Development And Validation of Supplemental Learning Material in Integral Calculus

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ABSTRACT

This study investigated the performance of Bachelor of Science in Civil Engineering (BSCE) students in Integral Calculus at Saint Louis College, aiming to develop and validate Supplemental Learning Material (SLM) to address academic gaps. Emphasizing Integral Calculus as essential in civil engineering, the study assessed students' proficiency in topics such as integration of rational fractions, algebraic and standard formulas (U-substitution), definite integrals, and geometric applications. A teacher-made multiple-choice test was administered to 19 second-year students and validated by five instructors. Data were gathered during the 2023–2024 midterm and analyzed using mean percentage scores and descriptive ratings. Results showed strengths in definite integrals and rational fractions, but weaknesses in algebraic and geometric concepts. Based on the findings, an SLM was developed, receiving a high content validity rating (mean = 4.19). The study concludes that focused supplemental materials can significantly improve students' understanding and recommends using interactive strategies and continuous assessment.

Keywords: Integral Calculus, Civil Engineering students, performance in Integral Calculus, strengths, weaknesses, descriptive-developmental, supplemental learning material

INTRODUCTION

Background of the Study

The Bachelor of Science in Civil Engineering is a vital academic discipline that significantly impacts society by applying mathematical and scientific knowledge to enhance infrastructure like bridges, dams, buildings, roads, railways, and utilities, thereby improving human life and societal quality (Tougwa, 2020). Civil engineering is crucial for reshaping the environment to meet human needs and safeguard society, underlining its paramount importance (Fang & Li, 2016).

To ensure the accuracy of engineering project designs, students must grasp the fundamentals of Engineering Mathematics throughout their academic journey. Engineering mathematics is a pivotal undergraduate course for science and engineering majors in various educational institutions, emphasizing the necessity of mathematical knowledge to cultivate analytical thinking skills (Nanayakkara & Peiris, 2016; Puzi et al., 2022). Core elements of Engineering Mathematics involve Basic Algebra, Advanced Algebra, Geometry, Trigonometry, Probability, Statistics, Differential Calculus, and Integral Calculus.

Among these subjects, Integral Calculus stands out as a vital component in the education of civil engineering students, equipping them with the tools to solve intricate engineering problems and make informed decisions. Integrating calculus into the curriculum enhances students' understanding of engineering principles and applications, especially in civil engineering, where analytical problem-solving is integral (Kabook et al., n.d.).

The proficiency of Bachelor of Science in Civil Engineering students in integral calculus significantly influences their ability to apply mathematical concepts in engineering design and analysis. Integral calculus is fundamental in civil engineering calculations such as determining volume, area, moment of inertia, and center of gravity, critical for designing sound structures (Nurhayati et al., 2023).

Despite its importance, students often struggle with integral calculus concepts, impacting their performance in engineering. Addressing these challenges requires the development of supplemental learning resources to improve students' mathematical reasoning and understanding. Tailored teaching materials and instructional strategies, such as guided discovery learning, can enhance students' comprehension of integral calculus and target areas of difficulty (Siahaan et al., 2023; Yuliana et al., 2017).

Moreover, incorporating visualization tools and interactive learning methods can enhance students' conceptual understanding of integral calculus, particularly beneficial for civil engineering students facing difficulties in this area (Septian et al., 2020).

Therefore, supporting Bachelor of Science in Civil Engineering students in their grasp of Integral Calculus through the development of supplementary learning materials, innovative teaching methods, and visualization tools is crucial to enhance their academic success and competency in the field.

Framework of the Study

The study is framed on various theories and concepts in the development and validation of supplemental learning material.

The researcher uses the following theories;

Zone of Proximal Development (ZPD)

Vygotsky's Zone of Proximal Development theory is very applicable to the student performance in Civil Engineering and particularly while students deal with integral calculus. It indeed takes a very specific relevance in teaching mathematics for this community as it underlines the importance of supporting and challenging the students appropriately while they handle complex mathematical concepts such as integral calculus.

Research has shown that students often struggle with conceptual understanding in integral calculus (Mahir, 2009). This aligns with the ZPD theory, as it emphasizes the need for targeted support to bridge the gap between a student's current understanding and the desired level of proficiency. Moreover, on the study of performance and confidence of undergraduate students in procedural and conceptual mathematics, it was discovered that there is an inter-relationship between students' mathematics confidence and performance, according to Engelbrecht et al. (2005).

This means that challenges are not only conceptual but also connected with the level of confidence, which can be dealt with effectively with the ZPD framework. By recognizing the unique needs and abilities of students within their ZPD, educators can tailor their instructional approaches to optimize student learning outcomes.

Cognitive Load Theory (CLT)

Cognitive Load Theory is a framework that seeks to understand the cognitive processes that occur in learning and how that cognitive load affects the student's performance. CLT emphasizes limitations of the capacity of working memory and the generation of schema automation in long-term memory (Chen & Chang, 2017). It focuses on reducing extraneous cognitive load that is very applicable in education contexts (Sweller, 2010). CLT further suggests that controlling intrinsic load is important for effective learning (Huang, 2018).

CLT has implications for teaching Integral Calculus to Civil Engineering students. Such students can apply CLT to inform design instruction and learning approach. One study on cognitive apprenticeship in engineering education found that for most students taking the class, their approach to cognition made a positive difference in learning, regardless of the preferred learning style for that student (Poitras & Poitras, 2011).

Another relevance of CLT in mathematics education is grounded on studies that applied the principles of CLT in understanding how reduced cognitive load impacts the performance of students in mathematics test items (Gillmor et al., 2015).

