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Relationship between students' problem-solving performance and attitudes toward chunking technique instruction in Calculus

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ABSTRACT

This study determined the relationship between performance and attitude of students taught using the chunking technique in Calculus. Finding instructional approaches that could simultaneously improve cognitive and affective outcomes is important, but few studies have investigated the relationship between performance and attitude resulting from the use of chunking. This study was conducted to bridge the existing gap in the literature by providing insight into the effect of chunking on the cognitive and affective aspects of learning among the students. The main objective of the study was to establish the relationship between performance and attitude towards the chunking technique. Besides that, the study also sought to determine the level of performance and attitude of the students exposed to chunking. In this quasi-experimental study, two treatment groups were used, and data were collected using problem-solving tests and attitude surveys. Descriptive analysis and Pearson product-moment correlation were used to analyze the data. There was no significant relationship between attitude and performance in the first treatment group. On the other hand, a positive correlation was observed between attitude and performance in the second treatment group. In conclusion, there is a significant relationship between performance and attitude towards the chunking technique. Additionally, it was observed that chunking has a great effect on the students' performance and attitude towards Calculus. Chunking was found to influence students' ability to organize information for better understanding. As a result, chunking can be used to effectively teach students how to solve problems in Calculus.

Contribution/Originality: This study documents current gaps in Philippine mathematics education by investigating the effects of the instructional strategy of chunking on students' performance in calculus and their attitudes toward mathematics as an intervening variable, leading to recommendations for calculus and STEM education interventions.

1. INTRODUCTION

Calculus is one of the most challenging subjects that college students in science, technology, engineering, and mathematics (STEM) programs must complete. In Nueva Ecija, students enrolled in Engineering and Education programs often struggle with the abstract ideas, multi-step formulas, and lengthy calculations that Calculus demands. This difficulty is not unique to the local setting: the Philippines has consistently ranked among the lowest-performing countries in international assessments of mathematics achievement (OECD, 2019), underscoring a persistent, system-wide need for instructional strategies that can improve both problem-solving performance and attitudes toward

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mathematics among STEM-related learners. Within Nueva Ecija specifically, there remain ongoing concerns about students' low performance and negative attitudes in Calculus classes, along with the factors that contribute to these outcomes.

To resolve this matter, many teachers have used proven methods that could improve the meaningful learning of students, which could lead to improvements in their academic performance and positive attitudes towards mathematics. One of these methods is the chunking technique, which is used to reduce the complexity of lessons by dividing the whole lesson into smaller, easily understandable segments or chunks. In cognitive learning, chunking is known as the process of decreasing the working memory load by grouping relevant information together (Sweller, 2011). Moreover, in mathematics, chunking is the best practice for developing pupils' problem-solving performance.

Prior research provides converging evidence that chunking facilitates problem-solving performance for populations and domains that include students with mathematics learning disabilities (Zhang, Indyk, & Greenstein, 2021) and general problem-solving tasks locally (Garcia, Ibarra, Antalan, & Taganap, 2025; Santos, Collantes, Ibañez, Ibarra, & Pentang, 2022). However, it remains unknown whether this procedure also influences learners' attitudes towards the discipline, specifically calculus.

Indeed, the body of work presents three areas of limitations linked to the current study. First, previous studies on chunking, including (Zhang et al., 2021) and Alhadi (2024), were conducted among students with mathematics learning disabilities or within geometry classes, not calculus classes, and not among general STEM students. Second, the only local studies conducted in the Philippines exploring students' attitudes about calculus chunking (Garcia et al., 2025; Santos et al., 2022) have focused only on problem-solving performance, not on both problem-solving performance and attitudes. Third, the only study conducted in the Philippines assessing students' attitudes towards calculus (Akinsola & Olowojaiye, 2008) was not conducted using chunking as an instructional procedure; thus, it remains unknown whether attitudes towards calculus are related to chunking. Indeed, since teachers in Nueva Ecija, Philippines, have yet to explore how chunking instruction can relate to students' problem-solving performance and attitudes towards calculus, the study will fill this gap.

For this reason, this study sought to examine whether there was any correlation between students' problem-solving performance and attitudes towards chunking technique instruction in Calculus. This research would help students and mathematics professors at Central Luzon State University and other colleges in Nueva Ecija and the Philippines in general.

2. LITERATURE REVIEW

One of the most common challenges that hinder students' effective problem-solving is cognitive overload. Information overload is a state in which a person is unable to process information because of an overwhelming amount of it in the working memory. Cognitive Load Theory is based on the idea that the information needs to be presented in a way that allows a learner to use the least amount of cognitive resources while processing the information (Sweller, 2011). Information-processing views of learning refer to cognitive load associated with working memory capacities (Hatague & Nabua, 2019), while developmental accounts focus on the emergence of increasingly efficient knowledge structures (Geary, 2003). In relation to the current study, the former includes the cognitive load imposed by chunking instruction, and the latter concerns the capacity building of chunking instruction as well.

Chunking refers to the process of organizing information into smaller, meaningful units, or chunks, which reduces the cognitive load required to learn the information (Miller, 1956). Chunking can be considered one of the strategies that enable a student to process information in a more effective and systematic way. For instance, chunking can help in the mathematical problem-solving process since it allows for breaking down the process of problem-solving into several steps (Garcia et al., 2025; Reyes, Insorio, Ingreso, Hilario, & Gutierrez, 2019). Therefore, it can provide students with a structure that should guide them through the process and ultimately assist students in learning how to effectively analyze and solve a multi-step problem.

