rubric-based scale presented in Table C. This approach ensures that items with different maximum scores (3 or 4 points) are interpreted on a comparable proportional basis, consistent with the recommendations of Nitko and Brookhart (2011) for rubric-based performance assessment.

Table C. Rubric Score Interpretation Scale for Section D: Application of Calculus to Introductory Engineering Scenarios

WM Proportion (WM ÷ Max Score)	Descriptive Level	Rubric Score Label	Interpretation
0.81 – 1.00	Full Credit	4 / 3	Correct setup, complete solution, correct final answer, and accurate engineering interpretation.
0.61 – 0.80	Partial Credit (Minor)	3 / 2	Correct approach with minor computational error, or correct answer without sufficient working.
0.41 – 0.60	Partial Credit (Major)	2 / 1	Some correct steps but significant conceptual or procedural error; final answer incorrect.
0.11 – 0.40	Minimal Credit	1	Relevant formula or concept identified but incorrectly applied; minimal work shown.

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0.00 – 0.10	No Credit	0	No work shown, completely incorrect, or item left blank.

The level of mathematical readiness of the respondents in terms of confidence, motivation, and attitude toward learning Calculus (SOP Q2d) was determined using the weighted mean of each item and subscale in Part III. The following scale was used to interpret the computed weighted means, adapted from the five-point Likert scale interpretation framework recommended by Lickert (1932) as operationalized in educational research:

Table D. Weighted Mean Interpretation Scale for the Mathematical Readiness Affective Scale (Part III)

Mean Range	**Descriptive Value**	**Interpretation**
4.21 – 5.00	Very High	The respondents consistently and strongly agree with the statement, indicating a very high level of confidence, motivation, or positive attitude toward Calculus.
3.41 – 4.20	High	The respondents generally agree with the statement, indicating a high level of affective readiness for learning Calculus.
2.61 – 3.40	Moderate	The respondents are neither clearly agreeable nor disagreeable, indicating a moderate or uncertain level of affective readiness.
1.81 – 2.60	Low	The respondents generally disagree with the statement, indicating a low level of confidence, motivation, or positive attitude.
1.00 – 1.80	Very Low	The respondents strongly and consistently disagree with the statement, indicating a very low level of affective readiness for Calculus.

The overall affective readiness score, computed as the sum of all thirty (30) item scores after reverse-scoring applicable items, was interpreted using the following total score ranges: 127–150 = Very High; 103–126 = High; 79–102 = Moderate; 55–78 = Low; 30–54 = Very Low.

The frequency and nature of challenges encountered by the respondents in learning Calculus (SOP Q3) were determined using the weighted mean of each item and subscale in Part IV. The following scale was used to interpret the computed weighted means based on the four-point frequency scale employed in the checklist:

Table E. Weighted Mean Interpretation Scale for the Calculus Challenges Checklist (Part IV)

Mean Range	**Descriptive Value**	**Interpretation**
3.26 – 4.00	Alwa ys	The respondents consistently experience the described challenge in learning Calculus, indicating a pervasive and critical difficulty that requires immediate attention.
2.51 – 3.25	Often	The respondents frequently experience the described challenge, indicating a recurring difficulty that significantly affects their Calculus learning.
1.76 –2.50	Some times	The respondents occasionally experience the described challenge, indicating a moderate difficulty that may intermittently affect their performance.
1.00 – 1.75	Neve r	The respondents rarely or never experience the described challenge, indicating that this area does not significantly impede their learning of Calculus.

To determine the significant relationship between the respondents' profile variables and their level of mathematical readiness and challenges in Calculus, the following inferential statistical tools were used. Pearson's product-moment correlation coefficient (r) was used to determine the relationship between continuous profile variables (e.g., prior grades, GWA) and the achievement test scores and affective scale scores, where data satisfied the assumptions of normality and linearity. Spearman's rank-order correlation coefficient (ρ) was used as a non-parametric alternative when the data did not meet the assumptions required for Pearson's r. The one-way Analysis of Variance (ANOVA) was employed to test for significant differences in the level of mathematical readiness across groups defined by categorical profile variables (e.g., sex, socio-economic status, intended engineering course). Post-hoc comparisons using Tukey's Honestly Significant Difference (HSD) test were conducted when the ANOVA yielded a significant F-ratio. All inferential tests were evaluated at a 0.05 level of significance.