Thus, Cognitive Load Theory provides valuable framework conditions to understand the learning process from a cognitive point of view and may offer insights in performance improvement opportunities for students in Integral Calculus courses offered to Civil Engineers.

Adaptive Learning Theory

Adaptive learning theory is the pedagogy that uses technology in tailoring the learning experiences of individual needs. This improves student performance because it caters to the needs of every individual student. It is very applicable for civil engineering students with integral calculus in respect to the adaptive learning theory; it would be able to cope with the learning needs and challenges in overcoming this complex mathematical subject. Actually, research has shown that the deployment of hypermedia-based e-books, an adaptive learning technology, actually enhanced students' achievement on integral calculus (Awaludin et al., 2020).

In this regard, deepening understanding in the theory of adaptive learning seems worth the effort as the possibility of helping them perform supports them individually with tailored resources and assistance to make integral calculus concepts 'click'.

This pillar of the adaptive learning theory, neural networks, has been applied in civil engineering and more so in the models concerning strength and control in structural contents (Jian et al., 2020). By incorporating neural network-based semi-active control models, adaptive learning theory would be better utilized to facilitate a better grasp of the mathematical underpinning of civil engineering structures leading to superior student performance in working with integral calculus subjects.

These discoveries are the further and more valued evidence of the capabilities of adaptive learning theory, well integrated with cutting-edge technologies and tailored approaches, for improved student performance in integral calculus within the field of civil engineering.

Research Paradigm

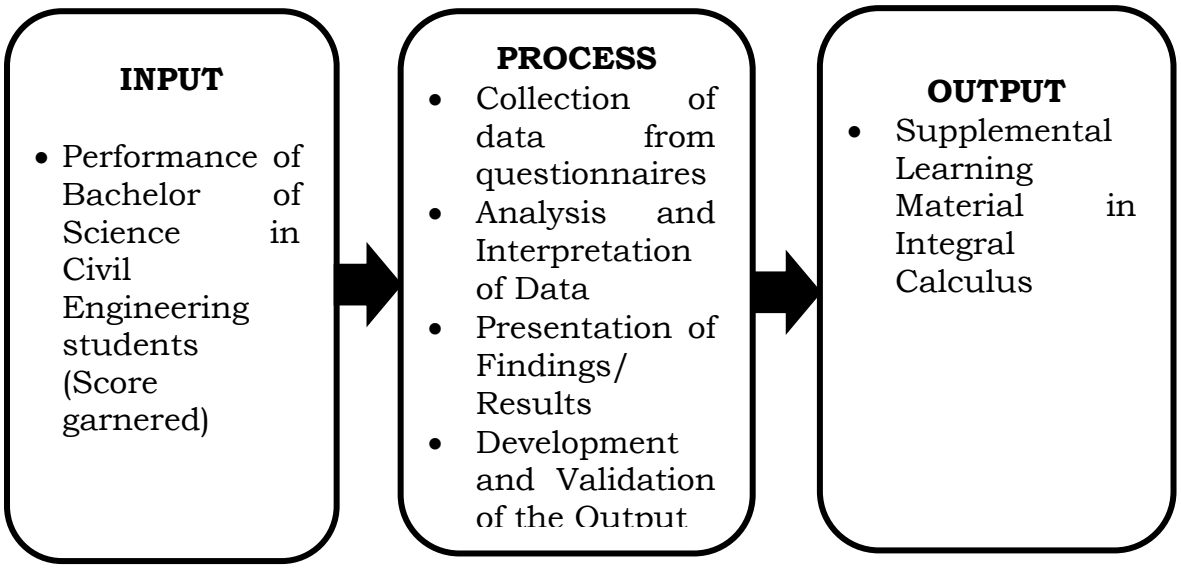

Figure 1. Research Paradigm of the Study

The researcher has chosen the Input Process Output (IPO) model. The researcher focuses on developing and validating Supplemental Learning Material (SLM) among students of Bachelor of Science in Civil Engineering students enrolled in Integral Calculus at Saint Louis College.

The IPO model comprises three main phases: Input, Process, and Output. In the illustrated diagram, the input consists of the score garnered by the Engineering students on their Midterm Exam School Year 2022-2023 Short Term. This initial phase involves administering of test questions with the topics included in the Integral

Calculus syllabus particularly topics on Geometric Application of Integral Calculus techniques incorporated with the objectives identified in the course learning plan.

During the process, the researcher facilitated the exam, checked the exam papers and collect all the scores garnered by the students. It provides understanding and interpretation of the researcher to what specific topics in the test questions the students had poor performance with. A pilot test was also administered outside the institution for validation of the exam particularly at the University of Northern Philippines with their respective Civil Engineering students currently taking Integral Calculus.

The final phase entails the analysis of the data collected and providing supporting evidence in developing supplemental learning material with the Integral Calculus topics included in the exam. The researcher focuses on the topics where most of the students got incorrect answers in each topic provided in the exam.

Statement of the Problem

This study aimed to identify the topics of Integral Calculus in which BSCE students have poor know-how and to develop and validate a supplementary learning material to hone these weaknesses.

Specifically, it sought to answer the following:

1. What is the level of performance of Bachelor of Science in Civil Engineering students in Integral Calculus along;

a) Integration of rational fractions,
b) Algebraic and additional standard formulas (including U-substitution),
c) and Definite integral,

2. What are the strengths and weaknesses of Bachelor of Science in Civil Engineering students in the identified topics in Integral Calculus?
3. What material can be developed to improve the performance of the Bachelor of Science in Civil Engineering students in Integral Calculus?
4. What is the level of acceptability of the developed material?

