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THE USE OF GRAPHIC VISUALIZATION IN ENHANCING STUDENTS' UNDERSTANDING OF INTEGRATION BY PARTS

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Abstract:

This study investigates the effectiveness of the LIATE Mnemonic Diagram as a visual instructional aid for improving students' understanding and application of the Integration by Parts (IBP) technique in undergraduate calculus. A quantitative research design was employed, involving 75 students enrolled in a first-year calculus course at Universiti Teknologi MARA (UiTM). Participants completed a pre-test and post-test to assess their ability to select appropriate functions for u and dv, and to apply the IBP formula accurately. Following instruction using the LIATE Mnemonic Diagram, students demonstrated significant improvements in both function selection and overall problem-solving performance. Descriptive statistics and paired sample t-tests confirmed the statistical significance of these gains. The findings indicate that the LIATE Mnemonic Diagram supports students in reducing common errors and enhancing procedural fluency. This study contributes to mathematics education by providing empirical evidence on the instructional value of visual mnemonic tools in facilitating conceptual understanding and accuracy in integral calculus.

Keywords:

Integration by Parts (IBP), Graphic Visualization, LIATE Mnemonic Diagram, Calculus Instruction

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Introduction

Integration by Parts (IBP) is a fundamental technique in integral calculus, widely applied in mathematics, physics, engineering, and computer science to solve complex integrals involving products of functions (Stewart, 2015). Despite its theoretical elegance, empirical evidence indicates that a substantial proportion of undergraduate students approximately 62% according to Chen and Lee (2024) struggle with the correct selection of functions u and dv, leading to procedural errors, cognitive overload, and diminished confidence in problem-solving.

Conventional instructional methods often emphasize repetitive practice and the memorization of heuristics such as the LIATE rule Logarithmic, Inverse Trigonometric, Algebraic, Trigonometric, and Exponential as a systematic guide for function selection (Tarmizi, 2010). However, studies show that relying solely on mnemonic memorization fails to promote deep conceptual understanding, resulting in mechanical application and persistent misconceptions (Alias & Ibrahim, 2022; Rittle-Johnson & Koedinger, 2009). This educational gap between procedural memorization and conceptual mastery is a critical barrier to students' success in advanced calculus.

Visual representation has been increasingly recognized as an effective pedagogical strategy to enhance mathematical understanding. Research by Arcavi (2003) and Stylianou (2010) demonstrated that graphic visualization tools can reduce cognitive load, clarify abstract processes, and improve procedural fluency. In particular, visual aids that elucidate hierarchical and logical relationships within mathematical components offer a scaffold that supports student reasoning and retention. However, while visual approaches have been widely adopted in general mathematics instruction, limited research has specifically examined their integration into the teaching of IBP, particularly through structured mnemonic visualizations.

To address this gap, the LIATE Mnemonic Diagram was developed as a structured instructional tool aimed at enhancing logical reasoning and minimizing selection errors in IBP applications (Siti Asmah & Alias, 2024). Unlike traditional memorization techniques, the diagram provides a visual map of function prioritization, facilitating more accurate decision-making and reducing cognitive burden during problem-solving. Preliminary studies suggest that visual-mnemonic hybrids can significantly improve students' procedural accuracy and conceptual retention (Green, 2023; Ahmed & Kumar, 2023), yet empirical evidence on their effectiveness in advanced calculus education remains scarce.

Therefore, this study aims to evaluate the impact of the LIATE Mnemonic Diagram on undergraduate students' mastery of IBP. Specifically, the research investigates whether the use of a structured visual mnemonic reduces common selection errors, enhances students' conceptual understanding, and improves academic performance in integral calculus. Through a quantitative design involving pre-test and post-test assessments, this study seeks to contribute empirical insights to the growing body of research advocating for innovative, evidence-based instructional strategies in higher mathematics education.