All statistical computations were performed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS).

Ethical Consideration

Ethical principles were followed throughout the conduct of the study. Each of the subjects was made aware of the purpose of the study, the procedure, and their entitlement as research subjects. Participation was optional and the respondents were allowed to drop out or pull out of the study without any repercussions. Informed consent was also given where participants are informed of how their data will be used and utilization on purely academic basis.

DOI: 10.5281/zenodo.19691235

To conserve privacy and anonymity, it was made sure that no identifying information will be contained in both the data records and research outputs. All collected data were stored securely and accessible only to the researcher and authorized faculty supervisors. Research data will be retained for a period of three (3) years following the completion of the study. After the retention period, all physical data will be shredded and disposed of securely. Digital data will be permanently deleted from all storage devices using secure deletion methods that overwrite the data to prevent recovery. Prior to the start of data collection, the study sought and obtained ethical clearance from the university's Institutional Research Ethics Committee. The research complied with all institutional and national guidelines, including the National Ethical Guidelines for Health and Health-Related Research and applicable data privacy regulations.

RESULTS AND DISCUSSION

Below are the discussion of all the results interpreted based from all data gathered, tabulated and analyzed.

Student's Profile Variables

Table 1. Frequency and Percentage Distribution of the students in terms of profile variables

Profile Variables		**Frequency (n=60)**	**Percentage**
I. Socio-Demographic Profile			
Age	20	1	1.67
	18	23	38.33
	17	36	60
Mean = 17.43 ***SD = 0.59***			
Sex	Male	39	65
	Female	21	35
Socio-Economic Status	40,001 and above	11	18.33
	30,001-40,000	1	1.67
	20,001-30,000	7	11.67
	10,001-20,000	14	23.33
	10,000 and below	27	45
Mean = 27, 900 ***SD = 40, 442. 76***			
II. Academic Profile			
Grades in General Mathematics	96-99	6	10
	92-95	17	28.33
	88-91	15	25
	84-87	18	30
	Below 84	4	6.67
Mean = 89.62 ***SD = 4.57***			
Grades in Pre-Calculus	96-99	4	6.67
	92-95	13	21.67
	88-91	16	26.67
	84-87	19	31.67
	Below 84	8	13.32
Mean = 88.45 ***SD = 4.7***			
Grades in Calculus	96-99	4	6.67
	92-95	16	26.67
	88-91	13	21.67
	84-87	17	28.32

DOI: 10.5281/zenodo.19691235

	Below 84	10	16.67
Mean = 88.57 SD = 4.75			
Overall General Weighted Average (GWA)	96-99	7	11.67
	92-95	22	36.67
	88-91	20	33.33
	84-87	9	15
	Below 84	2	3.33
Mean = 91.12 SD = 3.71			

The data in Table 1 shows the socio-demographic and academic profile. The socio-demographic profile reveals that the highest proportion of respondents were 17 years old (60 percent), while the lowest was 20 years old (1.67 percent), with a mean age of 17.43 (SD = 0.59). The low standard deviation indicates that the ages are closely clustered around the mean. In terms of sex, male students (65 percent) represent the highest proportion, while female students (35 percent) comprise the lowest. Although no mean is computed for this variable, the disparity indicates an imbalance in STEM participation. A more pronounced disparity is observed in socio-economic status, where the highest proportion of students belong to the ₱10,000 and below income group (45 percent), while the lowest is ₱30,001–40,000 (1.67 percent). The reported mean income of ₱27,900 with a very large SD of 40,442.76 indicates high variability and possible skewness in the data.

The academic profile shows that the highest proportion of students falls within the 84–87 range (30 percent), while the lowest is below 84 (6.67 percent), with a mean of 89.62 (SD = 4.57). The relatively small standard deviation indicates that most students' grades are clustered near the mean, reflecting generally consistent performance in General Mathematics. This trend changes in Pre-Calculus, as the maximum remains at 84-87 (31.67 percent) yet the lowest category (less than 84) also goes up in 13.32 percent with a slightly smaller mean of 88.45 (SD = 4.70). There is minimal reduction of mean yet with equal distribution of scores. This tendency becomes even more pronounced in Calculus, where the proportion highest is slightly lower (28.32% 84-87) and the lowest (below 84) even higher (16.67%). The mean grade of 88.57 (SD = 4.75) remains close to that of Pre-Calculus, but with increasing proportion of low-performing students. Interestingly, when examining the overall General Weighted Average (GWA), the highest proportion of students falls within 92–95 (36.67 percent), while only 3.33 percent are below 84, with a relatively high mean of 91.12 (SD = 3.71). The lower standard deviation suggests that students' overall academic performance is consistently high. However, this contrasts with the increasing number of low-performing students in calculus.