Assumptions

In this study, general statements are listed as follows:

1. The level of performance of Bachelor of Science in Civil Engineering students in Integral Calculus is satisfactory.
2. The strengths and weaknesses of Bachelor of Science in Civil Engineering students in the identified topics in Integral Calculus are determined.
3. The level of acceptability of the developed material is fair.

Scope and Limitations of the Study

This study was undertaken to determine the level of performance-based on the garnered grades through a teacher-made test on specific topics of Integral Calculus particularly the Integration of rational fractions, Algebraic, Definite integral, and Geometric application of Integral Calculus (Area under the curve and area between two curves) of enrolled Bachelor of Science in Civil Engineering second year students school year 2023-2024 of Saint Louis College located at San Fernando City, La Union.

Importance of the Study

This study will benefit the following entities:

Students

The study holds significant relevance for students navigating this complex mathematics domain. First of all, it answers an important gap left by traditional learning materials by providing supplementary materials tailored towards enhancing understanding and skill at Integral Calculus concepts. In addition, the validation process ensures that these learning materials work and are accurate so that students will receive reliable tools for enhancing their learning journey. This would eventually give the learner better, accessible, and effective supplementary materials that can guide them in their journey toward proficiency and confidence in the subject of Integral Calculus.

Instructors

This study is of prime importance to the instructors involved in teaching Integral Calculus to BSCE students. Factors influencing student performance will be understood, and instructors will find ways to adjust teaching methods because of specific problems detected in the research. Strategic intervention materials will provide instructors with a lot of value and effective support in student learning. Furthermore, the knowledge acquired from the research can guide pedagogical approaches, cultivating a more interactive and nurturing educational atmosphere that improves both student comprehension and the efficacy of instructors' teaching.

School Administrators

This study on the performance of BSCE students in Integral Calculus has much bearing on educational administrators. Specifically, the identification of particular problems that plague this subject, fundamental by nature, could give administrators an insight into some of the flaws existing in the curriculum. The results of this research will, therefore, facilitate informed decisions on updates to the curriculum and resource allocations that guarantee academic programs meet the demands of BSCE students. Further, additional learning materials developed from these findings could possibly result in better student performance and improved general quality of the program, which would eventually enhance the reputation of the institution.

Researcher

It contributes to the big league of educational research and narrows down its focus to the engineering education sphere. Scholars in this realm can take findings from this study to further probe the intricacies of students' achievement in integral calculus in diverse fields of engineering. The methodologies and insights the research produces may open avenues for further investigation, exploring new pedagogical methods, interventions, and evaluations, which could be applied not only to integral calculus but also in other demanding disciplines of engineering.

Future Researchers

The future researcher will find this study worthwhile because it opens avenues for deeper exploration into the student performance dynamics of classes like Integral Calculus in engineering programs. Guidance for future studies on improving student outcomes in similar contexts will be available in the identified challenges and effective intervention strategies. Moreover, it enables a methodological framework to assist in student performance related to technical subject matters and provides a roadmap for the replication or adaptation of the research design to diverse educational settings. New research inquiries may be inspired by this study to contribute to continuous improvement towards engineering education and student success.

Definition of Terms

These definitions are intended to promote uniformity and enable efficient communication of the research findings by offering clarity and a shared understanding of the significant terms used throughout the study.

Level of Performance

Level of performance refers to the measurable degree of proficiency exhibited by civil engineering students when solving problems related to Integral Calculus. This typically involves evaluating their scores to gauge their understanding and application of the concepts covered in the subject.

Integral Calculus

Integral Calculus is a branch of Calculus that focuses on the concept of integration. It involves the computation of integrals, which represent the accumulation of quantities and the determination of areas under curves. In the context of the research, Integral Calculus pertains to the specific mathematical concepts and techniques taught to Bachelor of Science in Civil Engineering students, forming a critical part of their education in applied mathematics.

Strengths of Civil Engineering Students in Integral Calculus

Strengths are the inherent capabilities and positive attributes that Civil Engineering students may possess in their study of Integral Calculus. Strengths can include analytical skills, mathematical aptitude, and a practical understanding of real-world applications. As to research, analytical and mathematical is being considered.

Weaknesses of Civil Engineering Students in Integral Calculus

Weaknesses signify the limitations, challenges, or areas where Civil Engineering students may encounter difficulties in comprehending or applying Integral Calculus concepts. Weaknesses could involve struggles with abstract reasoning, mathematical complexities, or challenges in connecting theoretical knowledge to practical scenarios. Factors which could led to these weaknesses are dependent to the students' way of grasping and absorbing concepts of the subject (e.g. instructional materials and related resources).

Supplemental Learning Material (SLM)

A Supplemental Learning Material (SLM) is an educational resource such as textbooks and worksheets specifically designed to address identified challenges, gaps, or weaknesses in a particular subject or topic and to complement traditional course materials and enhance the learning experience for students studying integral calculus. These materials aim to provide additional explanations, examples, practice exercises, or interactive activities to reinforce concepts, thereby facilitating deeper understanding, retention, and application of integral calculus principles. In the context of the research, the SLM is developed to provide targeted support and assistance to Civil Engineering students studying particular topics in Integral Calculus. It aims to enhance learning, bridge conceptual gaps, and improve overall performance through strategically designed instructional materials.

Level of Acceptability of the SLM

The level of acceptability of the SIM refers to the extent to which Civil Engineering students, instructors, and other stakeholders embrace and find value in the developed Supplemental Learning Material. It involves assessing the perceived effectiveness, relevance, and usability of the SLM in enhancing students' understanding of Integral Calculus. The level of acceptability serves as a crucial indicator of the potential success and impact of the intervention material on the target audience.

