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The Predictive Relationship Of Pre-Calculus And Basic Calculus With General Physics 1 And 2 Performance Of Senior High School STEM Students

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Abstract: This study examined the relationship between specialized mathematics subjects (Pre-Calculus and Basic Calculus) and specialized science subjects (General Physics 1 and General Physics 2) among Senior High School STEM students. A quantitative-correlational design was employed, analyzing the grades of 430 students from S.Y. 2023–2024. Descriptive statistics were used to determine mean grades, Pearson's correlation tested relationships among the four subjects, and multiple regression analysis was conducted to examine the predictive power of Pre-Calculus and Basic Calculus on Physics 1 and 2 performances. Results revealed that students generally performed well across subjects (with mean grades in the mid-80s). Correlation analysis showed that all subjects were significantly and positively related ($p < 0.001$). The strongest relationship was between Pre-Calculus and Basic Calculus ($r = 0.76$), confirming their sequential nature, while moderate to strong correlations were also found between Calculus and Physics subjects. Regression results showed that both Pre-Calculus and Basic Calculus significantly predicted Physics performance. For Physics 1, both were nearly equal predictors ($\beta = 0.387$ and $\beta = 0.393$), explaining 53% of the variance. For Physics 2, Basic Calculus was the stronger predictor ($\beta = 0.469$ vs. $\beta = 0.240$), accounting for 45% of the variance. This means that being strong in Math, especially in Basic Calculus, helps students in Physics. Teachers are then encouraged to connect Calculus and Physics lessons so students can clearly see how the two subjects work together.

Index Terms – Multiple regression, correlation, vertical alignment, mathematics, physics

I. INTRODUCTION

Improving STEM education requires an understanding of the connection between academic achievement in physics and calculus. Multiple studies report a strong positive correlation between students' performance in calculus and their grades in calculus-based physics courses (Quimson, 2021; AlAhmad et al., 2020). This indicates that students who do well in calculus tend to also perform well in physics (Jihe et al., 2021). This correlation is seen across various student populations and course styles at both the high school and college levels. Some studies even highlight that math skills are important for success in physics, but not always sufficient on their own (Quimson, 2021; Jihe et al., 2021). In simple words, students still need to apply math skills in physics contexts.

Some studies say that just being good at calculus does not always mean a student will be good at physics (Haldolaarachchige & Hettiarachchilage, 2022; Haldolaarachchige, 2022). What seems to matter more is how well students understand the ideas behind the physics, not just the math. For instance, if a student understands how forces work or how energy is used, they might do better in physics even if they are not that strong in calculus or other mathematics. Moreover, many students also have a hard time using what they learned in calculus when solving physics problems. They may know how to do calculus in math class, but they struggle when they have to apply it in physics (Quimson, 2022). This is especially true when setting up and solving problems that need integration or understanding how things change over time. Because of this, some experts believe that math and physics should be taught more closely together. When students learn both at the same time, they might understand better how the math connects to real-life science problems. Aside from math skills, sense of belonging, self-efficacy, and prior conceptual physics knowledge, also significantly influence physics performance even without good performance in calculus (Li & Singh, 2023; Haldolaarachchige & Hettiarachchilage, 2022).

The Philippine Department of Education (DepEd) will now be implementing a Strengthened Senior High School Curriculum. This curriculum introduces reforms in structure, instruction, and content for enhancing learner choice based on ability. Moreover, the SHS program shall transition from its current structure with four academic strands (i.e., ABM, HUMSS, GAS, and STEM) to only two educational pathways (Academic and Technical-Professional). As a result, unlike students who enrolled in STEM who take Pre-Calculus and Basic Calculus as pre-requisites to General Physics 1 and 2 subjects, students in the strengthened SHS curriculum can choose whether to take or not to take calculus as a pre-requisite to physics as their elective. This would eventually happen unless the school would strictly require students to take calculus as a pre-requisite elective to physics.

Mathematics and Physics are known to be closely connected, as Physics often requires mathematics to solve problems. However, little is known about how Senior High School students' performance in Calculus relates to and predicts their Physics achievement. Thus, this study determined the predictive relationship between the SHS STEM students' grades in pre-calculus, basic calculus, and general physics 1 and 2. With this, physics and mathematics educators would have a basis for developing related curricula and striving for curriculum alignment for improved STEM education. Students would eventually be cognitively prepared for their chosen career pathway in the strengthened SHS curriculum.