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Furthermore, the beneficial effect of chunking has been reported among diverse populations and multiple domains. For example, schematic chunking was revealed to substantially improve geometry performance of students with mathematics difficulties and those at risk of math failure (Zhang et al., 2021). Additionally, a meta-analysis of word-problem-solving interventions conducted by Zhang and Xin (2012) found that decomposition instruction, which requires dividing a problem into smaller sequential steps, led to improved performance of the participants. Similarly, schema-based instruction studies revealed that when students learned to represent a problem's critical features prior to solving it, mathematics word problem performance of students with learning disabilities improved (Jitendra & Hoff, 1996). At a lower level, chunking was found to facilitate statistical learning and memory (Isbilen, McCauley, Kidd, & Christiansen, 2020). Thus, overall, the body of knowledge reports on the beneficial effect of chunking instruction on mathematics performance. However, the majority of the studies concern either learners with mathematics difficulties or geometry and word problem-solving and do not address the effectiveness of chunking in calculus explicitly.

Another area of research that is related to the current study is the body of knowledge concerned with the relationship between students' attitudes towards the subject and their performance in mathematics. The results of the study conducted by Akinsola and Olowojaiye (2008) demonstrate that the instructional tactics used by teachers affect students' attitudes towards mathematics, which influence their performance. Similarly, Pajares and Graham (1999) found that self-efficacy expectations, which are part of students' attitudes towards the subject, predicted students' achievement in mathematics beyond the effect of prior performance. Lastly, the engagement literature also suggests that there is a link between student attitudes and performance since students who express a higher degree of interest in mathematics classes obtain higher grades (Fung, Tan, & Chen, 2018). Moreover, Emslander and Scherer (2022) argue that mathematics intelligence is related to executive functioning, which, among other things, includes working memory. Overall, the discussed body of knowledge links students' attitudes and performance; however, none of the studies examined the relationship between an individual's attitudes and chunking as an instructional tactic explicitly.

Together, the discussed pieces of research demonstrate that there is a significant amount of evidence that supports the effectiveness of chunking as an instructional tactic. However, to put the effectiveness of chunking in perspective, few studies have explored the relationship between chunking and students' attitudes towards learning mathematics. Specifically, chunking was reported to be one of the strategies that reduce cognitive load, thus effectively supporting the problem-solving process (Hatague & Nabua, 2019; Sweller, 2011). Chunking has been found to lead to performance improvement across mathematical domains and learner populations (Jitendra & Hoff, 1996; Zhang et al., 2021; Zhang & Xin, 2012). Students' attitudes towards the subject, on the other hand, have also been argued to predict performance (Akinsola & Olowojaiye, 2008; Fung et al., 2018; Pajares & Graham, 1999). However, the existing body of knowledge does not address the relationship between students' attitudes towards learning calculus and chunking instruction, which is the focus of the current study.

3. OBJECTIVES OF THE STUDY

This study aimed to determine the relationship between students' problem-solving performance and their attitudes toward chunking technique instruction in Calculus among college students at Central Luzon State University during the first semester of the 2025–2026 school year. Specifically, the study aimed to:

1. Determine the posttest scores in mathematical problem-solving among the treatment groups after exposure to chunking technique instruction.
2. Assess the effect of instruction in the chunking technique on the mathematical attitudes of the first and second treatment groups.
3. Determine the relationship between students' posttest scores in mathematical problem-solving and their attitudes toward chunking technique instruction in Calculus.

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4. METHODOLOGY

4.1. Research Design

This study employed a quantitative research design that involved conducting an experiment using quasi-experimental methods to assess the causal relationship between students' problem-solving performance and their attitudes toward the chunking method when learning Calculus. Within the study, two treatment groups were involved, each of which underwent a different experimental design. Namely, while Group A was subjected to a pretest-posttest control group design, Group B used the posttest-only design. This decision was made due to logistical limitations of the educational settings in which the respondents were located. In particular, Group A's academic calendar included a session reserved for conducting a pretest before studying the vector unit, which was not available for Group B. To respect the curricular constraints of both groups and facilitate the implementation of the chunking-based intervention, one group underwent the pretest-posttest procedure whereas another received a posttest-only treatment.

For the first treatment group, the pretest was conducted before chunking instruction and then the posttest, right after the intervention, to measure the amount learned. For the second treatment group, only the posttest was conducted, thus enabling the assessment of the participants' attitude toward the math lessons. Because the two treatment groups received different interventions, the pretest data could not be used to compare participants' problem-solving abilities before the intervention, which might introduce bias in the analysis. Specifically, the differences observed between Group A and Group B on the posttest can be attributed not to the chunking technique but to the initial differences between the two groups of participants, their differing years of study, and the study programs they followed. Therefore, it is necessary to analyze the results of the within-group comparison to evaluate the effect of the interventions applied. Thus, for Group A, the learning gains were measured by employing the pretest-posttest design, while for Group B, the changes in problem-solving ability and attitudes toward the lessons were explored. Additionally, since Group B had undergone the posttest only, the analysis of the within-group results provides this group with an opportunity to examine the effect of the chunking technique without having been subjected to pretest sensitization (Salkind & Frey, 2020). On the other hand, the within-group comparison for Group B does not allow for analyzing the learning gains attributable to the interventions, unlike in Group A. The between-group comparison was made on the posttest results only, and the findings are discussed further in this paper.