Literature Review

Graphic Visualization in Mathematics Education

Graphic visualization has become a transformative pedagogical approach in mathematics education, particularly for improving learners' comprehension of abstract concepts in advanced

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topics such as calculus (Arcavi, 2003; Stylianou, 2010). Techniques like IBP demand strategic reasoning and selection of function pairs (u and dv), posing cognitive challenges even for high-performing students (Smith, 2021; Jones & Patel, 2022). Graphic tools that illustrate procedural flows and functional hierarchies are shown to reduce mental workload and foster clarity in execution (Chen & Lee, 2024).

Several empirical studies support the use of visual aids in improving students' understanding of IBP. Smith (2021) reported that students exposed to structured visual representations were better able to sequence IBP steps and select appropriate functions. Jones and Patel (2022) further found that students taught with visual-based strategies made fewer procedural errors than those taught using conventional lectures. Chen and Lee (2024) expanded this research into online learning contexts, demonstrating that digital mnemonic diagrams significantly improved both conceptual retention and learner motivation.

Mnemonic Devices and Procedural Fluency

Mnemonic strategies such as LIATE—Logarithmic, Inverse Trigonometric, Algebraic, Trigonometric, Exponential—have long been used to guide function selection in IBP (Tarmizi, 2010). However, when used in isolation, these heuristics often promote rote memorization rather than deep understanding. Ahmed and Kumar (2023) found that traditional mnemonics, while initially effective, did not lead to sustained mastery of integration techniques.

To address this limitation, researchers have proposed the integration of mnemonic devices with graphic visualization. Green (2023) argued that visual-mnemonic tools support deeper conceptual mastery by simultaneously engaging verbal and visual processing pathways. While the short-term gains of these hybrid tools are well-documented, there remains a lack of longitudinal studies assessing their long-term impact on students' procedural fluency (Ahmed & Kumar, 2023).

Challenges and Limitations of Visual Aids

Despite their pedagogical promise, visual aids are not universally effective. Smith (2021) and Green (2023) noted that access to reliable technological platforms is a major barrier in under-resourced institutions. Chen and Lee (2024) highlighted that the instructional efficacy of digital diagrams varies based on levels of interactivity and students' familiarity with the delivery format.

Furthermore, individual differences in learning preferences can affect the utility of visual aids. Winn (2005) and Tversky, Morrison, and Betrancourt (2002) emphasized that learners with low spatial ability may derive less benefit from diagrams unless supported by structured guidance. Therefore, scalability and adaptability must be considered in the design of visual tools for broader applicability.

Theoretical Framework

This study is guided by Cognitive Load Theory (CLT), which asserts that instructional materials should minimize extraneous cognitive load to promote optimal learning (Sweller, 1988). Visual scaffolds, such as the LIATE Mnemonic Diagram, can serve as external supports to streamline decision-making in IBP and prevent overload.

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In addition, the study adopts Dual Coding Theory (Paivio, 1986), which proposes that learning is enhanced when information is processed through both verbal and visual channels. The LIATE Mnemonic Diagram, as a visual representation of the LIATE rule, is expected to support dual encoding and lead to improved conceptual and procedural performance.

Conceptual Framework

Based on the theoretical underpinnings, the following conceptual flow guides this study:
Graphic Visualization (LIATE Mnemonic Diagram)

- Reduced Cognitive Load
- Enhanced Conceptual Understanding and Procedural Fluency
- Improved Accuracy and Performance in IBP Tasks

This framework informs the design and evaluation of the visual mnemonic intervention for undergraduate students studying IBP.