Research Questions:

1) What are the average grades of SHS students in pre-calculus and basic calculus in S.Y. 2023–2024?
2) What are the average grades of SHS students in general physics 1 and general physics 2 in S.Y. 2024–2025?
3) Is there a significant relationship between pre-calculus, basic calculus, general physics 1, and general physics 2?
4) Can we predict the SHS students' General Physics 1 and 2 grades based on their Pre-Calculus and Calculus grades?
5) Which math subject (Pre-Calculus or Basic Calculus) better predicts performance in General Physics 1 and 2?

II. METHODS

Study Design

A quantitative-correlational research design was used in this study. It seeks to determine whether there is a meaningful correlation between students' academic performance in their specialized math subjects (Pre-Calculus and Basic Calculus) and their specialized physics subjects (General Physics 1 and General Physics 2). A correlational analysis established the magnitude and significance of relationships between the variables (Schober & Vetter, 2020). Additionally, multiple regression analysis was utilized to analyze and quantify the relationship between the outcome of interest (General Physics 1 grades then General Physics 2 grades) and two predictors or explanatory variables (Pre-Calculus and Basic Calculus grades) (Chen et al., 2021).

To note, the Pre-Calculus curriculum had Analytical Geometry, Series and Mathematical Induction, and Trigonometry. In addition, the Basic Calculus curriculum contained Limits and Continuity, Derivatives, and Integration. Meanwhile for General Physics 1, it comprised of Classical Mechanics (Translational, Rotational, and Celestial), Acoustics, Fluid Mechanics, and Thermodynamics. For General Physics 2, it consisted of Electricity and Magnetism, Optics, Relativity, and Atomic/Nuclear Physics.

Population and Sampling

Senior high school students who had already completed both specialized math courses (Pre-Calculus and Basic Calculus) and specialized physics courses (General Physics 1 and General Physics 2) were the study's participants. All students were included in the study using a survey sampling technique (Turner, 2020). The study population consisted of 430 students from the STEM (science, technology, engineering, and mathematics) strand. Moreover, a student must have taken the Pre-Calculus and Basic Calculus subjects during their Grade 11 (S.Y. 2023–2024) and the General Physics 1 and 2 subjects during their Grade 12 (S.Y. 2024–2025).

Instrumentation

The data for this study came from the official class records or grade sheets provided by the school registrar. These documents show the final grades of students in the four subjects. In simple words, no survey or test were given because the needed information was already recorded by the school.

Data Analysis

The analysis was done using JASP software version 0.19.1. The grades collected were first summarized using descriptive statistics, such as mean and standard deviation. To determine if the grades were related to one another, the Pearson correlation coefficients (Pearson's r) were computed. Correlation analysis measured how strong and in what direction the relationship was between the specialized subject grades (Janse et al., 2021). Then, multiple regression analysis was implemented to examine and model the relationship between the predictors (Pre-Calculus and Basic Calculus grades) and outcomes (General Physics 1 grades then General Physics 2 grades) (Ruan, 2024). To determine which specialized math subject would be the stronger predictor, standardized beta coefficients were compared (i.e., the larger the beta coefficient, the stronger the predictive capacity) (Mizumoto, 2022).

III. Results and Discussion

A. SHS Students' Grades in Pre-Calculus, Basic Calculus, General Physics 1, and General Physics 2 (RQ1 & RQ2)

Table 1 presents the descriptive statistics for students' grades in Pre-Calculus, Basic Calculus, General Physics 1, and General Physics 2. For the 430 students included in the analysis, the mean grade in Pre-Calculus was 86.16 (SD = 4.57), with scores ranging from 75 to 98. Additionally, the mean grade in Basic Calculus was 86.82 (SD = 4.48), also ranging from 75 to 98.

Table 1. Descriptive Statistics for Students' Grades in Pre-Calculus, Basic Calculus, General Physics 1, and General Physics 2

Subjects	N	Mean	Std. Dev.	Min	Max
PCalc	430	86.16	4.57	75.00	98.00
BCalc	430	86.82	4.48	75.00	98.00
GnPhys1	430	84.62	2.88	75.00	93.00
GnPhys2	430	84.01	3.24	75.00	92.00

The findings show that students generally performed well in both Pre-Calculus and Basic Calculus. The slightly higher average in Basic Calculus suggests that students were able to build upon the foundational knowledge gained in Pre-Calculus. In other words, this enabled them to perform consistently or even better in more advanced mathematical tasks. The results indicate that the mathematical preparation provided in Pre-Calculus was effective in supporting students as they transitioned into Basic Calculus.

