STRUCTURAL EQUATION MODELLING ANALYSIS OF THE RELATIONSHIP AMONG STUDENTS' INTELLECTUAL SUPPORTS, ATTITUDES, AND ACHIEVEMENT IN CALCULUS

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Abstract

Calculus is needed for many essential concepts in engineering and physical sciences. Its diverse applications in these fields require students to study and understand it rigorously; however, they find this subject very difficult. This study investigated the influence of attitudes and intellectual support on the academic performance of first-year college students studying calculus. A purposive sample of 211 students was selected from 233 enrolled students at Mindanao State University, General Santos City, comprising approximately 91% of the calculus students. The findings revealed a significant relationship between the intellectual support provided by peers and teachers and the students' performance in calculus. Additionally, students' attitudes toward calculus had a significant, albeit small, negative impact on their academic performance. The relationship between variables suggested that increased intellectual support positively influenced students' attitudes towards the subject. The Structural Equation Modelling (SEM) results give credence to the claim that intellectual supports have a substantial effect on calculus performance, while attitudes have a small negative effect. However, attitudes and intellectual supports correlated positively, suggesting that fostering positive attitudes through increased intellectual support could be beneficial. Based on these findings, it is recommended to bolster the learning environment with robust intellectual supports and to focus on enhancing students' attitudes towards calculus, despite the small negative effect observed.

Keywords: intellectual support, attitudes, achievement in calculus, SEM, Philippines

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1.0 Introduction

Globally, calculus is recognized as a fundamental component of science, engineering, and technology. Its principles are ubiquitous, serving as the backbone for numerous technological advancements and scientific breakthroughs. Despite its importance, students worldwide often perceive calculus as abstract, challenging, and monotonous. Narrowing our focus to the ASEAN region, we observe similar trends that extend to the local context of the Mindanao State University in General Santos City. This study examines how attitudes and academic support influence calculus performance among first-year engineering students at our university. We seek to address this globally relevant issue within our local context, aiming to improve student comprehension and interpretation of calculus, an integral subject for their academic and professional success.

Research literature has consistently highlighted students' struggles with calculus in global and ASEAN contexts. Students often need a deeper understanding and perform better on conceptual tasks (Department of Basic Education, 2015; Ferrer, 2016; Mokhtar *et al.*, 2010; Toh, 2009; Yuan, 2002). Bezuindenhout (2001) also identified misconceptions about fundamental calculus concepts among students. Moreover, studies have analyzed the impact of attitudes and intellectual support from key social agents on academic performance.

Despite these insightful findings, a gap persists in the literature regarding a comprehensive examination of the simultaneous impact of attitudes and academic support on calculus performance. Most prior research, globally and within the ASEAN region, has addressed these factors separately and focused on bivariate relationships, neglecting to study the interplay and potential causation among all three variables. In light of this, this research intends to bridge this gap by investigating the combined influence of attitudes and academic support on calculus performance among engineering students at Mindanao State University, General Santos City. Using Structural Equation Modeling (SEM), we plan to analyze these three variables concurrently, extending the investigation from correlation to causation and thus providing a more nuanced understanding of these factors. Through this study, we aim to contribute to the global body of knowledge while addressing a locally relevant issue.

This study was anchored on social cognitive theory, which stresses the idea that much human learning occurs in a social environment (Schunk, 2012). This social environment includes teachers and peers. It is by observing others that people acquire knowledge, rules, skills, strategies, beliefs, and attitudes. According to Zimmerman and Schunk (2003), the social cognitive theory makes some assumptions about learning and the performance of behaviors. These assumptions address the reciprocal interactions among persons, behaviors, and environments; enactive and vicarious learning (i.e., how learning occurs); the distinction between learning and performance; and the role of self-regulation. Bandura (1997) stressed that children learn in several ways. One way of learning is by observing others, which results in imitating those around them, or by simply listening to others. Children also mediate their learning via internal self-regulation, which they develop by learning from the environmental influences around them. He sees learning all types of behavior (including academic skills) as mediated by environmental influences.