Table 1: Summary of Selected Past Studies on Graphic Visualization and Mnemonic Devices in Mathematics Education

Author(s) & Year	Focus Area	Key Findings	Limitation
Smith (2021)	Visual aids in IBP	Helped sequence IBP steps and reduce errors	Lack of long-term retention data
Jones & Patel (2022)	Visual vs. traditional teaching	Visual aids improved IBP accuracy	Small sample size
Chen & Lee (2024)	Digital mnemonic tools	Enhanced retention and motivation in online settings	Requires technological infrastructure
Ahmed & Kumar (2023)	Mnemonics in advanced math	Short-term improvement using LIATE	Lack of longitudinal data
Green (2023)	Visual-mnemonic strategies	Boosted deeper conceptual mastery	Varies by learner cognitive style

Research Gap and Justification

While extensive research supports the separate use of visual aids and mnemonic devices in mathematics education, there is limited empirical evidence evaluating the combined effect of these tools specifically, structured mnemonic diagrams like the LIATE Mnemonic Diagram in the context of IBP. Furthermore, most studies have focused on short-term learning outcomes, with little attention to sustained conceptual understanding or broader implementation in varied learning environments.

This study seeks to fill that critical gap by examining the effectiveness of the LIATE Mnemonic Diagram as a visual instructional aid to improve students' mastery of IBP. The findings aim to contribute to the development of more evidence-based and scalable strategies for calculus instruction in higher education settings.

International Journal of Modern Education
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Traditional Techniques in Teaching Integration by Parts

Traditionally, IBP is taught through a formulaic approach that emphasizes memorization and repetitive practice. The standard formula:

$$\int u\,dv = uv - \int v\,du \qquad (1)$$

is introduced, and students are typically instructed to select *u* and *dv* based on their familiarity with functions and differentiation rules. The traditional method relies heavily on the LIATE rule, an acronym for Logarithmic, Inverse Trigonometric, Algebraic, Trigonometric, and Exponential functions, as a well-known strategy for selecting u and dv in IBP.

In this traditional approach, the instructional focus is on memorization, where students are encouraged to memorize the LIATE hierarchy to facilitate the selection process. Through repeated practice of example problems, students are expected to internalize the steps involved in applying the IBP formula. Instruction is typically delivered through written notes and lectures, where the emphasis is placed on understanding the algebraic manipulation of functions. While this method has been effective for some students, it has inherent limitations. The reliance on memorization can lead to the mechanical application of the formula without a deep understanding of the underlying concepts. Additionally, students may struggle with identifying the correct u and dv, leading to frequent errors and a lack of confidence in solving complex integrals.

Innovative Technique: The Use of Graphic Visualization through the LIATE Mnemonic Diagram

To address the limitations of the traditional method, an innovative approach that integrates visual aids has been developed. This method utilizes a mnemonic square diagram based on the LIATE rule, transforming the abstract process of IBP into a more intuitive and visual experience.

The innovative technique involves the following key components:

1. Development of the LIATE Mnemonic Diagram: The LIATE Mnemonic Diagram is designed to visually represent the LIATE hierarchy, providing a clear and systematic way for students to choose u and dv. Each function category (Logarithmic, Inverse Trigonometric, Algebraic, Trigonometric, Exponential) is arranged in a square grid, where the relative positions guide the selection process. The diagram is also color-coded and includes arrows or pathways that direct students towards the correct choices, thereby reducing the cognitive load associated with the decision-making process. The diagram, as shown in Figure 1, provides a visual representation of the logical flow and structure behind selecting u and dv, whereas the Table 2 offers practical examples of how to apply these selections to actual integrals.

International Journal of Modern Education
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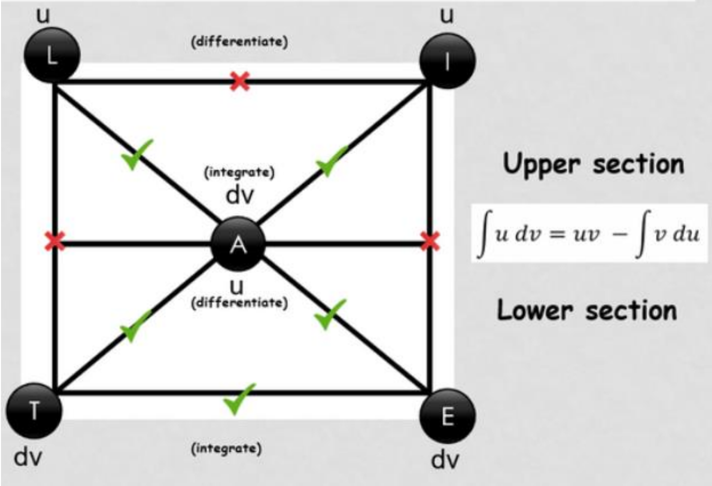