4.2. Respondents and Data Collection

The respondents comprised 69 college students from Central Luzon State University in the Philippines who were enrolled in Calculus III during the first semester of the 2025–2026 school year. Moreover, purposive sampling was applied in this study. The reason for purposive sampling was its better matching of the sample to the aims and objectives of the research, thus improving the rigor of the study and the trustworthiness of the data and results. Four aspects of this concept have been described: credibility, transferability, dependability, and confirmability (Campbell et al., 2020). Group A, which was administered a pretest and posttest, comprised second-year Bachelor of Science in Statistics students, and Group B, which was administered only a posttest, comprised third-year Bachelor of Secondary Education major in Mathematics students in Section 2.

At Central Luzon State University, the analysis of vectors in the plane and in space is part of the course syllabus of Calculus III (Math 2207 for the Bachelor of Science in Statistics and Math 3219 for the Bachelor of Secondary Education Major in Mathematics). Similarly, this is also the case for most universities that offer calculus courses that treat vector analysis as a preliminary topic to partial differentiation and multiple integration. The lesson plan, pretest, and posttest used for this study were developed based on the topics of the Calculus III service course for the respondents.

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Table 1. Distribution of the subjects of the study.

Treatment groups	Number of the subjects
Group A (T1)	32
Group B (T2)	37
Total	69

In Table 1, the distribution of the subjects is illustrated based on the treatment group to which they belong. Therefore, it can be seen that group A (T1) comprises 32 subjects, whereas group B (T2) accounts for 37 subjects, making a total of 69 subjects enlisted for the study.

In this study, there were three stages, namely the pre-treatment stage, treatment stage, and post-treatment stage. Pre-treatment Stage: Participants in Group A had one hour to answer the pretest on vectors. Outputs were collected, checked, and recorded to determine whether there were improvements after the intervention.

Experimental Stage: After the administration of a pretest to Group A, the researcher taught Group A and Group B lessons on vectors. Group A and Group B were taught by the researcher using the chunking technique. The teaching sessions lasted for three weeks. Each session lasted an hour and a half, which sufficed for all the topics needed.

Post-Treatment Stage: After the intervention, a posttest was administered to all groups to determine whether the effect of the intervention, which is the chunking technique, was significant. They had only an hour to answer the test. The results of the test were analyzed and examined to evaluate the effects of the chunking technique.

4.3. Ethical Consideration

This study followed proper research ethics and procedures throughout its duration. The study was approved by the Ethics Review Committee of Central Luzon State University (ERC Reference Code 2025-704). At all times, the respondents' personal information was kept confidential as mandated by the Data Privacy Act of 2012.

The study maintained proper research ethics by ensuring all references were correctly cited. The researchers acknowledged the work of other researchers by properly citing their works and including them in the reference list.

4.4. Instrumentation

To ensure the collection of the required data, the following instrument was utilized: a researcher-adapted test consisting of selected mathematical word problems linked to the identified competencies covered by the intervention. The tool was designed to measure the participants' achievement level in terms of problem-solving processes before and after the application of the chunking strategy. The intervention was evaluated by mathematics instructors from Central Luzon State University, College of Science – Department of Mathematics and Physics, who possess extensive and in-depth knowledge of Mathematics Education for content and reliability.

To assess the respondents' performance on the test items, a researcher-made rubric was utilized, which was developed and validated by the researchers. It consisted of four criteria, including (1) Solution Strategy and Process, (2) Conceptual Understanding, (3) Accuracy of Calculations, and (4) Explanation and Clarity. Each criterion was quantified using a four-level scoring guide, which included Excellent (2.5), Proficient (2), Developing (1), and Beginning (0). Following the scoring guidelines, respondents' solutions reflected either excellent responses, which indicated the presence of an accurate solution process, conceptual understanding, precision, and explanation, or beginning performance, which implied the opposite. To evaluate the tool's validity, the researcher-made rubric was subjected to content validation, which involved mathematics professors and instructors with extensive expertise in calculus and problem-solving. As a result, the tool's clarity, coverage, applicability, and relevance were approved by the members of the validation board, who also provided essential recommendations for improvement. In terms of reliability, the tool was developed based on clearly defined criteria, thus implying the possibility of consistent measurements. In addition, the utilization of well-defined levels and descriptors can be considered a reliability indicator since they allow consistent scoring and eliminate measurement errors. Overall, the researcher-made rubric's

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validity and reliability are satisfactory, allowing it to be used for scoring the participants' responses on the researcher-adapted test.

The second instrument was an attitudinal questionnaire designed to measure the participants' attitudes towards the chunking technique strategy. Each item is answerable with a four-level Likert scale (SA – Strongly Agree; A – Agree; D – Disagree; SD – Strongly Disagree) regarding their attitudes towards the chunking technique strategy. The questionnaire was adapted, with the author's permission via email, from the study entitled "Effects of Chunking Intervention on Enhancing Geometry Performance in High School Students with Mathematics Learning Difficulties" by Alhadi (2024).

4.5. Data Analysis

This study employed various data analysis methods that are in accordance with the defined objectives. The matrix of data analysis methods utilized in this research is presented in Table 2.

Table 2. Matrix of data analysis methods.