Review of Literature

A review of related studies and literature that directly affect the current study is presented in this chapter. The purpose of this study is to determine engineering students' proficiency levels in particular Integral Calculus topics. The researcher collected relevant studies and material from websites. The fact was developed by the researcher to bolster the research.

Level of Performance in Integral Calculus

Abad (2020) explored probing the academic performance of fresher civil engineering students in mathematics, focusing on their profiles, diagnostic test performance, and differences in performance based on profile variables. The study was at Eastern Visayas State University with 131 civil engineering students. One area to improve numeracy such as algebraic expressions, equations, and trigonometry follows: notable disparities in performance were identified in relation to profile variables, highlighting the necessity of customized interventions.

The research offers valuable perspectives regarding the efficacy of civil engineering students in integral calculus. The results will guide the formulation of a numeracy enhancement extension initiative aimed at bolstering students' mathematical competencies within engineering curricula. Suggestions encompass the identification of institutions for targeted intervention and the creation of educational modules designed to improve students' numeracy abilities.

The additional value of this research study is that it gives a panoramic view of student achievement in civil engineering in integral calculus, particularly to algebraic expressions, equations, and trigonometry. The results can be developed into further resources targeted at specific areas students need help with and guidance concerning integral calculus preparation, which will align well with the goal of this research project, the preparation of strategic intervention materials.

Strengths and Weaknesses

Mahir (2009) research in conceptual and procedural knowledge, concerning the integration of undergraduate students. It depicts how the students have inadequate conceptual understanding of integration, the relationship between integrals and area, and the fundamental theorem of calculus. The study emphasizes that students need such integration of both conceptual and procedural knowledge to attain competent mathematical education. It indicates introducing new concepts by using many examples, adequate homework to enhance conceptual understanding, and avoiding questions that may only lead to memorization. The research group consisted of 62 first-year calculus course graduates whose conceptual and procedural knowledge in the theory of integration was to be determined for improvement purposes.

The connection to the present research lies in acknowledging gaps in students' conceptual understanding of integration, which constitutes an important factor in developing supplementary learning resources. The study's emphasis on a balance between the conceptual understanding and procedural skills it aims to achieve aligns with the concentration of the present study on the performance of civil engineering students in integral calculus as well as the development of supplementary educational materials.

The potential contribution of the current research lies in providing valuable insights into students' conceptual and procedural competencies within the domain of integration theory, which may aid in the creation of effective supplementary learning resources for civil engineering students. Gaining an understanding of the challenges faced by students, along with the proposed methods for enhancing conceptual understanding, can inform the development of supplementary learning resources aimed at improving the academic performance of civil engineering students in integral calculus.

Supplemental Learning Material

A discussion on SLM was that the study conducted by Arpilleda (2021) on the effectiveness of SIM in enhancing mathematical competency disclosed a statistically significant difference in the performance results of the treatment group as compared to those of the control group, thus bringing out the facilitating effect of the intervention material on the attainment of the least mastered competency.

The study proposed that students in need should be given appropriate time to acquire crucial skills, in tandem with the creation of additional intervention tools. The above findings and recommendations also hold great implications for the present study of the Bachelor of Science in Civil Engineering's performance on Integral Calculus, thus hinting at a potential link between both research works. Building competency in specific

mathematical areas is the focus of the paper, which aligns with the purpose of improving student performance in Integral Calculus, so this study can be an addition to what already exists. In that sense, the current study would benefit from a focused methodology in creating more teaching aids meant to target specific areas of competencies within Integral Calculus.

More directly, broad inferences from the earlier study for students, teachers, and school administrators could provide great insights into informing how effective strategies can be developed to improve the civil engineering students' performance in the subject of Integral Calculus.

On the other hand, Siahaan, et. al. (2023) work is aimed at the preparation of integral calculus didactical materials for improvement of students' mathematical reasoning abilities. It focuses on the mastering integral material and high-level reasoning since analytical reasoning is to be applied to the calculus concepts, leading to a critical, logical and systematic scientific mindset.

The feasibility of teaching materials was reviewed by assessing the coverage, accuracy, and relevance of the material used. In its development model, the study employs the ADDIE model-analyzing, designing, developing, implementing, and evaluating. With these, significant improvements in learning outcomes were brought about.

To enhance students' competence in mathematical reasoning through the development of integral calculus educational materials. Activities: Preparation, review, and validation of the educational material developed to improve students' understanding and problem-solving capabilities. Validation by the experts exhibited that the teaching material possesses high validity and relevance with indications of marked improvements towards achieving learning results.

The study's findings demonstrate the importance of mathematics education in shaping individuals and the need for an education system oriented towards problem-solving, critical thinking, and logical reasoning. It highlights the significance of mastering integral calculus for students and the impact on understanding other mathematical concepts. The development of teaching materials was shown to be valid and relevant, contributing to improved learning outcomes and students' mathematical reasoning abilities.

Ethical Consideration

In conducting this action research on "Development and Validation of Supplemental Learning Material in Integral Calculus", ethical considerations were observed to ensure the integrity of the study and the protection of all participants.

Participation is entirely voluntary, and all individuals involved fully informed about the research objectives, procedures, potential benefits, and any associated risks before giving their explicit consent.

Moreover, participants were also assured of their right to withdraw from the study at any time without facing any consequences.

To maintain confidentiality and anonymity, a coding or pseudonym system was implemented, ensuring that no personally identifiable information will be disclosed. All collected data were securely managed and accessible only to the researcher, adhering to strict ethical standards to protect the privacy of participants.