Figure 1: LIATE Mnemonic Diagram

Table 2: Examples of How To Apply These Selections To Actual Integrals

Section Diagram	**Product of functions (LIATE)**	u	dv
Upper Section	$\int x\ln(x)\,dx$ **(AL)**	**A:** $u = \ln(x)$	**L:** $dv = xdx$
	$\int x\tan^{-1}(x)\,dx$ **(AI)**	**A:** $u = \tan^{-1}(x)$	**I:** $dv = xdx$
Lower Section (Repeated or Tabular by parts)	$\int x\sin(x)\,dx$ **(AT)**	**A:** $u = x$	**T:** $dv = \sin(x)dx$
	$\int xe^x dx$ **(AE)**	**A :** $u = x$	**E:** $dv = e^x dx$
Special Case	$\int \sin(x)e^x dx$ **(TE)**	**T:** $u = \sin(x)$	**E:** $dv = e^x dx$
Complicated Integrals	$\int \ln(x)\tan^{-1}(x)\,dx$ **(LI)** $\int \sin x\ln(x)\,dx$ **(LT)** $\int e^x\tan^{-1}(x)\,dx$ **(TE)**	Poor function pairings to product	

2. Interactive Learning with Visual Tools: Students engage with the LIATE Mnemonic Diagram through interactive learning sessions. These sessions can be facilitated by digital platforms that allow students to manipulate the diagram and explore different scenarios in real-time. By visualizing the integration process, students gain a better understanding of how the choice of u and dv affects the outcome of the integral. This approach promotes active learning and encourages students to experiment with different function pairs. This dynamic visualization, as shown in Figure 2.

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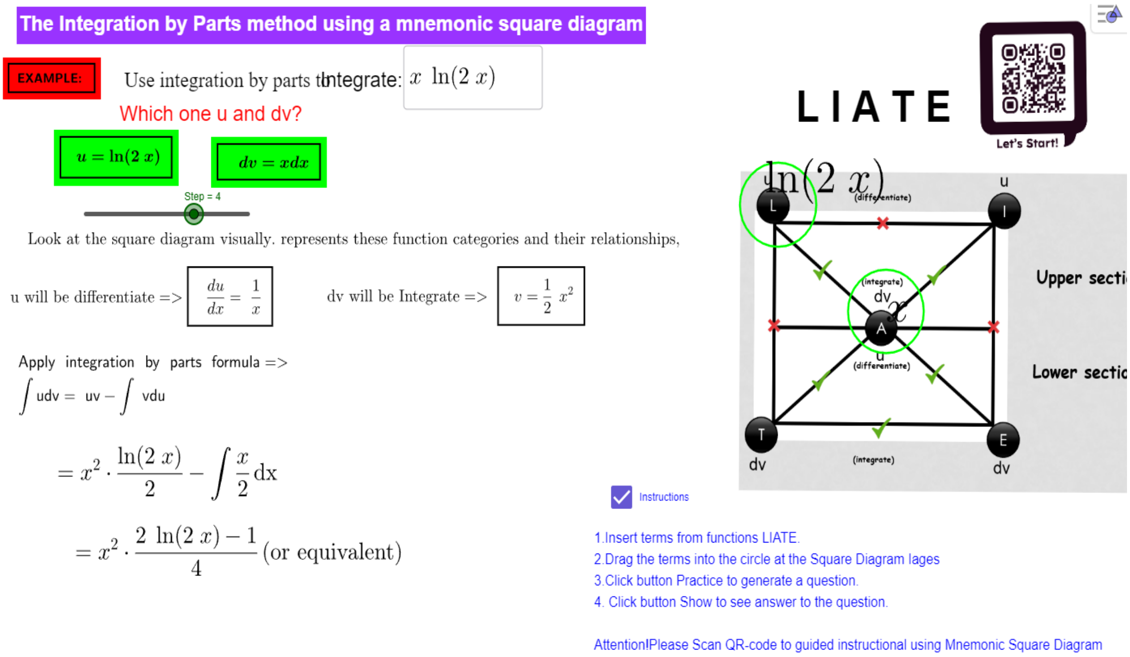