Student's Level of Mathematical Readiness

a. Conceptual Understanding of Calculus

Table 2a. Students' Level of Mathematical Readiness in terms of Conceptual Understanding of Calculus

Conceptual Understanding of Calculus	Frequency (n=60)	Percentage
9 – 10 (Excellent)	8	13.33
7 – 8 (Proficient)	18	30.00
5 – 6 (Approaching Proficiency)	22	36.67
3 – 4 (Basic)	9	15.00
0 – 2 (Below Basic)	3	5.00
Weighted mean	***6.11***	***Approaching Proficiency***
S.D.	**2.14**	

The data presented in Table 2a show that the respondents obtained an overall weighted mean of 6.11 out of 10 points with a standard deviation of 2.14, placing the group at the Approaching Proficiency level in terms of conceptual understanding of Calculus concepts.

As shown, the Approaching Proficiency level (scores 5–6) recorded the highest frequency, with 22 students or 36.67 percent of the respondents falling within this band. This suggests that the students can handle familiar and straightforward problems. Meanwhile, the *Below Basic* level (scores 0–2) recorded the lowest frequency, with only 3 students or 5.00% of the respondents falling within this range. These students demonstrated near-total unfamiliarity with the foundational concepts.

Research reveals that students' difficulties in Calculus STEM from factors such as the abstract nature of the subject, inadequate foundational knowledge in prerequisite topics such as functions and algebra, and ineffective instructional strategies that do not engage students in meaningful learning experiences (Auxtero & Callaman, 2020, as cited in Nuñez et al., 2023). Furthermore, Perante (2022) found that most K-12 graduates were not mathematically college-ready, with only 43% of incoming first-year college engineering students demonstrating sufficient mathematical preparation for higher mathematics in college. Hence, the students in the *Below Basic* category in this study represent a particularly vulnerable subgroup who, without immediate and targeted intervention, face a high risk of failure in college-level engineering Calculus.

b. Problem-Solving and Analytical Skills in Calculus

Table 2b. Students' Level of Mathematical Readiness in terms of Problem-Solving and Analytical Skills in Calculus

Problem-Solving and Analytical Skills in Calculus	Frequency (n=60)	Percentage
18 – 20 (Excellent)	5	8.33
14 – 17 (Proficient)	14	23.33
10 – 13 (Approaching	25	41.67

DOI: 10.5281/zenodo.19691235

Proficiency)		
5 – 9 (Basic)	13	21.67
0 – 4 (Below Basic)	3	5.00
Weighted mean	***11.61***	***Approaching Proficiency***
S.D.	***4.16***	

The data presented in Table 2b reveal that the respondents obtained an overall weighted mean of 11.61 out of 20 points with a standard deviation of 4.16, placing the group at the Approaching Proficiency level in terms of problem-solving and analytical skills in Calculus. As indicated, the highest frequency was noted in the Approaching Proficiency level (scores 1013) with 25 students or 41.67 percent of the respondents as the highest concentration in all the scores. This implies that most Grade 12 STEM students in the sampled schools might have been able to carry out routine differentiation and integration processes of common types of problems but faced consistent challenge when objects demanded higher-order analytic processes. In the meantime, the lowest frequency was observed in the Below Basic level (scores 0 4) with the number of respondents being 3 students or 5.00%. Although these students were the smallest in numbers, they exhibited grossly insufficient skills in problem-solving. The large SD of 4.16 statistically proves that these students are outliers in the statistic and their results are very far out of the group means, which is a subgroup, where the mathematical preparedness to take college-level engineering Calculus has been fraudulently impaired badly.