The study prioritized the well-being of participants by minimizing any potential risks, whether physical, psychological, or emotional. Any concerns that arise during the research process was promptly addressed to ensure a safe and comfortable experience for all involved.

Additionally, integrity and transparency uphold throughout the study, ensuring honesty in data collection, analysis, and reporting.

Findings were presented accurately without bias or misrepresentation.

By adhering to these ethical principles, this study aims to uphold he rights, dignity, and well-being of all participants while contributing educational development and introducing reliable learning resources for the students who are taking Integral Calculus subject.

METHODOLOGY

Research Design

This study utilized a descriptive developmental research design, a systematic approach for designing and refining educational products and processes (Richey & Klein, 2007; van den Akker, 2006; McKenney & Reeves, 2018), which is a suitable and valuable method for identifying students' level of performance on specific topics in Integral Calculus. The researcher administered a teacher-made, multiple-choice problem-solving test to gather data, a common strategy in descriptive studies aimed at quantifying current performance levels (Fraenkel, Wallen, & Hyun, 2012). By employing this design, the researcher can assess students' mathematics performance, interpret the results, and use the findings to develop a Supplementary Learning Material in Integral Calculus for the topics included in the test.

Population and Locale of the Study

The study was conducted at Saint Louis College, San Fernando City, La Union. The respondents were Civil Engineering students enrolled in Integral Calculus in the College of Engineering and Architecture under the instructional class of the researcher. The nineteen (19) respondents/students belong to the class of CEA-2A.

Likewise, five (5) professors/instructors in Integral Calculus were tapped as evaluators of the crafted teacher-made test. The selected educators were all deemed to be experts in the subject as they were all able to finish their Master's education and teaching Integral Calculus in the Civil Engineering Department.

Research Instrument

In gathering the data, teacher-made test was developed and utilized. The test was made for the second-year Civil Engineering students. It was composed of twenty (20) items of problem-solving of multiple choices type which was leveraged to gauge the mastery and know-how of the learners in the specific topics of Integral Calculus such as Integration of rational fractions, Algebraic and additional standard formulas (Including U-substitution), Definite integral, and Geometric application of Integral Calculus (Area under the curve and area between two curves). The researcher referred the topics from the syllabus developed and submitted to the College before the semester started. For the learner's sake of latest and fresh know-how with regards to the Integral Calculus topics included on the test, at the time of test were administered, the researcher used the Midterm exam schedule of the learners. The topics and items on the teacher-made test were lifted from the approved syllabus from the Civil Engineering Program Head and the Dean based from the Policies, Standards, and Guidelines for the Bachelor of Science in Civil Engineering Program noted in the Commission on Higher Education Memorandum Order No. 92 Series of 2017.

The same test was also utilized as pilot test for content validation of the teacher-made test in Integral Calculus which was also administered to the enrolled Civil Engineering students in Integral Calculus at the University of Northern Philippines, Vigan City, Ilocos Sur.

In the conduct of the study, the researcher first secured the permission from the concerned educational institutions both Saint Louis College and University of Northern Philippines in order to abide the protocols and set rules and regulation of each institution.

After granting the permission from the two tertiary institutions, the researcher handed the teacher-made test to the respective students synchronously and then collected after the test has done.

After collecting the data, the researcher with the help of the Statistician, analyzed the results from the teacher-made test to determine the strengths and weaknesses of the students regarding the Integral Calculus topics included in the exam as reference for the development of the supplemental learning material.

To determine the validity of the developed supplemental learning material, the researcher requested the support and assistance of the Integral Calculus instructors and professors considered as experts in the subject. Upon their approval, they were given the original copies of the developed and prepared supplementary learning material together with the questionnaire indicating the measurement of validity of the output. After the questionnaires collected from the experts, the Researcher tabulated, analyzed, and interpreted the data. Additionally, comments and suggestions were noted for the content refinement and improvement of the developed SLM.

Treatment of Data

In treating the data, the following statistical tools were used:

1. **Mean Percentage Score** was used to determine the level of mastery or performance of the Civil Engineering students.
2. **Mean** was used to describe the validity of the developed supplementary learning material.

Categorization of Data

The matrix and norms below were utilized in describing the data.

Level of Performance

Mean	Descriptive Equivalent Rating
4.01-5.00	Excellent
3.01-4.00	Very Satisfactory
2.01-3.00	Satisfactory
1.01-2.00	Fair
0.00-1.00	Poor

Students who garnered DER below satisfactory were considered as least mastered competencies.

Level of Acceptability of Supplementary Learning Material

Numerical Value	Scale	Descriptive Equivalent Rating
5	4.21-5.00	Very Highly Acceptable (VHA)
4	3.41-4.20	Highly Acceptable (HA)
3	2.61-3.40	Moderately Acceptable (MA)
2	1.81-2.60	Slightly Acceptable (SA)
1	1.00-1.80	Not Acceptable (NA)

RESULTS AND DISCUSSION

This chapter presents the results, discussions, conclusions and recommendations in accordance with the statement of the problems on Chapter I.

Table 1 presents the level of performance, with Descriptive Equivalent Rating of Poor to Excellent, of the second-year level Civil Engineering students in Integral Calculus based from the garnered scores of Midterm Examination School Year 2023-2024.