Figure 2: Dynamic Visualization of Integration by Parts

3. Step-by-Step Visual Explanation: In addition to the LIATE Mnemonic Diagram, the innovative method includes step-by-step visual explanations of the integration process. These explanations are presented through instructional videos or interactive software, where each step in the formula application is accompanied by corresponding visual cues. This method bridges the gap between theory and practice, enabling students to see the immediate impact of their choices on the integral and providing immediate feedback on their problem-solving approach.

4. Assessment and Feedback: The innovative approach includes regular assessments that incorporate visual components, such as diagram-based quizzes or interactive problem-solving exercises. These assessments are designed to reinforce the visual learning process and provide immediate feedback to students. Feedback is delivered in a manner that highlights both correct and incorrect selections, helping students to refine their understanding and avoid common pitfalls in the application of the IBP formula.

Table 3: The Comparison Between The Traditional and Innovative Techniques

Comparison Aspect	Traditional Technique	Innovative Technique
Memorization vs. Visualization	Relies on memorization of rules and repeated practice.	Emphasizes visualization and active engagement with learning material.
Cognitive Load	High cognitive load due to constant recall and application of the LIATE rule without visual guidance.	Reduced cognitive load with clear and systematic visual aids that simplify decision-making.
Student Engagement	Less dynamic and can be intimidating for some students.	Enhances student engagement through interactive tools and visual explanations, making learning more dynamic.

International Journal of Modern Education IJMOE
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Volume 7 Issue 25 (June 2025) PP. 264-275
DOI: 10.35631/IJMOE.725019

Error Reduction	Higher likelihood of errors in selecting *u* and *dv*.	Provides a structured visual framework that reduces errors and increases accuracy in problem-solving.

Methodology

This study adopted a quantitative research design to evaluate the effectiveness of a visual instructional tool, the LIATE Mnemonic Diagram in enhancing undergraduate students' understanding of the IBP technique in calculus. The study was conducted over a four-week instructional period during the March–April 2025 semester at the Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA (UiTM). A total of 75 undergraduate students enrolled in a first-year calculus course were selected through random sampling to ensure representation and reduce selection bias. Uniform instructional delivery was maintained throughout the study period to ensure consistency in the learning experience across all participants.

A pre-test and post-test design was employed to assess changes in students' conceptual and procedural understanding of IBP before and after the instructional intervention. The pre-test, administered at the outset, evaluated students' baseline abilities in identifying appropriate functions for u and dv, and in applying the IBP formula accurately. Following the traditional instruction phase, students were introduced to the LIATE Mnemonic Diagram during a targeted instructional session, which aimed to reinforce the LIATE rule (Logarithmic, Inverse Trigonometric, Algebraic, Trigonometric, Exponential) using structured visual cues.

Data Analysis

Quantitative data analysis was conducted to assess the impact of the LIATE Mnemonic Diagram on students' understanding and problem-solving performance. The data were obtained from students' scores on the pre-test and post-test assessments, both of which were designed to be equivalent in terms of content and difficulty. These assessments measured students' procedural accuracy in applying the IBP formula, as well as their ability to correctly select function pairs in accordance with the LIATE rule.