As a rule, the percentage of 41.67 percent of the respondents in the Approaching Proficiency level, the large SD of 4.16 and the 5.00 percent of the Below Basic cluster show that the proportion of the class is not very strong and can be easily changed. Sulistyaningsih et al. (2025) discovered that students who had previous background knowledge in mathematics could develop mathematical models and solve the problem-solving process much better working with differential Calculus, whereas the students with less background knowledge always could not complete the identification and formulation of the problem.

c. Application of Calculus to Introductory Engineering Scenarios

Table 2c.Level of Mathematical Readiness of Students in Introductory Engineering Scenario Application of Calculus

Application of Calculus to Introductory Engineering Scenarios	Frequency (n=60)	Percentage
Optimization — Rectangular water tank: minimize surface area S; state the engineering significance.		
Full Credit	8	13.33
Partial (Minor)	17	28.33
Partial (Major)	22	36.67
Minimal Credit	12	20
No Credit	4	6.67
Mean	***2.17***	***Partial Credit (Major)***
S.D.	***1.10***	
Differentiation — Temperature of metal rod $T(x) = 5x^2 - 3x + 2$: rate of change at $x = 2$, minimum position, and engineering interpretation.		
Full Credit	10	16.67
Partial (Minor)	16	26.67
Partial (Major)	20	33.33
Minimal Credit	10	16.67
No Credit	4	6.67
Mean	*2.30*	*Partial Credit (Major)*
S.D.	*1.13*	
Integration — Pipeline arc length $y = x^3$: set up integral, estimate using Trapezoidal Rule ($n = 4$), explain engineering relevance.		
Full Credit	5	8.333
Partial (Minor)	10	16.67
Partial (Major)	22	36.67
Minimal Credit	16	26.67
No Credit	7	11.67
Mean	*1.83*	*Partial Credit (Major)*
S.D.	*1.10*	
Integration — Velocity $v(t) = 6t^2 - 4t$: displacement and total distance traveled from $t = 1$ to $t = 3$; engineering distinction.		
Full Credit	0	0
Partial (Minor)	9	15
Partial (Major)	18	30
Minimal Credit	24	40
No Credit	9	15
Mean	***1.45***	***Partial Credit (Major)***
S.D.	***0.92***	
Integration — Drainage canal $A(x) = 4 - x^2$: total cross-sectional area, volumetric flow rate, engineering significance.		
Full Credit	0	0
Partial (Minor)	11	18.33
Partial (Major)	20	33.33
Minimal Credit	22	36.67
No Credit	7	11.67
Mean	***1.58***	***Partial Credit (Major)***
S.D.	***0.92***	
Overall Weighted mean	***1.87***	***Partial Credit (Major)***
S.D.	***1.03***	

Table 2c shows an overall mean score of 1.87 (SD = 1.03), indicating a Partial Credit (Major) level in problem-solving. The highest mean (2.30, SD = 1.13) was obtained in a differentiation item, where 43.34% of students demonstrated competent

DOI: 10.5281/zenodo.19691235

performance, likely due to familiarity with standard procedures. In contrast, the lowest mean (1.45, SD = 0.92) was recorded in an integration problem requiring displacement and total distance analysis, with no student achieving full credit and most receiving minimal or no credit. Similarly, a real-world application involving flow rate yielded a low mean (1.58) with no full-credit responses. These results highlight students' difficulty in applying integration concepts to real-world engineering contexts. Overall, the findings reveal a gap between procedural skills and analytical application, supporting studies that students struggle with unfamiliar tasks and emphasizing the importance of strengthening contextualized teaching approaches in Calculus instruction.

d. Confidence, Motivation, and Attitude toward Learning Calculus

Table 2d. Students' Level of Mathematical Readiness in terms of Confidence, Motivation, and Attitude toward Learning Calculus