Moreover, this study was based primarily on applying the expectancy-value models of behavior to mathematics achievement (Eccles & Wigfield, 1995). They posited the important influence of three expectancy-value factors on math achievement. These factors included students' expectations for success, their perceptions of task difficulty, and their perceptions of task value.

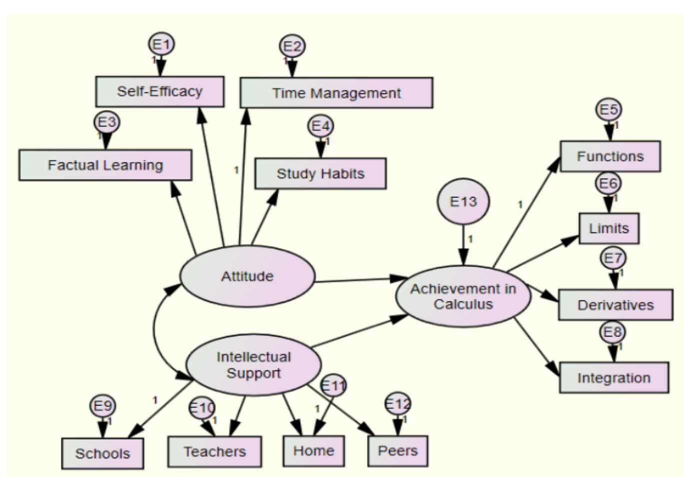

Figure 1. Conceptual Framework of the Study

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Presented in Figure 1 is the conceptual paradigm of the study. The independent variables of the study are attitudes and intellectual support, while the dependent variable is achievement in calculus. The indicators for attitudes include: time management, which refers to the process of planning how to organize time and activities; study habits, which refer to the degree to which the student engages in regular acts of studying that are characterized by appropriate studying routines (e.g., reviews of material) occurring in an environment that is conducive to studying; self-efficacy, which refers to a context-specific assessment of competence to perform a specific task, a judgment of one's capabilities to execute particular behaviors in specific situations; and factual learning refers to the importance of calculus in daily life. The indicators for intellectual support include: teachers support, which includes teacher's interest in pupils' progress in mathematics learning, patience in answering their queries, motivation for them to be active and competitive in class discussions and activities, competence in content and pedagogy in mathematics; peer support includes the development of the study habits with the help of their classmates and friends and preference to share/discuss ideas about calculus problems; home support includes assistance from family members in home works, in making requirements, and follow-up of their progress; and school support includes adequacy of mathematics textbooks and other supplementary reading materials, facilities, and equipment necessary for their academic growth, and structured program in learning mathematics. The research questions of this study are as follows: (1) Is there a significant relationship between the student's intellectual support and academic achievement in calculus? (2) Is there a significant relationship between the student's attitude and academic achievement in calculus? (3) Is there a significant relationship between the students' intellectual support and attitude? (4) What is the structural equation model of the study?

2. Methodology

This study employed a quantitative, non-experimental research design utilizing correlational and causal-relationship techniques. In non-experimental research, data are collected in their natural environments without introducing changes or treatments (Gehle, 2013). The non-experimental quantitative method was suitable for this investigation since the variables were identified and studied as they naturally occurred.

The study was conducted among 211 first-year engineering students at Fatima Campus, Mindanao State University, General Santos City, during the Academic Year 2019–2020. The respondents were purposefully selected from a total of 233 enrolled students at the college. Purposive sampling was chosen to ensure that the sample accurately reflected the specific subgroup of interest: first-year engineering students struggling with calculus. This method allowed the research to concentrate on participants who were most likely to contribute valuable data. Moreover, the researchers identified the following students to be included in the sample using Lwanga & Lemeshow's (1991) formula:

n=(z^2 pq)/ε^2

where z=1.96, p=0.8359, q=0.1641,and ε=0.05.