Descriptive statistics were first computed to summarize the data, including measures of central tendency (mean) and dispersion (standard deviation). These metrics provided an overview of students' overall performance and variability across both assessments. To determine the statistical significance of the observed changes in student scores, a paired sample t-test was performed. This inferential technique was chosen to evaluate whether the mean difference between pre-test and post-test scores was statistically significant, thereby validating the effectiveness of the LIATE Mnemonic Diagram as an instructional intervention.

Results and Discussion

The demographic profile of the participants was first examined to provide context for the subsequent analysis of instructional outcomes. Figure 3 presents a pie chart illustrating the gender distribution among the 75 undergraduate students who participated in the study. The chart indicates that 53.3% of the participants were male (40 students), while 46.7% were female (35 students). Figure 4 illustrates the distribution of the 75 students involved in the study according to their faculty affiliations. Bar chart shows that the Faculty of Electrical Engineering had the highest representation, contributing 32 students (42.7%) to the sample. This was

International Journal of Modern Education
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followed by the Faculty of Mechanical Engineering with 23 students (30.7%), and the Faculty of Civil Engineering with 20 students (26.6%).

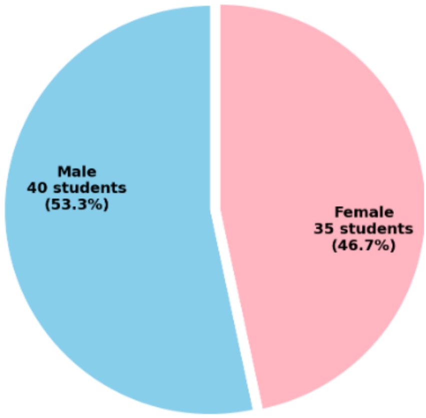

Figure 3: Pie Chart of Respondents' Gender

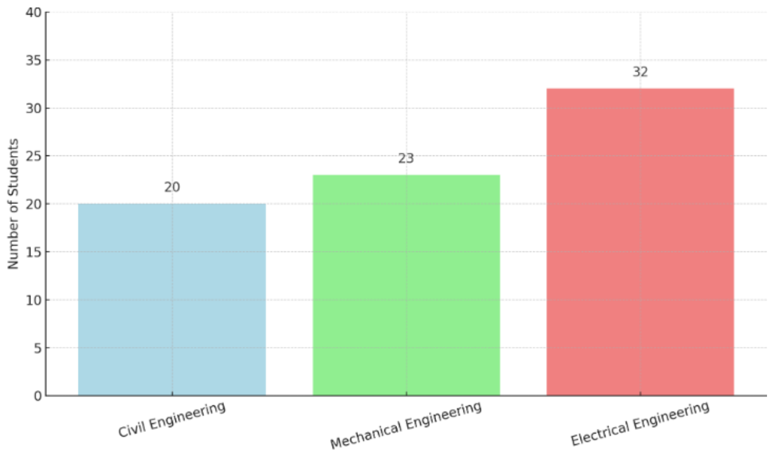

Figure 4: Bar Chart of Respondents' Distribution by Faculty

The analysis of students' performance before and after the intervention demonstrates clear evidence of the effectiveness of the LIATE Mnemonic Diagram in improving understanding and application of the IBP technique. The pre-test results in Table 4 indicated a mean score of 5.32 (SD = 1.232), reflecting the students' limited initial proficiency in selecting appropriate functions for u and dv, as well as applying the IBP formula accurately. Following the instructional intervention incorporating the LIATE Mnemonic Diagram, the post-test mean score increased substantially to 8.96 (SD = 1.120). This notable improvement highlights the positive impact of the mnemonic-based approach, supporting previous research that emphasizes the role of structured visual aids in enhancing students' comprehension of complex mathematical procedures (Stylianides & Stylianides, 2007).