Table 1 Midterm Examination Garnered Scores

Topics	**Number of Items**	**Mean**	**DER**
1. Integration of rational fractions	5	2.05	S
2. Algebraic and additional standard formulas (including U-substitution)	5	0.79	P
3. Definite integral	5	3.63	VS
4. Geometric application of Integral Calculus (Area under the curve and area between two curves)	5	1.95	F
Total	**20**	**2.10**	**S**
Legend: DER - Descriptive Equivalent Rating S - Satisfactory VS - Very Satisfactory P - Poor F - Fair			

As shown in the table, there are four topics included in the Midterm Examination which has five item problems per topic. Based from the third column, mean of each topic has been calculated and recorded through the mean score of all students in each topic. In the last column, Descriptive Equivalent Rating has been established which serves as a parameter to determine the level of performance of each student in the topics included in the examination.

Definite integral of functions garnered the highest mean equivalent to 3.63 described as very satisfactory; followed by the integration of rational fractions with an equivalent mean of 2.05 described as satisfactory. On the other hand, geometric application of Integral Calculus specifically area under a curve and area between two curves had an equivalent mean of 1.95 described as fair and Algebraic and additional standard formulas (including U-substitution) garnered the lowest mean with an equivalent percentage of 0.79 which described as poor.

The findings imply that the level of performance identifying (strength and weaknesses) of second-year level Civil Engineering students in Integral Calculus which is reflected to their Midterm examination performance is satisfactory as manifested in the test results.

This corroborates the findings of Mahir (2009) in conceptual and procedural knowledge, concerning the integration of undergraduate students together with the finding of Abad (2020) explored probing the academic performance of fresher civil engineering students in mathematics, focusing on their profiles, diagnostic test performance, and differences in performance based on profile variables.

Strengths and Weaknesses

Table 2 Level of Performance Table

Topics	**Number of Items**	**Mean**	**DER**
1. Integration of rational fractions	5	2.05	S
2. Algebraic and standard formulas	5	0.79	W
3. Definite integral	5	3.63	S
4. Geometric application of Integral Calculus (Area under the curve and area between two curves)	5	1.95	W
Total	**20**	**2.10**	**S**
Legend: DER - Descriptive Equivalent Rating S - Strength P - Weakness			

Table 2 presents the level of performance of the second-year level Civil Engineering students and the strengths and weaknesses of Integral Calculus topics included from the Midterm Examination were identified. Topics with descriptive equivalents ranging to 0.00 to 2.00 which described as fair and poor were considered as weakness.

As gleaned on the Table 2, the topics Algebraic and additional standard formulas (including U-substitution) and Geometric application of Integral Calculus (Area under the curve and area between two curves) were described as weaknesses of the students which are poor and fair respectively.

This therefore implies that the rest of the topics included in the Midterm Examination namely integration of rational fractions and definite integral were the strengths of the second-year level Civil Engineering students.

The over-all mean is 2.10 described as satisfactory based from the teacher-made test administered with the specified Integral Calculus topics.

Validity of the Supplementary Learning Material

The level of validity of the developed supplemental learning material is presented in Table 3.

Table 3. Level of validity of the supplementary learning material

	Mean	**DER**
A. Organization		
1. The organization and selection of topics follow the difficulties encountered by the learners.	3.8	MV
2. Organization is flexible, permitting variation in sequence.	4	HV
3. Material within the topics is well organized.	4.4	VHV
4. Approach is suitable to the wide range of learners.	3.8	HV
5. The organization is presented at a variety of cognitive levels.	4.2	HV
Sub Mean	**4.04**	**HV**
B. Mechanics		
1. Topics, titles, and subheadings are concrete, meaningful, and interesting	4.4	VHV
2. Writing style of the text is appealing to the learners.	4.2	HV
3. Questions are well - constructed and useful for review.	4.6	VHV
4. Activities are suited to the learners' interests.	4.4	VHV
5. Activities are thought - provoking and challenging.	4	HV
6. Text provides positive and motivating models for both sexes as well as for the other racial, ethnic, and socio-economic groups.	4.4	VHV
Sub Mean	**4.33**	**VHV**
C. Appropriateness		
1. Reading level of the text is fitting to the grade level of the learners.	4	HV
2. The text vocabulary is suitable.	4.4	VHV
3. New concepts explicitly linked to the learners' prior knowledge and experiences.	4.2	HV

4. Text introduces abstract concepts by accompanying them with concrete examples.	4.2	HV
5. Text avoids irrelevant details.	4.2	HV
Sub Mean	**4.2**	**HV**
Grand Mean	**4.19**	**HV**
Legend: DER - Descriptive Equivalent Rating VHV- Very Highly Valid HV- Highly Valid		

The supplementary learning material was evaluated by five experienced Mathematics teachers from different schools along content, organization, mechanics, and appropriateness. It can be gleaned from the table that the supplementary learning material has a mean rating of 4.04 described as highly valid. On its mechanics, the material has a mean rating of 4.33 described as very highly valid. Meanwhile, the material was judged highly valid along appropriateness with 4.2 mean rating. As a whole, the material in terms of its validity has a mean rating of 4.19 described as highly valid.

The results of the evaluation and assessment of the five experts in the field of Mathematics reveal that the supplementary learning material along organization, mechanics, and appropriateness is an acceptable and timely instructional material that can supplement the use of textbooks. Since the material satisfactorily met the standards and judgment of the experienced Mathematics teachers, it is therefore appropriate and ready for use by civil engineering students. Furthermore, this means that the supplementary learning material can be utilized according to its purpose - to improve competence level of learners in Integral Calculus particularly in the application of Integral Calculus.

A discussion on SLM was that the study conducted by Arpilleda (2021) on the effectiveness of SIM in enhancing mathematical competency disclosed a statistically significant difference in the performance results of the treatment group as compared to those of the control group, thus bringing out the facilitating effect of the intervention material on the attainment of the least mastered competency. This means that supplemental learning materials are vital and appropriate in grasp of mathematical knowledge of learners.