Objectives	Type of data	Statistical tool for analysis
1. Determine the posttest scores in mathematical problem-solving among the treatment groups after exposure to chunking technique instruction	Quantitative, Continuous	Descriptive Statistics – Frequencies, Means, SD, Percentages
2. Assess the effect of instruction using the chunking technique on the mathematical attitudes of the first and second treatment groups	Quantitative, Continuous	Descriptive Statistics – Means, SD
3. Determine the relationship between students' posttest scores in mathematical problem-solving and their attitudes toward chunking technique instruction in Calculus.	Quantitative, Continuous	Inferential Statistics – Bivariate Correlational Analysis (Pearson's Coefficient *r*)

5. RESULTS

5.1. Posttest Score

Table 3 presents the mean and standard deviation of the posttest scores for the two groups involved in the study.

Table 3. Posttest scores of the two groups.

Classification	Score range	Posttest			
		Group A (T1)		Group B (T2)	
		f	%	f	%
Outstanding	45 – 50	9	28.13	8	21.62
Very Satisfactory	40 – 44	2	6.25	6	16.22
Satisfactory	35 – 39	3	9.38	4	10.81
Fair	30 – 34	3	9.38	7	18.92
Poor	0 – 29	15	46.88	12	32.43
Mean		33.16		31.85	
SD		11.3		11.88	

Both treatment groups performed equally well on the posttest, since students in Group A (T1) attained a mean score of 33.16 (SD = 11.30), whereas students in Group B (T2) attained a mean score of 31.85 (SD = 11.88). The standard deviations were equal and showed the dispersion of the scores around the mean to be almost identical for both treatment groups. Overall, more students in Group A (T1) were in the Outstanding category than those in Group B (T2), while more Group B (T2) students were in the Very Satisfactory and Fair categories. To check whether the observed difference between the means of 33.16 (Group A) and 31.85 (Group B) could have occurred by chance, I used an independent-samples t-test with a formula for calculating a t-statistic to obtain a result, which would allow me to determine whether to reject the null hypothesis. The results revealed no significant difference between the

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posttest results for the treatment groups, t(67) = 0.47, p = .642, where both means proved to be statistically equal, because the calculated effect size (Cohen's d = 0.11) was small and close to zero. Therefore, even though Group A (T1) appeared to score higher on the posttest, this difference was not statistically significant. Moreover, since a pretest was administered only to Group A, there is insufficient information about the initial equivalence of the two groups, so the comparison of the posttest results should be regarded as descriptive only for the purpose of describing the observed difference between the means in favor of Group A (see Section 4.1). What can be concluded from the analysis is that the posttest results for both groups were equal, which implies that these groups achieved the same level of problem-solving after reading the text in chunks.

5.2. Assessment of the Effect of Chunking Technique on the Mathematical Attitude of Treatment Groups

Table 4 displays the results of the mean values for attitudes toward mathematics using the chunking technique in the first treatment group.

Table 4. First treatment group's attitude mean value towards the chunking technique.

Statements	Mean	SD	Description
I like my participation in this project.	3.31	0.78	Strongly Agree
I like the way of teaching calculus in this project.	3.5	0.76	Strongly Agree
I feel that I can learn calculus better after I enrolled in this project.	3.41	0.67	Strongly Agree
I like learning calculus after I participated in this project.	3.13	1.07	Agree
I enjoy learning calculus more when it is taught in smaller, manageable units.	3.57	0.84	Strongly Agree
I feel my performance in calculus has improved after I joined this project.	3.5	0.84	Strongly Agree
Overall Mean	3.4	0.66	Strongly Agree

Note: 1.00 – 1.74 (Strongly Disagree)
2.50 – 3.24 (Agree)
1.75 – 2.49 (Disagree)
3.25 – 4.00 (Strongly Agree)

According to the table, the initial treatment group demonstrates a positive attitude towards calculus when it is taught by the chunking method, with a mean of 3.40 (Strongly Agree). The table below represents the mean and standard deviation of students' agreement with six statements about their attitude towards calculus after participating in a project using the chunking technique. The scores varied from 3.13 to 3.57, with an average of 3.40 and an overall standard deviation of 0.66. The two items with the highest mean scores were "I enjoy learning calculus more when it is taught in smaller, manageable units," with a score of 3.57 (SD = 0.84), Strongly Agree, and "I like the way calculus is being taught" and "I feel that my performance has improved in calculus," with a score of 3.50, Strongly Agree, for both items. The item with the lowest score was "I like learning calculus after I participated in this project," with a mean of 3.13 (SD = 1.07), Agree. According to the provided data, all items have scores that fall within the Agree to Strongly Agree range, with an overall average of 3.40 Strongly Agree. The overall mean is within the Strongly Agree category (3.25–4.00). Thus, the data indicate that the first treatment group has a positive attitude towards calculus after participating in the project. Moreover, the Strongly Agree response to the item regarding enjoying learning calculus more when it is taught in smaller, manageable units suggests that the chunking technique makes the subject matter easier to understand and less overwhelming, which reduces students' anxiety.

Table 5 displays the results of the mean value of the second treatment group's attitude towards mathematics using the chunking technique.

Table 5 indicates that the statement, "I enjoy learning calculus more when it is taught in smaller, manageable units," received the most positive response, with a mean of 3.27 and a Strongly Agree label. On the other hand, the statement, "I feel that I can learn calculus better after enrolling in this project," received the lowest mean of 3.08, which is still Agree. All items have standard deviations between 1.04 and 1.14, denoting an intermediate range. The overall mean of the attitude score is 3.19, indicating Agree.

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Table 5. Second treatment group's attitude mean value towards the chunking technique.