Furthermore, the mean grade of students in General Physics 1 was 84.62 (SD = 2.88), with scores ranging from 75 to 93. Meanwhile, the mean grade in General Physics 2 was slightly lower at 84.01 (SD = 3.24), with scores ranging from 75 to 92. This indicates that students generally achieved satisfactory performance in both physics courses. However, the average grade in General Physics 2 was marginally lower compared to General Physics 1. In addition, the spread of the scores was wider (SD = 3.24 versus 2.88). This suggests that while students maintained competence across both courses, they may have found General Physics 2 slightly more challenging. It is important to note that General Physics 1 covered mechanics topics that are more concrete and directly connected to everyday experiences. Meanwhile, General Physics 2 introduced more abstract and mathematically intensive concepts such as electricity, magnetism, and relativity. These may explain the slight decline in average performance as well as greater variability of grades. It is thus important, most especially in the basic education curriculum, to have a strong sequential learning in mathematics (Espiritu & Vendicacion, 2024; Ai et al., 2022). Strong performance in Pre-Calculus provided a foundation for understanding Basic Calculus concepts, which in turn becomes critical for subjects such as General Physics.

B. Relationship between Pre-Calculus, Basic Calculus, General Physics 1, and General Physics 2 (RQ3)

Table 2 presents the correlation coefficients among Pre-Calculus, Basic Calculus, General Physics 1, and General Physics 2. As observed, all correlation values were positive and statistically significant ($p < 0.001$). This is an indication that higher performance in one subject was associated with higher performance in the others.

Table 2. Relationship between Pre-Calculus, Basic Calculus, and General Physics 1 and 2

Variables	PCalc	BCalc	GnPhys1	GnPhys2
PCalc	–	–	–	–
BCalc	0.76 <0.001	–	–	–
GnPhys1	0.68 <0.001	0.69 <0.001	–	–
GnPhys2	0.59 <0.001	0.65 <0.001	0.66 <0.001	–

Notably, the strongest relationship was found between Pre-Calculus and Basic Calculus ($r = 0.76$, $p < 0.001$). This tells us that there was a close connection between students' performance in these two mathematical courses. Moreover, both Pre-Calculus and Basic Calculus showed moderately strong correlations with General Physics 1 ($r = 0.68$ and $r = 0.69$, respectively, $p < 0.001$). Similarly, Pre-Calculus and Basic Calculus were positively correlated with General Physics 2 ($r = 0.59$ and $r = 0.65$, respectively, $p < 0.001$). Finally, a significant relationship was also seen between General Physics 1 and General Physics 2 ($r = 0.66$, $p < 0.001$).

The correlation analysis demonstrated that the students' achievements in Pre-Calculus, Basic Calculus, General Physics 1, and General Physics 2 were strongly interconnected. To note, mastery of foundational Pre-Calculus skills support success in more advanced Basic Calculus concepts. The very high correlation between Pre-Calculus and Basic Calculus reflects this sequential nature of mathematics instruction.

Furthermore, the moderately strong correlations between Calculus and Physics confirm the role of mathematics as the "language of Physics" (Ge, 2024). Students who were able to perform well in Calculus subjects were better equipped to handle the demands of Physics, such as quantitative and problem-solving demands (Su, 2024). Moreover, the significant relationship between General Physics 1 and General Physics 2 also emphasizes the cumulative structure of Physics education (Jiang et al., 2024). Specifically, a high performance in General Physics 1 provided a foundation for tackling the more abstract contents of General Physics 2.

The Cognitive Load Theory by Sweller (1988) posits that learning complex concepts requires sufficient working memory resources (Sweller, 2024). The strong correlations of Calculus and Physics grades observed in this study simply tells that students with stronger Calculus skills can devote more cognitive resources to conceptual understanding in Physics rather than struggling with computations (Jihe et al., 2021; Chen et al., 2021). In particular, Calculus gives students schemas and problem-solving strategies that reduce extraneous cognitive load when engaging with Physics tasks (Quimson, 2021). Moreover, in the lens of the Constructivist theory of Piaget (1970), learners build new knowledge upon prior knowledge (Brau, 2020). Pre-Calculus serves as the foundation, equipping students with analytical geometry, series, and trigonometry, while Basic Calculus develops more advanced mathematical reasoning (Ge, 2024).

C. Predicting General Physics 1 Performance from Pre-Calculus and Basic Calculus (RQ4a)

Table 3 presents the regression model summary for General Physics 1. The model was statistically significant, $F(2, 427) = 245.36$, $p < 0.001$, with an overall multiple correlation of $R = 0.73$.