The questionnaire used in the study comprised 65 items divided into three parts: Part 1 dealt with attitudes, including indicators such as time management, study habits, self-efficacy, and factual learning. Part 2 addressed intellectual support, encompassing indicators such as home support, peer support, teacher support, and school support. A five-point Likert scale was employed to assess the attitudes and intellectual support levels of the engineering students. Part 3 consisted of test items to gauge their calculus achievement.

The questionnaire underwent a rigorous validation process. This involved an expert review to ensure content validity, followed by a pilot study on a small representative sample. Based on the feedback and results from the pilot study, necessary adjustments were made to improve the clarity and relevance of the items. Reliability was assessed using Cronbach's alpha, which resulted in satisfactory values above 0.7 for all scales.

Data analysis began with Confirmatory Factor Analysis (CFA), used to verify the factor structure of the attitudes and intellectual supports. The interrelations among the indicators and variables were computed as Pearson product-moment correlations, then converted into a covariance matrix. While CFA was utilized in the initial stages, the title of the study mentions SEM (Structural Equation Modeling) due to its integral role in testing the hypothesized model. SEM was selected because it allowed for the simultaneous examination of relationships between observed variables and latent constructs, including the constructs themselves. Thus, SEM provided a more nuanced view of the intricate relationships among attitudes, intellectual supports, and calculus achievement than could be achieved with CFA alone.

The measurement model was then tested using SEM on the total data set of 211 subjects. SEM was used not only to confirm the structure of the observed data but also to understand the causal relationships among the variables. The model fit was assessed using multiple fit indices, including the Chi-square Test of Model Fit, Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA), to ensure a robust evaluation.

3.0 Results and Discussion

The correlations between students' academic support from numerous sources and their academic achievement in calculus are depicted in Table 1. Correlation coefficients (r-values) and their significance levels (p-values) are displayed for each component of academic support (school, home, peers, teachers) and overall intellectual support concerning various calculus topics (functions, limits, integration, differentiation), as well as overall calculus performance.

Table 1. Correlation between the students' intellectual support and academic achievement in calculus

Intellectual Support	Calculus Performance				
	Functions	Limits	Integration	Differentiation	Overall
School	-.034	.002	.118	-.001	.030
	.620	.997	.088	.994	.666
Home	.079	.084	.133	.010	.096
	.250	.222	.054	.889	.163
Peers	.173*	.212**	.245**	.200**	.278**
	.012	.002	.000	.004	.000
Teacher	.181**	.253**	.241**	.141*	.270*
	.008	.000	.000	.041	.000
Overall	.132	.184**	.250**	.114	**.225****
	.055	.008	.000	.098	**.001**

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

The analysis reveals a significant correlation between peer and teacher support and performance in calculus. In contrast, there is no correlation between school and family support. Notably, the aggregate correlation between academic support and calculus performance was significant (r=0.225, p<0.05), rejecting the null hypothesis. In corroboration with the conducted interviews, students find peer discussions and teacher explanations more effective for conceptualizing calculus. This is consistent with the statistically significant correlations discovered between peer and teacher support. Educators could also confirm that direct instruction and peer-to-peer collaboration frequently enhance students' comprehension of complex topics in calculus.

Consistent with previous research emphasizing the central role of peer and teacher support in academic achievement, these findings confirm the importance of peer and teacher support. According to Van Der Wilt *et al.,* (2018), peer interactions significantly improve mathematical learning. Similarly, Guillory (2013) emphasized the impact of teacher support on students' math performance, which parallels the findings of our study. However, the non-significant correlation between family and school support contradicts previous research, suggesting that these factors may play a secondary role in complex subjects such as calculus or operate differently in various contexts. More research is necessary to comprehend these dynamics completely.

Table 2 shows the correlations between the calculus performance of students and their attitudes regarding time management, study habits, self-efficacy, and empirical learning. Provided are correlation coefficients (r-values) and their corresponding p-values. It reveals a considerable positive relationship between time management, self-efficacy, and academic achievement in calculus. Despite this, there is no correlation between study habits and empirical knowledge. Overall, there was a significant correlation between attitude and calculus performance (r=0.146, p<0.05), rejecting the null hypothesis.