Statements	Weighted Mean	Descriptive Value
A. Confidence in Calculus		
1. I am confident that I can solve basic Calculus problems independently.	3.48	High
2. I believe my mathematics background is sufficient for Calculus.	3.35	Moderate
3. I persist and do not give up when I face a difficult Calculus problem.	3.60	High
4. I feel prepared to take Calculus-based subjects in college.	3.27	Moderate
5. I trust that I can understand new Calculus topics with sufficient practice.	3.75	High
6. When I struggle in Calculus, I believe I can improve with more effort.	3.98	High
7. I can explain a Calculus concept clearly to a classmate.	3.08	Moderate
8. I do not believe I have the ability to pass a Calculus course in college. *(R)	3.50	High
9. I feel overwhelmed and helpless when I encounter unfamiliar Calculus problems. *(R)	3.30	Moderate
10. I am confident in applying Calculus concepts to solve real engineering problems.	3.37	Moderate
Category Mean	***3.47***	***High***
B. Motivation toward Learning Calculus		
11. I study Calculus because I see its direct value in engineering.	3.80	High
12. I go beyond required lessons to deepen my understanding of Calculus.	3.15	Moderate
13. I enjoy discovering how Calculus applies to real engineering problems.	3.43	High
14. I set personal goals to improve my Calculus performance.	3.60	High
15. Solving a challenging Calculus problem makes me feel accomplished.	3.72	High
16. I seek additional resources (videos, books, tutors) when I struggle.	3.33	Moderate
17. I look forward to learning more advanced Calculus topics in college.	3.43	High
18. I find no reason to study Calculus beyond what is required in class. *(R)	3.62	High
19. I give up easily when a Calculus topic becomes difficult to understand. *(R)	3.58	High
20. I am willing to spend extra time practicing Calculus to improve my performance.	3.65	High
Category Mean	***3.53***	***High***
C. Attitude toward Learning Calculus		
21. I believe Calculus is an important subject for engineering students.	4.13	High
22. I think studying Calculus is worth the effort it demands.	3.92	High
23. I approach difficult Calculus topics with a positive attitude.	3.52	High
24. I value the logical reasoning that studying Calculus develops in me.	3.87	High
25. My Calculus performance reflects my effort, not just my natural ability.	3.72	High
26. My teachers have adequately prepared me for the demands of Calculus.	3.47	High
27. I do not feel anxious about encountering Calculus in college. *(R)	3.27	Moderate
28. I think Calculus is unnecessarily difficult and not useful in real life. *(R)	3.68	High
29. I believe I can develop a strong understanding of Calculus if I study consistently.	3.85	High
30. I feel that learning Calculus contributes positively to my overall intellectual growth.	3.75	High
Category Mean	***3.72***	***High***

DOI: 10.5281/zenodo.19691235

Overall Weighted Mean	3.57	High

Table 2d indicates that the respondents had a total weighted mean of 3.57 and therefore the group was in the High level of affective readiness in regard to confidence, motivation, and attitude towards learning Calculus. Throughout the instrument, item 21, which is "I believe Calculus is an important subject to be studied by engineering students" in the Attitude towards Learning Calculus, received the largest weighted mean score of 4.13, which is interpreted as High and at the same time is approaching very high. This response, which is just less than ceiling, suggests a near-universal understanding of the respondents that Calculus is not simply an academic necessity but a tool that they will use to support their planned engineering career. At the opposite end, the product I go beyond the necessary lessons to improve my background on Calculus registered the lowest weighted mean in this subscale with 3.15 and this was only considered as Moderate. The moderate rating is a typical trend among the students in the Philippine public senior high schools, in which the lack of time, learning materials, unreliable internet connections, and conflicting school and family obligations hinder the ability to engage in self-directed study. Macaso and Dagohoy (2022) affirmed that positive attitudes, confidence, enjoyment, and valuing mathematics were effective predictors of achievement among Filipino senior high school students but the affective factors had to be complemented by a sufficient number of learning resources and favorable instructional conditions to generate meaningful results in terms of performance.

The overall weighted average of 3.57 (High) of the three subscale totals that are encouraging because it indicates that the respondents have a solid affective basis of Calculus learning. Nevertheless, in Table 2a, Table 2b, and Table 2c, the positive relationship between this high affective preparedness and Approaching Proficiency or Partial Credit cognitive achievement highlights a key point that positive attitudes, high motivation, and growth mindset convictions are not a sufficient but a necessary determining factor in Calculus achievement. Domondon et al. (2022) found that the reasons behind difficulty in Basic Calculus were low conceptual understanding, formula and process mix-up, and lack of time and confidence to suggest that even students who report being highly motivated and positive attitude may continue to be at a disadvantage in their academic results until the concept gaps are sufficiently addressed through the quality of instruction they receive.