International Journal of Modern Education
IJMOE
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Volume 7 Issue 25 (June 2025) PP. 264-275
DOI: 10.35631/IJMOE.725019

Table 4: Paired Samples Statistics

Pair	Mean	N	Standard Deviation
Pre – test	5.32	75	1.232
Post – test	8.96	75	1.120

The paired samples correlation in Table 5 further confirmed this improvement, with a strong positive correlation coefficient of r=0.861, p-value 0.000<0.001, indicating consistent performance gains across the student cohort. Such a high correlation suggests that the intervention benefitted students regardless of their initial levels of understanding. Earlier studies have reported similar findings, demonstrating that the use of mnemonic devices and structured visual frameworks can significantly improve learners' abilities to internalize and apply problem-solving strategies in mathematics (Gurlitt et al., 2012; Fiorella & Mayer, 2016). These results align with cognitive load theory, which explains that effective visual aids help reduce extraneous cognitive load, enabling learners to focus more efficiently on the essential aspects of the task (Sweller, 2010).

Table 5: Paired Samples Correlation

Pair	N	Correlation	p-value
Pre – test & Post – test	75	0.861	0.000

Further statistical analysis using the paired sample t-test (Table 6) yielded a highly significant result, test statistic=−50.114, p-value 0.000<0.001, with a mean difference of -3.64. This outcome is consistent with findings from Pape et al. (2012), who reported that mnemonic and visual scaffolding techniques notably enhance procedural fluency and accuracy in advanced calculus instruction. The results from this study, therefore, provide strong evidence that the LIATE Mnemonic Diagram not only improved immediate comprehension but also enhanced students' ability to apply the IBP method with greater confidence and accuracy.

Table 6: Paired Samples Test

	Paired Differences				
Pair	**Mean**	**Standard Deviation**	**Standard Error Mean**	**t – Statistic**	**p-Value**
Pre – test & Post – test	-3.640	0.629	0.073	-50.114	0.000

The effectiveness of the LIATE Mnemonic Diagram can be attributed to its clear, systematic prioritization of functions — Logarithmic, Inverse Trigonometric, Algebraic, Trigonometric, and Exponential — which provided students with a straightforward cognitive framework for tackling IBP problems. Previous research has shown that structured heuristics significantly improve problem-solving efficiency and reduce errors in tasks requiring multiple procedural steps (Montague, 2008). The improvement observed in this study suggests that the mnemonic successfully guided students through complex decision-making processes, enabling them to approach IBP problems with improved clarity and procedural accuracy.

Moreover, the consistency of improvement across all students indicates the broad applicability of the LIATE Mnemonic Diagram. The findings echo the conclusions of Rittle-Johnson and Koedinger (2009), who emphasized that visual supports can bridge gaps in students' prior knowledge and promote more equitable learning outcomes. This aspect is particularly significant for higher education settings, where student cohorts often display diverse levels of preparedness. By supporting students across a range of initial competencies, the LIATE Mnemonic Diagram proves to be not only an effective instructional aid but also a valuable resource for addressing varied learner needs in calculus education.

The results of this study clearly establish the effectiveness of the LIATE Mnemonic Diagram in enhancing students' understanding and application of the IBP technique. By providing a structured visual framework and reducing cognitive complexity, the diagram substantially improved students' procedural fluency and problem-solving accuracy. These findings contribute to the broader body of knowledge supporting the integration of visual and mnemonic strategies in mathematics education and offer practical insights for educators seeking to improve student outcomes in advanced calculus instruction.

Conclusion

This study examined the use of the LIATE Mnemonic Diagram as a visual aid to support students' understanding of the IBP technique in a first-year undergraduate calculus course. Through a quantitative design involving pre-test and post-test assessments of 75 students, the findings demonstrated that the diagram significantly improved students' ability to select appropriate functions for u and dv, as well as their overall accuracy in applying the IBP formula. The statistical analysis confirmed that these improvements were both meaningful and consistent across the sample.