Table 3. Model Summary for General Physics 1

Model	R	R2	Adjusted R2	RMSE	p	Durbin-Watson		
						Autocor-relation	Statistic	p
M1	0.73	0.54	0.53	1.97	<0.001	-0.062	2.122	0.21

Note. M1 includes PCalc, BCalc

Furthermore, the predictors (Pre-Calculus and Basic Calculus) together explained 54% of the variance in General Physics 1 grades, with adjusted R2 = 0.53 and root mean square error (RMSE) of 1.97. Moreover, the Durbin-Watson statistic (2.12, p = 0.21) indicated no violation of independence of errors. The results indicate that Pre-Calculus and Basic Calculus grades significantly predict students' performance in General Physics 1. With more than half of the variance in General Physics 1 explained by these two mathematics subjects.

Table 4. Coefficients for the Model for General Physics 1

Variables	Estimate	SE	Standardized	95% CI		p
				LL	UL	
Intercept	41.63	1.94	–	37.81	45.45	<0.001
PCalc	0.24	0.03	0.387	0.18	0.31	<0.001
BCalc	0.25	0.03	0.393	0.19	0.32	<0.001

Based on Table 4, the regression equation for predicting General Physics 1 was:

$$GnPhys1 = 41.63 + 0.24(PCalc) + 0.25(BCalc)$$

Both predictors were statistically significant ($p < 0.001$), with standardized coefficients showing that Pre-Calculus ($\beta = 0.387$) and Basic Calculus ($\beta = 0.393$) contributed almost equally to General Physics 1 performance. This suggests that while Pre-Calculus provides the foundational algebraic and functional skills needed for Physics problem-solving, Basic Calculus strengthens the analytical and computational abilities required for topics such as kinematics and dynamics (AlAhmad et al., 2020; Greene & Lopez, 2019).

To note once again, in the lens of the Constructivist Theory, success in Physics depend on prior mastery of pre-requisite mathematics concepts (Brau, 2020). The results showing that Pre-Calculus and Basic Calculus significantly predict General Physics 1 performance support this constructivist principle (Zajda, 2021). As an honorable mention, Bloom's Taxonomy (Bloom, 1956) highlights the skills progression from lower-order to higher-order thinking (Larsen et al., 2022). To be particular, Pre-Calculus develops knowledge and comprehension, Basic Calculus fosters application and analysis, and General Physics requires synthesis and evaluation of both conceptual and mathematical knowledge.

D. Predicting General Physics 2 Performance from Pre-Calculus and Basic Calculus (RQ4b)

Table 5 presents the regression model summary for General Physics 2. The model was statistically significant, $F(2, 427) = 173.10$, $p < 0.001$, with a multiple correlation of $R = 0.67$.

Table 5. Model Summary for General Physics 2

Model	R	R2	Adjusted R2	R2 Change	p	Durbin-Watson		
						Autocor-relation	Statistic	p
M2	0.67	0.45	0.45	2.41	<0.001	0.027	1.95	0.59

Note. M2 includes PCalc, BCalc

The predictors (Pre-Calculus and Basic Calculus) explained 45% of the variance in General Physics 2, with Adjusted R2 = 0.45 and RMSE = 2.41. Moreover, the Durbin-Watson statistic (1.95, p = 0.59) confirmed that the independence of errors assumption was satisfied. The results show that Pre-Calculus and Basic Calculus were significant predictors of students' achievement in General Physics 2, accounting for nearly half of the variance in grades.

Table 6. Coefficients for the Model for General Physics 2

Variables	Estimate	SE	Standardized	95% CI		p
				LL	UL	
Intercept	39.98	2.38	–	35.31	44.66	<0.001
PCalc	0.17	0.04	0.240	0.09	0.25	<0.001
BCalc	0.34	0.04	0.469	0.26	0.42	<0.001

Looking at Table 6, the regression equation for predicting General Physics 2 was:

$$GnPhys2 = 39.98 + 0.17(PCalc) + 0.34(BCalc)$$

Both Pre-Calculus ($\beta = 0.240$, $p < 0.001$) and Basic Calculus ($\beta = 0.469$, $p < 0.001$) were found to be significant predictors, with Basic Calculus exerting a stronger effect on General Physics 2 performance. Basic Calculus emerged as the stronger predictor of General Physics 2 performance. This is expected, as General Physics 2 involved more abstract and mathematically intensive topics such as electricity, magnetism, and relativity. Notably, if one is to compare to the General Physics 1 model (Adjusted R2 = 0.53), the predictive power here is slightly lower (Adjusted R2 = 0.45), which indicates that additional factors beyond Calculus may influence students' performance in General Physics 2.