Statements	Mean	SD	Description
I like my participation in this project.	3.16	1.14	Agree
I like the way of teaching calculus in this project.	3.14	1.08	Agree
I feel that I can learn calculus better after I enrolled in this project.	3.08	1.12	Agree
I like learning calculus after I participated in this project.	3.24	1.11	Agree
I enjoy learning calculus more when it is taught in smaller, manageable units.	3.27	1.04	Strongly Agree
I feel my performance in calculus has improved after I joined this project.	3.19	1.13	Agree
Overall Mean	3.19	1.03	Agree

Note: 1.00 – 1.74 (Strongly Disagree)
2.50 – 3.24 (Agree)
1.75 – 2.49 (Disagree)
3.25 – 4.00 (Strongly Agree)

It appears that chunking calculus as a way to intensify students' enjoyment has proven to be a beneficial strategy. The statement about learning calculus in smaller chunks being associated with positive attitudes received a Strongly Agree response from learners. Therefore, it is possible to suggest that breaking down complex math concepts into smaller, understandable modules is more effective for boosting students' enjoyment; in turn, it helps them develop positive attitudes towards the subject. Despite respondents being unsure whether they can learn calculus better following the described system (Mean: 3.08), they positively perceive its applicability and value. In general, attitudes towards chunking in relation to the treatment group are Agree. The overall mean score of 3.19 denotes such an attitude, implying that the majority of students appreciate the way the material is restructured in this project. The positive disposition towards the chunking method should benefit their calculus studies, as well as their persistence in learning it. Given that the overall average remains within the Agree threshold, one can say that the participants prefer learning math in smaller units. Moreover, those who answered "I Agree" to items concerning positive attitudes and willingness to participate in class more frequently were motivated to continue studying calculus despite its complexity.

5.3. Correlation between Posttest Score and Mathematical Attitude towards Chunking Technique

Table 6 presents the results of the test of the relationship between the posttest scores of the first and second treatment groups and mathematical attitude in the chunking technique using Pearson's r correlation.

Table 6. Test of relationship between posttest scores of both treatment groups and mathematical attitude in the chunking technique.

Group	Correlation of attitude and posttest score	r value	p
T1	Attitude and Posttest Score	0.255	0.158
T2		0.562	<0.001

The analysis highlights varied results for the two treatment groups. In this case, treatment group 1 (T1) has a Pearson correlation coefficient of r = 0.255 with an associated p-value of 0.158. On the other hand, treatment group 2 (T2) reports a correlation coefficient of r = 0.562 with a p-value less than 0.001. Procedure T1 had a weak positive correlation that was not statistically significant at the 0.05 level. This implies that for procedure T1, the initial attitude of the participants had no significant effect on determining their posttest results. At the same time, procedure T2 had a moderate positive correlation, which was highly statistically significant. This finding suggests that for T2, initial attitudes had significant predictive power over the final achievements of the participants. In other words, a positive attitude towards the chunking methodology predicted improved performance on the posttest. Alternatively, the improved performance could have triggered the positive attitudes reported among the participants. The significant correlation reported for T2 is in line with the academic literature on the relationship between attitude and achievement. Studies have shown that positive attitudes towards mathematics and new pedagogical strategies and

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innovations have a positive influence on students' performance. In cases where the strategies have been deemed effective by the students, such as in the current case of chunking as a bottom-up chunking instruction, increased motivation levels have been recorded (Jiang, Zhang, Jiang, & Xiong, 2022; Zhang et al., 2021). Previous trials on similar treatment groups using specialized strategies to achieve positive attitudes towards the subject have also reported correlation coefficients of up to 0.6 (Julian, 2017). This coincides with the 0.562 coefficient that was reported for T2. It is safe to assume that the chunking technique used in the study was effective in bridging the cognitive rule knowledge and the skill set required to perform mathematical tasks (Yushau, 2006).

6. CONCLUSION

This study aimed to determine the students' problem-solving performance and attitude toward chunking technique instruction in Calculus among college students at Central Luzon State University for the first semester of School Year 2025–2026. The results of the data analysis revealed that the chunking technique fosters positive attitudes toward learning calculus. The treatment groups, particularly T1, showed high levels of agreement with positive statements about calculus after being taught using the chunking method. The overall means of 3.40 ("Strongly Agree") and 3.19 ("Agree") for T1 and T2, respectively, suggest that students liked the chunking technique, believed that they could learn calculus better with it, and felt that it helped them perform better in the lessons. This implies that the chunking technique can make difficult concepts easier and, therefore, reduce the anxiety associated with learning calculus. A positive attitude toward the chunking technique can be used as a reliable indicator of performance in calculus, depending on the group of students. In this study, for instance, there was a moderate-to-large positive and significant correlation between attitude and posttest performance for T2 ($r = 0.562$, $p < 0.001$). This suggests that students who had a positive attitude toward the chunking technique scored higher on the posttest. This might be because the chunking technique promotes active learning, which enhances a positive attitude toward learning calculus and, by extension, improves performance. On the other hand, there was no significant correlation between attitude and performance for T1 ($r = 0.255$, $p = 0.158$). This could indicate that the relationship between attitude and performance might depend on the class or the manner in which the chunking technique was administered.

This study has methodological limitations that should be considered when interpreting its findings. Because Group A and Group B were assessed using different designs, with only Group A completing a pretest, the pre-intervention equivalence of the two groups could not be empirically verified, and the posttest comparison between T1 and T2 should therefore be interpreted as descriptive rather than as evidence of one group's superiority over the other. In addition, the use of purposive sampling and a relatively small number of respondents ($n = 69$) from a single institution limits the generalizability of the findings. Future research should adopt a consistent pretest–posttest design across all comparison groups, include a larger and more diverse sample, and consider a true control group that does not receive chunking instruction to more rigorously isolate the intervention's effect on problem-solving performance and mathematical attitudes.