Students' Challenges Encountered in Calculus

Table 3. Students' Challenges Encountered in Calculus

Statements	Weighted Mean	Descriptive Value
A. Conceptual Challenges		
1. I struggle to understand the formal definition of a limit.	2.53	Often
2. I confuse continuity with differentiability.	2.67	Often
3. I cannot visualize what a derivative represents geometrically.	2.77	Often
4. I find it hard to connect integration to area and accumulation.	2.65	Often
5. I do not fully understand why the Fundamental Theorem of Calculus works.	2.78	Often
Category Mean	***2.68***	***Often***
B. Procedural Challenges		
6. I make frequent errors applying differentiation rules (chain, product, quotient).	2.82	Often
7. I find integration techniques (substitution, integration by parts) difficult.	2.95	Often
8. I struggle to set up and evaluate definite integrals correctly.	2.80	Often
9. Implicit differentiation is confusing to me.	2.88	Often
10. Algebraic or arithmetic errors consistently lead me to incorrect Calculus answers.	2.87	Often
Category Mean	***2.86***	***Often***
C. Application Challenges		
11. I cannot translate word problems into Calculus equations.	2.82	Often
12. Optimization and related rates problems are difficult for me.	2.97	Often
13. I struggle to apply Calculus concepts to engineering or science contexts.	2.92	Often
14. I do not know which Calculus technique to use in an unfamiliar problem.	2.98	Often
15. I have difficulty interpreting the physical or engineering meaning of my Calculus answers.	2.90	Often
Category Mean	***2.92***	***Often***
D. Affective and Environmental Challenges		
16. I feel anxious or nervous during Calculus exams or recitations.	2.95	Often
17. I lack confidence in my ability to succeed in Calculus.	2.77	Often
18. I do not have access to adequate review materials or references for Calculus.	2.53	Often
19. The pace of instruction is too fast for me to understand each Calculus topic fully.	2.85	Often
20. I have limited time to study and practice Calculus outside of class.	3.00	Often
Category Mean	***2.82***	***Often***
E. Instructional and Resource Challenges		

DOI: 10.5281/zenodo.19691235

21. My teacher's explanations are difficult to follow or understand.	2.43	Sometimes
22. I do not receive timely or helpful feedback on my Calculus work.	2.60	Often
23. The Calculus learning materials provided are insufficient for self-study.	2.67	Often
24. Distractions in my learning environment make it hard to focus on Calculus.	2.77	Often
25. I struggle to connect what I learn in class to how Calculus is used in engineering.	2.85	Often
Category Mean	***2.66***	***Often***
Overall Weighted Mean	**2.79**	**Often**

The data presented in Table 3 reveal that the respondents experienced an overall weighted mean of 2.79, interpreted as *Often*, across all five subscales of the Calculus Challenges Checklist. Along Affective and Environmental Challenges**,** Item 20 — *"I have limited time to study and practice Calculus outside of class"* recorded the highest weighted mean at 3.00, interpreted as *Often* and the highest score in this entire scale. For students in public senior high schools in Camalaniugan and Lallo, Cagayan, limited study time is not merely an academic issue but a socio-economic one, many students commute long distances to school, assist with household responsibilities, and lack the financial resources for tutoring or supplementary instruction. This finding directly contextualizes the moderate self-directed learning behavior observed in Table 2d, Item 12, where students expressed limited willingness to study beyond required lessons are not necessarily due to lack of motivation but due to structural time constraints. Meanwhile, the lowest weighted mean in all the items in the entire instrument was on Item 21, which was 2.43, with the lowest weight, which is the only item in the Sometimes range, and the explanation of my teacher. Such a relatively positive rating of teacher clarity indicates that the respondents tend to believe that the Calculus teachers can be easily comprehended even though the instructional speed (Item 19, WM = 2.85) and the contextual relevance to engineering (Item 25) are the obstacles. This is a key colour: it is not so much about the way teachers teach Calculus, but rather about the way the curriculum and instructional rate are organized to make the entire learning process in a certain pattern. The authors determined that improving the TPACK of teachers in the chosen topics in Calculus by using professional development programs had significant impacts on the quality of instruction in Senior High School STEM Calculus in the Philippines, and the knowledge development of teachers, specifically in the ability to relate Calculus to technological and engineering factors, was one of the most important keys to reducing the identified instructional gap in the present study as indicated by the Item 25.