The results provide evidence that visual scaffolds, such as the LIATE Mnemonic Diagram, can play a valuable role in addressing common difficulties students face when learning complex integration methods. The structured, rule-based format of the diagram appeared to reduce uncertainty and improve procedural clarity, enabling students to apply the technique with greater confidence. These findings are in line with existing research that highlights the benefits of combining mnemonic strategies with visual representations in mathematics education.

By contributing new empirical data on the application of the LIATE Mnemonic Diagram, this study offers practical insights for educators and curriculum designers aiming to strengthen instructional approaches in calculus. The evidence suggests that such tools not only support students' problem-solving accuracy but also promote clearer understanding of procedural steps in integration. Incorporating well-designed visual aids into calculus instruction may help bridge the gap between conceptual knowledge and effective application, ultimately enhancing student outcomes in integral calculus.

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References

Ahmed, R., & Kumar, S. (2023). The impact of mnemonic devices on long-term retention of mathematical techniques. Journal of Mathematics Education, 15(2), 45–59.

Alias, F. A., & Ibrahim, M. S. (2022). Visual mnemonic strategies in enhancing mathematics problem-solving skills. Journal of Educational Research and Practice, 12(2), 89–102.

International Journal of Modern Education
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DOI: 10.35631/IJMOE.725019
Arcavi, A. (2003). The role of visual representations in the learning of mathematics. Educational Studies in Mathematics, 52(3), 215–241. https://doi.org/10.1023/A:1024312321077

Chen, L., & Lee, H. (2024). Digital mnemonic tools for online learning: Enhancing student retention in integral calculus. Journal of Online Mathematics Education, 9(1), 22–35.

Crockcroft, W. H., & Boyd, A. (2008). Mathematics counts: Report of the Committee of Inquiry into the Teaching of Mathematics in Schools. London: Her Majesty's Stationery Office.

Green, P. (2023). Long-term effectiveness of mnemonic devices in advanced mathematics. Mathematics Teaching Research Journal, 7(1), 14–27.

Jones, T., & Patel, R. (2022). Comparing visual aids and traditional methods in teaching integration by parts. International Journal of Mathematics Education, 13(3), 68–80.

Paivio, A. (1986). Mental representations: A dual coding approach. Oxford University Press.

Rittle-Johnson, B., & Koedinger, K. R. (2009). Iterating between lessons on concepts and procedures can improve mathematics knowledge. British Journal of Educational Psychology, 79(3), 483–500. https://doi.org/10.1348/000709908X398106

Siti Asmah, M., & Alias, F. A. (2024). Enhancing students' understanding of integration by parts through the LIATE Mnemonic Diagram. Journal of Mathematics Teaching and Learning, 18(1), 33–48.

Smith, A. (2021). Visual aids in teaching integration by parts: Improving accuracy and engagement. Journal of Mathematics Instruction, 12(2), 55–64.

Stewart, J. (2015). Calculus: Early transcendentals (8th ed.). Brooks/Cole Cengage Learning.

Stylianou, D. A. (2010). Teachers' conceptions of representation in mathematics instruction. Journal of Mathematical Behavior, 29(2), 58–75. https://doi.org/10.1016/j.jmathb.2010.01.001

Sweller, J. (2010). Cognitive load theory: Recent theoretical advances. Cognitive Science, 38(2), 257–285. https://doi.org/10.1111/j.1551-6709.2010.01117.x

Tarmizi, R. A. (2010). Visualizing mathematics: The role of visual-spatial ability in problem solving. Procedia Social and Behavioral Sciences, 8, 552–560. https://doi.org/10.1016/j.sbspro.2010.12.076

Tversky, B., Morrison, J. B., & Betrancourt, M. (2002). Animation: Can it facilitate? International Journal of Human-Computer Studies, 57(4), 247–262. https://doi.org/10.1006/ijhc.2002.1017

Winn, W. D. (2005). Learning from maps and diagrams. Educational Psychology Review, 17(2), 111–123. https://doi.org/10.1007/s10648-005-2596-x