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Appendix 1. The Scoring Rubric of the Mathematical Problem-Solving Test.

Criteria	Excellent (2.5)	Proficient (2)	Developing (1)	Beginning (0)
1. Solution Strategy and Process	Shows a clear, logical, and efficient strategy; all steps are organized and justified.	Solution process is generally logical, though some steps may lack explanation or clarity.	Steps are incomplete, disorganized, or show gaps in reasoning.	No clear strategy; steps are missing or incorrect.
2. Conceptual Understanding	Demonstrates strong understanding of concepts	Demonstrates good understanding with minor misconceptions.	Demonstrates partial understanding with notable misconceptions.	Lacks conceptual understanding; misapplies vector principles.
3. Accuracy of Calculations	All computations are correct and well-presented.	Most computations are correct; minor arithmetic/Algebraic mistakes.	Some correct computations, but multiple major errors.	Most computations incorrect.
4. Explanation & Clarity	Solution is clearly organized by chunks, with reasoning explained for each step.	Mostly clear; some steps lack explanation.	Limited clarity; chunks are not well-explained.	Disorganized; no explanations provided.

Appendix 1 reflects the scoring rubric used to grade the students on the Mathematical Problem-Solving Test. There are four areas against which the students' performance was assessed. These include solution strategy and process, conceptual understanding, accuracy of calculations, and explanation/solution clarity. Each area was scored using the following four levels: Excellent (2.5), Proficient (2), Developing (1), and Beginning (0). For each level, specific criteria applicable to students' problem-solving process, understanding of concepts, accuracy, and clarity of solutions are provided. The rubric, therefore, serves as a grading guide for the Mathematical Problem-Solving Test.

Questionnaire: Attitude Towards Mathematics with Chunking Technique

Directions: Please read each statement clearly and put a check mark (✓) in the box that corresponds to your answer. Also, please refer to the following scales when answering:

SA - Strongly Agree

A - Agree

SD - Strongly Disagree

D - Disagree

No.	Items	SA	A	D	SD
1	I like my participation in this project.				
2	I like the way of teaching calculus in this project.				
3	I feel that I can learn calculus better after I enrolled in this project.				
4	I like learning calculus after I participated in this project.				
5	I enjoy learning calculus more when it is taught in smaller, manageable units.				
6	I feel my performance in calculus has improved after I joined this project.				

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Sample Lesson Plan

I. Objectives	
Content Objectives	The learners describe a plane vector using correct notation.
	The learners perform basic vector operations (addition, subtraction, scalar multiplication).
	The learners compute vector magnitude and direction.
	The learners express a vector in component form and in terms of unit vectors.
1. CONTENT	Vectors in the Plane
2. LEARNING RESOURCES	
A. References	Calculus Volume 3 by Strang and Herman (2016)
Textbook pages	pp. 90 – 108
1. Procedures	
A. Reviewing previous lesson or presenting new lesson (REVIEW)	Reintroduce the Cartesian coordinate plane. In a two-dimensional Cartesian coordinate system, the abscissa is the first coordinate in an ordered pair (x,y) and represents the horizontal distance from the y-axis, while the ordinate is the second coordinate and represents the vertical distance from the x-axis.
B. Presenting examples/instances of the new lesson (PRE-ACTIVITY)	The teacher will present the topic and the learning objective of the lesson. The presentation consists of examples that can maximize the knowledge of students.
C. Discussing new concepts and practicing new skills (DEEPENING)	Session 1: Vector representation Sketch vector $\langle 3, 4 \rangle$. • Step 1: Identify the chunks. ○ Starting point (origin) and direction. ○ Components $x = 3, y = 4$. ○ Drawing the vector as an arrow on a coordinate plane. • Step 2: Retrieve prior knowledge. ○ Recall how to plot points $(3, 4)$. ○ Understand movement along x- and y-axes. ○ Know that vectors have both magnitude and direction. • Step 3: Problem solving. ○ Draw vector from origin to $(3, 4)$. ○ Label components. ○ Write in component form $\langle 3, 4 \rangle$. Session 2: Vector operations Add $\langle 2, 3 \rangle$ and $\langle -1, 5 \rangle$. • Step 1: Identify the chunks. ○ x-components $\rightarrow 2 + (-1)$ ○ y-components $\rightarrow 3 + 5$ ○ Combine results to form the resultant vector. • Step 2: Retrieve prior knowledge. ○ Addition of integers. ○ Concept of component-wise addition. • Step 3: Problem solving. ○ x: $2 + (-1) = 1$ ○ y: $3 + 5 = 8$ ○ Result: $\langle 1, 8 \rangle$ Subtract $\langle 1, -2 \rangle$ from $\langle 4, 1 \rangle$. • Step 1: Identify the chunks. ○ x-components $\rightarrow 4 - 1$ ○ y-components $\rightarrow 1 - (-2)$ ○ Write the result in $\langle x, y \rangle$ • Step 2: Retrieve prior knowledge. ○ Integer subtraction ○ Understanding vector subtraction as tail-to-head

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- Step 3: Problem solving.
  - $x: 4 - 1 = 3$
  - $y: 1 - (-2) = 3$
  - Result: $\langle 3, 3 \rangle$

Let v have initial point $A(2, 5)$ and terminal point $B(8, 13)$, and $w = \langle -2, 4 \rangle$. Find $v - 2w$