CONCLUSIONS

Based from the findings, the following are the conditions drawn:

1. The study revealed that the majority of civil engineering students struggled with algebraic and geometric applications of integral calculus, as indicated by their satisfactory rating in these areas.
2. The findings support the need for developing targeted supplemental learning materials (SLMs) to address the specific challenges students face in integral calculus, particularly in understanding complex algebraic and geometric concepts.
3. The study highlights the necessity of improving teaching methods for integral calculus. Since many students struggled with abstract mathematical reasoning, instructional strategies that promote deeper conceptual understanding, such as guided learning methods, could be beneficial.

RECOMMENDATIONS

The following are the recommendations offered based from the findings and conclusions of the study.

1. It is recommended to create supplemental learning materials that specifically target the identified weak areas, particularly algebraic manipulations and the geometric applications of integral calculus. These materials should provide detailed explanations, practical examples, and additional exercises.

2. To help students understand complex integral calculus topics, it is recommended to incorporate more interactive tools into the curriculum. This approach could aid students in comprehending abstract concepts like areas under curves and volumes of solids.
3. While procedural knowledge is important, more emphasis should be placed on strengthening students' conceptual understanding of integral calculus. Strategies such as guided discovery and problem-based learning should be employed to help students grasp the underlying principles.
4. It is recommended to conduct frequent assessments to monitor student progress and identify areas where they continue to struggle. Providing timely feedback and offering remedial instruction could help students improve their performance in integral calculus.
5. Faculty members teaching integral calculus should receive additional training in modern instructional techniques that promote active learning and conceptual engagement. This will enable them to better support students in mastering challenging topics.

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APPENDICES

Appendix "A"

Supplementary Learning Material Validation Questionnaire

ILOCOS SUR POLYTECHNIC STATE COLLEGE-GRADUATE SCHOOL
Tagudin, Ilocos Sur

VALIDATION QUESTIONNAIRE

Directions: Please evaluate the level of validity of the proposed Supplemental Learning Material for Civil Engineering students taking Integral Calculus by using the scale below. Put a check mark on the blank for each item.

Point	Scale	Descriptive Equivalent Rating
5	4.21-5.00	Very Highly Valid (VHV)
4	3.41-4.20	Highly Valid (HV)
3	2.61-3.40	Moderately Valid (MV)
2	1.81-2.60	Slightly Valid (SV)
1	1.00-1.80	Not Valid (NV)

	5	4	3	2	1
A. Content					
1. The content is up-to-date.					
2. Content is accurate.					
3. Content is appropriate to the target user.					
4. Content includes adequate development of concepts and is appropriate to the target user.					
5. Content is relevant to the learners.					
B. Organization					
1. The organization and selection of topics follow the difficulties encountered by the learners.					
2. Organization is flexible, permitting variation in sequence.					
3. Material within the topics is well organized.					
4. Approach is suitable to the wide range of learners.					
5. The organization is presented at a variety of cognitive levels.					
C. Mechanics					
1. Topics, titles, and subheadings are concrete, meaningful, and interesting					
2. Writing style of the text is appealing to the learners.					
3. Questions are well - constructed and useful for review.					
4. Activities are suited to the learners' interests.					
5. Activities are thought - provoking and challenging.					
6. Text provides positive and motivating models for both sexes as well as for the other racial, ethnic, and socio-economic groups.					
D. Appropriateness					
1. Reading level of the text is fitting to the grade level of the learners.					
2. The text vocabulary is suitable.					

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3. New concepts explicitly linked to the learners' prior knowledge and experiences.					
4. Text introduces abstract concepts by accompanying them with concrete examples.					
5. Text avoids irrelevant details.					

Appendix "B"

Content Validation Form

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Tagudin Campus, Graduate School
Tagudin, Ilocos Sur

CONTENT VALIDATION FORM

Name: _____ Position/Title: _____
(Optional)
Address: _____

DIRECTION: Please evaluate the attached questionnaire and teacher-made test using the scale below.

Check your answer using the scale below:

5 – Excellent
4 – Very Satisfactory
3 – Satisfactory
2 - Fair
1 - Poor

CRITERIA	5	4	3	2	1
1. Each item is related to the competencies of the subject and is suitable for the set of learners.					
2. Direction is clearly stated and easy to understand.					
3. The test is suitable to use as instrument for the researcher.					
4. The test is free from errors in spelling, as well as in grammar.					
5. The test is comprehensive enough to cover the subject/course.					

Comments/Suggestions: _____

The researcher

Appendix "C"

Teacher-Made Test

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Tagudin, Ilocos Sur

Name: _____ Section: _____
Instructor: _____Subject: Integral Calculus

Directions: Evaluate the following integration problem. Choose and encircle the letter of the correct answer.