As implied by the Cognitive Load Theory, the strong predictive power of Calculus on Physics grades observed aligns with the thought that students with stronger Calculus skills can devote more cognitive resources to conceptual understanding in Physics rather than struggling with computations (Sweller, 2024; Sweller, 2019). Further, the Transfer of Learning Theory by Thorndike (1922) and Perkins and Salomon (1992) explains how skills acquired in one domain (such as mathematics) can be applied to another (i.e., Physics) (Nathan & Alibali, 2021). The regression results, where Basic Calculus more strongly predicted General Physics 2, exemplify far transfer. This is because abstract mathematical concepts are applied to scientific context (Zhu et al., 2020). To generalize, positive transfer occurs when the skills from Calculus, such as differentiation and integration, are applied in solving Physics problems involving motion, energy, waves, and electromagnetism (Chen et al., 2021). As a final note, the finding that Basic Calculus is the stronger predictor of General Physics 2, as implied by Bloom's Taxonomy (Bloom, 1956), reflects progression, wherein, higher-order skills in mathematics enable higher-order reasoning in advanced Physics (Larsen et al., 2022).

E. Comparing the Predictive Power of Pre-Calculus and Basic Calculus (RQ5)

Tables 4 and 6 present the regression coefficients for General Physics 1 and 2. The findings show that both Pre-Calculus and Basic Calculus contributed significantly to students' performance in General Physics for Senior High School, but the degree of influence varied by course. Specifically, both Pre-Calculus ($\beta = 0.387$, $p < 0.001$) and Basic Calculus ($\beta = 0.393$, $p < 0.001$) were significant predictors for General Physics 1. The standardized coefficients indicate that Basic Calculus had slightly stronger effect, though the difference was minimal. This suggests that students need a balanced foundation of analytical geometry, series and mathematical induction, trigonometry, limits and continuity, derivatives, and integration to succeed in the kinematics, dynamics, acoustics, fluid mechanics, and thermodynamics contents of General Physics 1.

Additionally, Pre-Calculus ($\beta = 0.240$, $p < 0.001$) and Basic Calculus ($\beta = 0.469$, $p < 0.001$) were also significant predictors for General Physics 2. But in this case, Basic Calculus demonstrated a clearly stronger predictive power. This highlights the increasing importance of geometric, trigonometric, and calculus-based reasoning in mastering more abstract and mathematically demanding topics, such as electricity, magnetism, optics, relativity, and atomic/nuclear phenomena. Notably, while Pre-Calculus remains important, success in General Physics 2 relies more heavily on the skills developed in Basic Calculus.

According to Shulman's Pedagogical Content Knowledge (PCK) Framework (1986), subject content and pedagogy must be integrated for instruction to be effective (Tallman, 2023). To ensure that students see the connection between mathematical formulas and physical phenomena, teachers need to integrate mathematical skills into Physics instruction. In simple words, the strong link between Calculus and Physics performance highlights that teachers must bridge Calculus and Physics contents.

IV. Conclusion

This study looked at how specialized mathematics subjects (Pre-Calculus and Basic Calculus) are connected to specialized science subjects (General Physics 1 and General Physics 2) for Senior High School STEM strand. Firstly, it was seen that students did well in both Calculus and Physics, with average grades in the mid-80s. But their grades in Physics were slightly lower, especially in General Physics 2, which has harder and more abstract topics. Second, it was found that all subjects were significantly related. That is, students who are good in Calculus are usually also good in Physics. Pre-Calculus and Basic Calculus were very closely linked, because the lessons in Pre-Calculus prepare students for Basic Calculus. Moreover, General Physics 1 and General Physics 2 were also significantly related, which shows that doing well in the first Physics subject helps in doing well in the second. Third, it was found that both Pre-Calculus and Basic Calculus were important in predicting General Physics grades. The regression equations are the following: GnPhys1 = 41.63 + 0.24(PCalc) + 0.25(BCalc) and GnPhys2 = 39.98 + 0.17(PCalc) + 0.34(BCalc). For General Physics 1, both subjects mattered almost equally. But for General Physics 2, Basic Calculus was clearly more important, since Physics 2 topics use more advanced math. To summarize, this study shows that being strong in math, particularly Calculus, helps students do better in Physics.

Based on the results, while math and science are two separate subjects, schools should make sure that math skills are practiced and connected to science lessons. For instance, teachers can give activities where math problems are applied to real-life science examples, like using formulas for motion in Physics, simple experiments with speed and distance, or graph interpretations. In higher levels, review sessions in Pre-Calculus before starting Basic Calculus can also help learners build stronger foundations. Similarly, Physics teachers can explain how the math students already know is used in solving Physics problems. Furthermore, Math and Physics educators and curriculum experts can conduct vertical alignment; that is, they should plan topics that connect the two subjects, so students will clearly see how their learned concepts in Math can be used right away in their Science classes.

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