Table 2. Correlation between the students' attitude and academic achievement in calculus

Attitude	Calculus Performance				
	Functions	Limits	Integration	Differentiation	Overall
Time Management	.183**	.264**	.082	.189**	.242**
	.008	.000	.238	.006	.000
Study Habits	-.026	.125	.006	-.026	.029
	.708	.069	.930	.709	.678
Self-efficacy	.100	.157*	.052	.098	.137*
	.149	.022	.450	.156	0.47
Factual learning	.024	.048	.059	.022	.051
	.725	.490	.391	.756	.463
Overall	.089	.191**	.065	.089	**.146***
	.200	.005	.348	.198	**.034**

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

Through interviews with students and teachers, the positive correlations between time management, self-efficacy, and academic performance in calculus could be confirmed. Students may describe how effective time management and self-efficacy (confidence in one's abilities) have enabled them to excel in calculus. Teachers may share their observations that students who effectively manage their time and exhibit high self-efficacy frequently outperform their peers in calculus.

These findings are consistent with recent studies that emphasize the importance of time management and self-efficacy for academic achievement. For example, empirical findings by Zhou and Winne (2019) confirm the correlation between effective time management and superior academic performance. Similarly, Joet *et al.,* (2020) suggest that self-efficacy beliefs can have a substantial effect on academic performance. The non-significant correlation between study practices, factual learning, and calculus performance observed in this study suggests that these factors may not be as influential for calculus achievement or that they may operate differently depending on the context. This further indicates that additional investigation is required to better comprehend these relationships.

The correlation between students' attitudes, specifically time management, study habits, self-efficacy, and empirical learning, and the intellectual support they receive from school, home, instructors, and peers is depicted in Table 3.

Table 3. Correlation between the students' attitude and academic achievement in calculus

Attitude	Calculus Performance				
	School	Home	Peers	Teachers	Overall
Time	.211**	.417**	.326**	.349**	.452**
Management	.002	.000	.000	.000	.000
Study Habits	.287**	.359**	.172*	.160*	.346**
	..000	.000	.012	.020	.000
Self-efficacy	.216**	.254**	.305**	.334**	.381**
	.002	.000	.000	.000	.000
Factual learning	.143*	.224**	.188**	.219**	.268**
	.037	.001	.006	.001	.000
Overall	.280**	.409**	.312**	.344**	**.470****
	.000	.000	.000	.000	**.000**

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

The data demonstrates a significant positive correlation between all attitude components and all forms of intellectual support. The correlation between time management and overall intellectual support is the strongest (r=0.452, p0.05). Therefore, the null hypothesis stating that there is no correlation between student attitudes and intellectual support is rejected.

Students' and educational stakeholders' personal experiences and observations could bolster these findings. Students with excellent time management and study habits, for instance, may report receiving strong intellectual support from their instructors, families, and peers. Similarly, instructors and guardians could share examples of how students with high self-efficacy and factual learning utilize their support most effectively. According to recent research, there is a correlation between the attitudes of students and the intellectual support they receive. Corroborating the findings herein, Bandura and Locke (2019) illustrated how the motivation and behaviors of students, which include time management and self-efficacy, are correlated with perceived social support from instructors and peers. Moreover, Jeynes (2016) reaffirmed that parental involvement positively affects children's school motivation. However, the significant correlation observed in our analysis suggests that these relationships may be especially important for calculus achievement, a sentiment echoed by Brten and Olaussen (2020).

The hypothetical model consisted of five first-order factors: time management, study habits, and self-efficacy *(factual learning, school*