- Step 1: Identify the chunks.
  - Find the component form of vector v from its initial and terminal points.
  - Multiply vector w by scalar 2: $2w$.
  - Subtract $2w$ from v.
- Step 2: Retrieve prior knowledge.
  - How to express a vector from two points using:
    $$v = \langle x_2 - x_1, y_2 - y_1 \rangle$$
  - How to perform scalar multiplication:
    $$a \cdot \langle x, y \rangle = \langle a \cdot x, a \cdot y \rangle$$
  - How to subtract vectors in component form:
    $$\langle a, b \rangle - \langle c, d \rangle = \langle a - c, b - d \rangle$$
- Step 3: Problem solving.
  - Find v: Initial: $A(2, 5)$, Terminal: $B(8, 13)$
    $$v = \langle 8 - 2, 13 - 5 \rangle = \langle 6, 8 \rangle$$
  - Multiply w by 2.
    $$2w = 2 \cdot \langle -2, 4 \rangle = \langle -4, 8 \rangle$$
  - Subtract vectors.

$$v - 2w = \langle 6, 8 \rangle - \langle -4, 8 \rangle = \langle 6 - (-4), 8 - 8 \rangle = \langle 10, 0 \rangle$$

Session 3: Magnitude and direction

Find the magnitude of $\langle 3, 4 \rangle$.

- Step 1: Identify the chunks.
  - Recall that $x = 3,\ y = 4$
- Step 2: Retrieve prior knowledge.
  - Recall the Pythagorean theorem. Formula for magnitude $\|v\| = \sqrt{(x^2 + y^2)}$.
- Step 3: Problem solving.
  - $\sqrt{(3^2 + 4^2)} = \sqrt{(9 + 16)} = \sqrt{25} = 5$

Find the magnitude and direction of $\langle 4, -3 \rangle$

- Step 1: Identify the chunks.
  - Use $\|v\| = \sqrt{(x^2 + y^2)}$
  - Adjust angle based on quadrant.
- Step 2: Retrieve prior knowledge.
  - Recall arctangent function.
  - Understand 4th quadrant: $x > 0, y < 0$.
  - Find direction: $\theta = \tan^{-1}\left(\frac{y}{x}\right)$
- Step 3: Problem solving.
  - Magnitude: $\sqrt{(4^2 + (-3)^2)} = \sqrt{(16 + 9)} = \sqrt{25} = 5$
  - $\theta = \tan^{-1}(-\frac{3}{4}) \approx -36.87°$
  - Direction: $360° - 36.87° = 323.13°$

Find the component form of a vector with magnitude 4 that forms an angle of $-45°$ with the x −axis.

- Step 1: Identify the chunks.
  - The magnitude of the vector is given: $\|v\| = 4$

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- The direction is given by the angle with the x −axis: $\theta = -45°$

- Step 2: Retrieve prior knowledge.
  - A vector's component form from magnitude and angle is found using:
- $v = \langle \|v\| \cos\theta\, , \|v\| \sin\theta \rangle$
  - $\cos(-45°) = \cos 45° = \frac{\sqrt{2}}{2}$
  - $\sin(-45°) = -\sin 45° = -\frac{\sqrt{2}}{2}$
- Step 3: Problem solving.
  - $v = \langle 4\cos(-45°)\, , 4\sin(-45°) \rangle$
  - $v = \langle 4 \cdot \frac{\sqrt{2}}{2}, 4 \cdot \left(-\frac{\sqrt{2}}{2}\right) \rangle$
  - $v = \langle 2\sqrt{2}, -2\sqrt{2} \rangle$

Session 4: vector in component form

Express a vector with an initial point $A(-3, 4)$ and terminal point $B(1, 2)$ in component form.

- Step 1: Identify the chunks.
  - Identify initial point $(x_1, y_1) = (-3, 4)$
  - Identify terminal point $(x_2, y_2) = (1, 2)$
- Step 2: Retrieve prior knowledge.
  - A vector in the plane is represented as the difference between its terminal and initial coordinates.
  - Component form uses the formula:

    $$v = \langle x_2 - x_1, y_2 - y_1 \rangle$$
  - Subtracting integers (including negative values) is essential in this context.

- Step 3: Problem solving. Use the chunks and retrieved knowledge:
  - $x_2 - x_1 = 1 - (-3) = 1 + 3 = 4$
  - $y_2 - y_1 = 2 - 4 = -2$
  - $v = \langle 4, -2 \rangle$

Session 5: vector in terms of standard unit vectors.

Express $w = \langle 3,\ 4 \rangle$ in terms of standard unit vectors.

- Step 1: Identify the chunks.
  - Recognize that the vector w is in component form $\langle a,\ b \rangle$
- Step 2: Retrieve prior knowledge.
  - Any vector $\langle a, b \rangle$ can be rewritten as $a\mathrm{i} + b\mathrm{j}$.
  - Identify the standard unit vectors i and j, where $\mathrm{i} = \langle 1,0 \rangle$ and $\mathrm{j} = \langle 0,1 \rangle$
  - i represents horizontal direction; j represents the vertical direction.
- Step 3: Problem solving.
  - $w = \langle 3,\ 4 \rangle$
  - $w = 3\mathrm{i} + 4\mathrm{j}$

Problem: A boat travels east at 10 km/h. A current pushes it north at 5 km/h. What is its resultant velocity?