1. $\int \frac{12x+18}{(x+2)(x+4)(x-1)}dx$

a. $\ln(x+2) - 3\ln(x+4) + 2\ln(x-1) + C$
b. $2\ln(x+2) - 3\ln(x+4) + 2\ln(x-1) + C$
c. $\ln(x+2) - 3\ln(x+4) - 2\ln(x-1) + C$
d. $2\ln(x+2) + 3\ln(x+4) + 2\ln(x-1) + C$

2. $\int \frac{dx}{(x-4)(x+8)}$

a. $\frac{1}{12}\ln(x-4) - \frac{1}{12}(x+8) + C$
b. $\frac{1}{12}\ln(x-4) + \frac{1}{12}(x+8) + C$
c. $\frac{1}{10}\ln(x-4) - \frac{1}{12}(x+8) + C$
d. $\frac{1}{10}\ln(x-4) + \frac{1}{12}(x+8) + C$

3. $\int \frac{2x-5}{x(x-1)^3}dx$

a. $5\ln(x) - 5\ln(x-1) - \frac{5}{x-1} + \frac{3}{2(x-1)2} + C$
b. $5\ln(x) + \ln(x-1) - \frac{5}{x-1} + \frac{3}{2(x-1)2} + C$
c. $5\ln(x) - 5\ln(x-1) - \frac{5}{x-1} - \frac{3}{2(x-1)2} + C$
d. $5\ln(x) - 5\ln(x-1) + \frac{5}{x-1} + \frac{3}{2(x-1)2} + C$

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4. $\int \frac{x^2}{x+1} dx$
a. $x + 1 + \frac{1}{x+1}$
b. $x - 1 + \frac{1}{x+1}$
c. $x - 1 - \frac{1}{x+1}$
d. $x - 1 + \frac{1}{x-1}$

5. $\int \frac{1}{(x-2)(x-3)} dx$
a. $ln(x-3) + ln(x-4) + C$
b. $ln(x-2) - ln(x-3) + C$
c. $ln(x-2) + ln(x-3) + C$
d. $-ln(x-2) + ln(x-3) + C$

6. $\int_2^5 (2x+3)\, dx$
a. 20 b. 30 c. 40 d. 50

7. $\int_1^9 \left(\sqrt{x} - \frac{4}{\sqrt{x}}\right) dx$
a. $\frac{4}{3}$ b. $\frac{5}{3}$ c. $\frac{7}{3}$ d. $\frac{8}{3}$

8. $\int_3^4 \sqrt{4-x}\, dx$
a. $\frac{1}{3}$ b. $\frac{2}{3}$ c. $\frac{4}{3}$ d. $\frac{5}{3}$

9. $\int_2^5 \left(3x^2 + \frac{4}{x^2}\right) dx$
a. $\frac{590}{5}$ b. $\frac{591}{5}$ c. $\frac{592}{5}$ d. $\frac{593}{5}$

10. $\int_0^{\sqrt{3}} x(x^2+1) dx$
a. $\frac{13}{4}$ b. $\frac{14}{4}$ c. $\frac{15}{4}$ d. $\frac{16}{4}$

11. $\int \frac{dx}{x - x^{\frac{1}{3}}}$
a. $-\frac{3}{2}x^{\frac{2}{3}} + C$ b. $\frac{3}{2}x^{\frac{2}{3}} + C$
c. $-\frac{4}{3}x^{\frac{2}{3}} + C$ d. $\frac{4}{3}x^{\frac{2}{3}} + C$

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12. $\int x(x+4)^{1/3}\, dx$
a. $\frac{3}{7}(x+4)^{7/3} + 3(x-4)^{\frac{1}{3}} + C$ b. $\frac{3}{7}(x+4)^{7/3} - 3(x-4)^{\frac{1}{3}} + C$
c. $\frac{3}{7}(x+4)^{7/3} - 2(x-4)^{\frac{1}{3}} + C$ d. $\frac{3}{7}(x+4)^{7/3} + 2(x-4)^{\frac{1}{3}} + C$

13. $\int \frac{(8x+1)}{\sqrt{4x-3}} dx$
a. $\frac{(\sqrt{4x+3})^3}{2} + \frac{7}{2}\sqrt{4x+3} + C$ b. $\frac{(\sqrt{4x+3})^3}{3} + \frac{7}{2}\sqrt{4x+3} + C$
c. $\frac{(\sqrt{4x+3})^3}{2} + \frac{5}{2}\sqrt{4x+3} + C$ d. $\frac{(\sqrt{4x+3})^3}{3} - \frac{7}{2}\sqrt{4x+3} + C$

14. $\int \frac{dx}{x^2+25}$

a. $\frac{2}{5}\tan^{-1}\frac{x}{5} + C$ b. $\frac{1}{5}\tan^{-1}\frac{x}{5} + C$ c. $-\frac{2}{5}\tan^{-1}\frac{x}{5} + C$ d. $-\frac{1}{5}\tan^{-1}\frac{x}{5} + C$

15. $\int \frac{dx}{\sqrt{4-x^2}}$

a. $\sin^{-1}\frac{x}{2} + C$ b. $\frac{1}{2}\sin^{-1}\frac{x}{2} + C$ c. $-\frac{1}{2}\sin^{-1}\frac{x}{2} + C$ d. $-\sin^{-1}\frac{x}{2} + C$

16. Find the area under the curve $y=3x^2$ from x=1 to x=2
a. 5 b. 6 c. 7 d. 8

17. Find the area under the curve $y=4-x^2$ from x=-3 to x=3
a. $\frac{46}{3}$ b. $\frac{46}{5}$ c. $\frac{46}{7}$ d. $\frac{46}{9}$

18. Find the area bounded by the curve $y = 9 - x^2$ and the x-axis
a. 34 b. 36 c. 38 d. 40

19. Find the area bounded by the curve $x = y^2 + 2y$ and the line $x = 3$
a. $\frac{32}{3}$ b. $\frac{32}{5}$ c. $\frac{32}{7}$ d. $\frac{32}{9}$

20. Solve the area bounded by the curve $y = 4x - x^2$ and the lines $x = -2$ and $y = 4$.
a. $\frac{64}{3}$ b. $\frac{65}{5}$ c. $\frac{66}{7}$ d. $\frac{67}{9}$