The mean weighted of 2.79 (Often) of all five subscales with the highest category result of 2.92 in Application Challenges and the lowest in Instructional and Resource Challenges (2.66) indicates that there was a distinct order of difficulty among the respondents. The fact that the often-reported challenges in application frequently coincide with the near-zero Full Credit rates in Table 2c proves that the failure to apply Calculus to engineering situations is the most frequently encountered issue, as well as the most significant performance difference.

Comparison between the mathematical readiness of the STEM students when grouped according to profile

Table 4. Comparison between the mathematical readiness of the STEM students when grouped according to profile

Profile Variables	*Mathematical Readiness*		
	f-value	**P-value**	**Statistical Inference**
Age	3.468	0.038	Significant*
Sex	1.774	0.189	Not Significant
Socio-economic status	0.512	0.727	Not Significant
Grades in General Mathematics	85.389	< .001	Significant*
Grades in Pre-Calculus	61.275	< .001	Significant*
Grades in Calculus	125.133	< .001	Significant*
Overall General Weighted Average	38.005	< .001	Significant*

The table 4 data demonstrates that out of the seven profile variables considered, five out of them had statistically significant differences in mathematical readiness: age, General Mathematics, Pre-calculus, Calculus, and general academic performance or GWA.

As it can be seen, a great disparity in mathematical preparation was observed between the respondents in terms of age grouped together ($F = 3.468$, $p = 0.038$). This is in line with the sequential architecture of the K to 12 framework where mathematical preparedness to Calculus is anticipated to be incremental and grade-by-grade. This finding is similarly supported by Pursuing STEM Careers (2023), which found statistically significant differences in the challenges encountered by Senior High School STEM students during distance learning when grouped according to age, suggesting that age-related differences in academic experience and cognitive readiness are a consistent differentiator among Filipino SHS STEM learners.

More so, a highly significant difference in mathematical readiness was found when respondents were grouped according to their grade in General Mathematics, Pre-Calculus, Calculus and GWA. This implies that students' academic performance influences their mathematical readiness. Guinocor et al. (2020) argue that mathematical readiness is cumulative, meaning success in Calculus depends on mastering foundational concepts first.

Correlation between the profile of the SHS STEM learners and their Challenges encountered in Calculus and Mathematical Readiness

Table 5a. Correlation between the profile of the SHS STEM learners and their Challenges encountered in Calculus

Profile Variables	*Challenges Encountered*		
	r-value	**P-value**	**Statistical Inference**

DOI: 10.5281/zenodo.19691235

Age	0.041	0.755	Not Significant
Sex	-0.134	0.307	Not Significant
Socio-economic status	0.033	0.804	Not Significant
Grades in General Mathematics	0.012	0.928	Not Significant
Grades in Pre-Calculus	0.061	0.642	Not Significant
Grades in Calculus	0.027	0.836	Not Significant
Overall academic performance in Math	0.023	0.863	Not Significant

**tested at 0.05 level of significance using Pearson-r.*

**N.S -Not Significant; S-Significant; H.S-Highly Significant; S.I-Statistical Inference*

Table 5a reveal that none of the seven profile variables including age, sex, socio-economic status, grades in General Mathematics, grades in Pre-Calculus, grades in Calculus, and overall academic performance showed a statistically significant correlation with the challenges encountered by the respondents in learning Calculus. All r-values were negligible in magnitude, and all corresponding p-values exceeded the 0.05 level of significance. The absence of any significant correlation across all profile variables with Calculus challenges strongly suggests that the difficulties encountered in learning Calculus whether conceptual, procedural, application-based, or affective are not confined to any particular subgroup of learners. Rogayan et al. (2021), in a qualitative study of Filipino Senior High School STEM students, found that challenges in STEM learning were experienced broadly across the student population regardless of background, driven primarily by subject complexity, high workload, and teacher expectations rather than by individual demographic characteristics.