- Step 1: Identify the chunks.
  - Represent the eastward vector $\langle 10, 0 \rangle$.
  - Represent current as $\langle 0, 5 \rangle$.
  - Add vectors; find magnitude and direction.
-
- Step 2: Retrieve prior knowledge.
  - Vector addition

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	○ Magnitude and direction formulas • Step 3: Problem solving. ○ $\langle 10, 0\rangle + \langle 0, 5\rangle = \langle 10, 5\rangle$ ○ $\text{Magnitude} = \sqrt{10^2 + 5^2} = \sqrt{100 + 25} = \sqrt{125} \approx 11.18$ km/h$\theta = \tan^{-1}(\frac{5}{10}) \approx 26.57°$ from east.
D. Making generalizations and abstractions about the lesson (GENERALIZATION)	Let's have a recap! In this lesson, students learned how to represent and manipulate vectors in the plane. They practiced locating vectors using components, finding magnitude and direction, and performing operations such as vector addition, scalar multiplication, and subtraction. The class also covered geometric and algebraic interpretations of vectors, including how to use the distance and midpoint formulas. By the end of the lesson, students should be able to apply vectors in the plane to solve problems involving displacement, force, and velocity in two dimensions.

Posttest

1. Find the work done by force F = ⟨5, 6, −2⟩ (measured in Newtons) that moves a particle from point P(3, −1, 0) to point Q(2, 3, 1) along a straight line (the distance is measured in meters).

Guiding Question	**Answer**
Which key part of the problem should I focus on first? What exact information is required in the final answer?	
Which given data or conditions can I convert into mathematical symbols, equations, or diagrams?	
What smaller steps or sub-problems can I solve first before combining them? Which strategies (Algebraic manipulation, drawing a figure, working backward, etc.) can be applied to each step or sub-problem?	
Solve each step or sub-problem one at a time, keeping track of intermediate results. How do these partial solutions connect toward the whole answer?	
Can I check each step or sub-problem individually to see if it's correct? Does combining all steps or sub-problems lead to a logical, accurate final solution? Is the answer reasonable and consistent with the problem's conditions?	

2. Consider points A(3, −1, 2), B(2, 1, 5), and C(1, −2, −2). Find the area of triangle ABC.

Guiding Question	**Answer**
Which key part of the problem should I focus on first? What exact information is required in the final answer?	
Which given data or conditions can I convert into mathematical symbols, equations, or diagrams?	
What smaller steps or sub-problems can I solve first before combining them? Which strategies (Algebraic manipulation, drawing a figure, working backward, etc.) can be applied to each step or sub-problem?	
Solve each step or sub-problem one at a time, keeping track of intermediate results. How do these partial solutions connect toward the whole answer?	
Can I check each step or sub-problem individually to see if it's correct? Does combining all steps or sub-problems lead to a logical, accurate final solution? Is the answer reasonable and consistent with the problem's conditions?	

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3. A baseball player throws a baseball at an angle of 30° with the horizontal. If the initial speed of the ball is 100 mph, find the horizontal and vertical components of the initial velocity vector of the baseball. (Round to two decimal places.)

Guiding Question	Answer
Which key part of the problem should I focus on first? What exact information is required in the final answer?	
Which given data or conditions can I convert into mathematical symbols, equations, or diagrams?	
What smaller steps or sub-problems can I solve first before combining them? Which strategies (Algebraic manipulation, drawing a figure, working backward, etc.) can be applied to each step or sub-problem?	
Solve each step or sub-problem one at a time, keeping track of intermediate results. How do these partial solutions connect toward the whole answer?	
Can I check each step or sub-problem individually to see if it's correct? Does combining all steps or sub-problems lead to a logical, accurate final solution? Is the answer reasonable and consistent with the problem's conditions?	

4. A point guard is standing on the court preparing to pass the ball. His teammate is positioned 20 feet down the court and 15 feet to the point guard's left. The point guard throws the basketball at a speed of 60 feet per minute toward his teammate at an upward angle of 30°. Write the initial velocity vector of the pass in component form.

Guiding Question	Answer
Which key part of the problem should I focus on first? What exact information is required in the final answer?	
Which given data or conditions can I convert into mathematical symbols, equations, or diagrams?	
What smaller steps or sub-problems can I solve first before combining them? Which strategies (Algebraic manipulation, drawing a figure, working backward, etc.) can be applied to each step or sub-problem?	
Solve each step or sub-problem one at a time, keeping track of intermediate results. How do these partial solutions connect toward the whole answer?	
Can I check each step or sub-problem individually to see if it's correct? Does combining all steps or sub-problems lead to a logical, accurate final solution? Is the answer reasonable and consistent with the problem's conditions?	

5. A mechanic uses a 12-in. wrench to turn a bolt. The wrench makes a 30° angle with the horizontal. If the mechanic applies a vertical force of 10 lb on the wrench handle, what is the magnitude of the torque? Express the answer in foot-pounds rounded to two decimal places.

Guiding Question	Answer
Which key part of the problem should I focus on first? What exact information is required in the final answer?	
Which given data or conditions can I convert into mathematical symbols, equations, or diagrams?	
What smaller steps or sub-problems can I solve first before combining them? Which strategies (Algebraic manipulation, drawing a figure, working backward, etc.) can be applied to each step or sub-problem?	
Solve each step or sub-problem one at a time, keeping track of intermediate results. How do these partial solutions connect toward the whole answer?	
Can I check each step or sub-problem individually to see if it's correct? Does combining all steps or sub-problems lead to a logical, accurate final solution? Is the answer reasonable and consistent with the problem's conditions?	

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