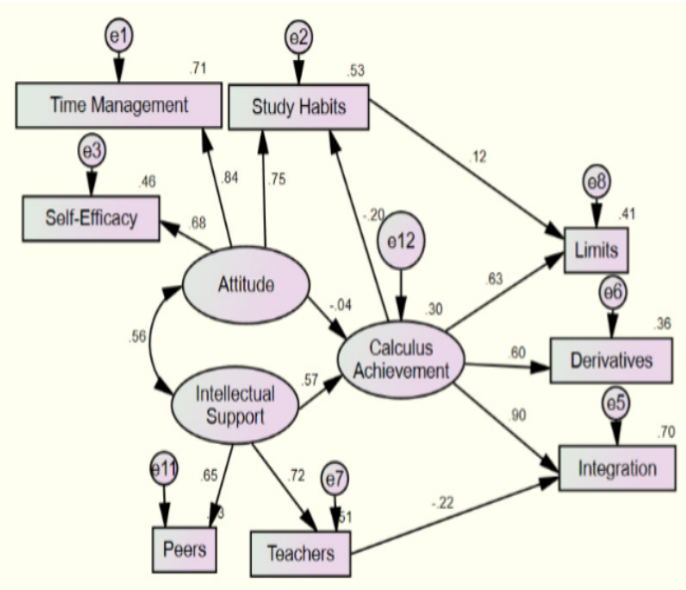

Fig. 2. Structural equation model of the study (standardized estimates)

support, and home support were not included in this analysis), and two second-order factors: attitude towards calculus and intellectual support received. The latent constructs are highly represented by their respective factors, with beta greater than 0.60. Table 4 shows the results of the goodness-of-fit measures of the model. The model fit values have successfully met the criteria set by each index (CMIN/DF < 2.0), (TLI, CFI > .90), and RMSEA < 0.08 with a PCLOSE > 0.05. This means that the model fits well with the data and therefore asserts a good fit model for determining relationships between intellectual support and attitude toward calculus performance.

Table 4. Goodness fit measures

Index	Criterion	Model Fit Value
CMIN/DF	<2.0	0.864
TLI	>0.90	1.009
CFI	>0.90	1.000
GFI	>0.90	0.986
PCLOSE	<0.05	0.907
RMSEA	<0.08	0.000
RMR	Good model have small RMR	0.014

4. Conclusion

The findings of this study indicate that students' attitudes toward calculus and the intellectual support they receive significantly impact their academic performance. Peer and teacher support are significantly correlated with calculus performance, whereas school and family support are not significantly correlated with calculus performance. This highlights the crucial role that colleagues and instructors play in the academic success of students, specifically their calculus performance. Accordingly, it is recommended that calculus instruction include more opportunities for collaborative learning and that instructors develop their supportive positions further.

The results indicate that time management and self-efficacy are significantly related to academic achievement in calculus, whereas study habits and empirical learning lack a significant relationship. In the context of calculus learning, educators can place greater emphasis on cultivating students' time management skills and enhancing their self-efficacy beliefs. In addition, the study found strong positive correlations between all aspects of student attitudes (time management, study practices, self-efficacy, and factual learning) and all forms of intellectual support (school, family, teachers, and peers). This comprehensive association highlights the need for a holistic approach to increasing calculus performance that considers both intellectual support and attitudes.

The structural equation model used in this investigation confirmed these relationships, exhibiting acceptable fit values and meeting the index-specific criteria. This demonstrates that both student attitudes and intellectual support have a substantial effect on calculus achievement. These findings provide educators with vital insights for enhancing calculus instruction and learning. Calculus performance could be considerably enhanced by concentrating on fostering positive student attitudes, particularly regarding time management and self-efficacy, and enhancing intellectual support, particularly from peers and instructors. This necessitates pedagogical strategies that foster these attitudes and provide these supports within the context of calculus education. To sum up, there is an interdependence between student attitudes, intellectual support, and calculus performance. The findings highlight the potential of a holistic approach to calculus instruction, one that considers both curriculum content and socio-emotional aspects of learning. As a result, this study provides substantial contributions to both practice and research in calculus education, with the ultimate goal of enhancing student learning outcomes. It is recommended that future research delve deeper into the intricate relationship between attitudes, intellectual support, and calculus performance in various learning contexts. Additionally, it would be beneficial to investigate more specific strategies that can foster intellectual support and enhance attitudes toward calculus. This could involve examining teacher training programs centered on supportive instructional strategies or investigating interventions designed to improve students' time management and self-efficacy.

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