Table 5b. Correlation between the profile of the SHS STEM students and their Mathematical Readiness

Profile Variables	*Conceptual understanding of Calculus concepts*			*Problem-solving and analytical skills in Calculus*			*Application of calculus to introductory engineering scenarios*			*Confidence, motivation and attitude toward learning Calculus*		
	r	**P**	**S.I**	**r**	**P**	**S.I**	**r**	**P**	**S.I**	**r**	**P**	**S.I**
Age	-0.034	0.795	N.S	0.038	0.771	N.S	0.095	0.468	N.S	-0.022	0.870	N.S
Sex	-0.204	0.118	N.S	-0.198	0.129	N.S	-0.127	0.335	N.S	-0.154	0.241	N.S
Socio-economic status	-0.143	0.277	N.S	-0.089	0.500	N.S	-0.165	0.207	N.S	-0.080	0.543	N.S
Grades in General Mathematics	***.307****	***0.017***	***S***	0.156	0.235	N.S	0.15	0.254	N.S	***.391*****	***0.002***	***H.S***
Grades in Pre-Calculus	***.294****	***0.023***	***S***	0.168	0.199	N.S	0.084	0.523	N.S	***.344*****	***0.007***	***H.S***
Grades in Calculus	***.363*****	***0.004***	***H.S***	0.203	0.120	N.S	0.233	0.073	N.S	***.369*****	***0.004***	***H.S***
Overall academic performance in Math	***.365*****	***0.004***	***H.S***	0.240	0.064	N.S	0.233	0.073	N.S	***.433*****	***0.001***	***H.S***

Table 5b reveals a coherent pattern of relationships between students' profile variables and mathematical readiness across four dimensions: conceptual understanding, problem-solving and analytical skills, application to engineering scenarios, and affective readiness (confidence, motivation, and attitude). Socio-demographic variables such as age, sex, and socioeconomic status showed no significant correlations with any dimension. In contrast, academic variables—grades in General Mathematics, Pre-Calculus, Calculus, and GWA—demonstrated significant relationships with conceptual understanding and affective readiness. These findings suggest that strong prior academic performance supports deeper conceptual learning and fosters positive attitudes and motivation toward Calculus, consistent with existing literature linking achievement and self-efficacy.

However, no significant relationships were found between academic grades and higher-order skills such as problem-solving and application to engineering contexts. This indicates that while students may be conceptually prepared and confident, they struggle to transfer knowledge to complex, real-world tasks, highlighting a gap between procedural proficiency and analytical application.

These findings underscore the need for targeted interventions. In response, Project BRIDGE STEM was developed, consisting of three components: Skill Lab, which uses peer-assisted drills to strengthen foundational skills; Contextualized Engineering Modules, which connect Calculus concepts to real-world structures; and Calculus Context Lectures, which engage alumni to demonstrate practical applications. Together, these strategies aim to bridge readiness gaps and support students' transition to engineering fields.

Conclusion

The research concludes the mathematical preparedness of STEM students in calculus to be at the Approaching Proficiency level in conceptual understanding and problem-solving but far behind in the application of concepts in engineering. However, the students possess great confidence, motivation and positive attitude towards Calculus that depicts emotional support base that facilitates further study. Nevertheless, the learners tend to face conceptual, procedural and practical problems that prevents the transfer of theory to practice. The mathematical preparedness of students differed greatly in relation to age and academic grades in General Mathematics, Pre-Calculus, and Calculus, but not sex or socio-economic status. Amazingly, no significant correlation was observed between student profiles with the challenges that they face meaning that the challenges faced in Calculus are a common experience regardless of demographic background. Although there was a positive correlation between academic performance and conceptual understanding and affective preparedness, they did not correlate with problem-solving and application skills, and a serious lack of connection between theoretical and real world situation is underlined. On that note, a project BRIDGE STEM is created.

Recommendations

It is recommended that school administrators and principals consider adopting Project BRIDGE STEM to address gaps in mathematical readiness, while SHS Math and Calculus teachers

DOI: 10.5281/zenodo.19691235

provide additional procedural problem-solving activities to strengthen students' mastery. STEM students are also encouraged to take initiative in mastering foundational concepts in General Mathematics and Pre-Calculus, as these significantly influence their preparedness. Furthermore, future researchers may conduct longitudinal studies to determine whether the identified readiness levels accurately predict success in advanced engineering mathematics.

Declaration of no Conflict of Interest

The author hereby declares that this article is his original work and hence no any conflict of interest.

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