Effectiveness of Using AI-Based Contextual Mathematics Teaching Materials on Integral Material for Improving Mathematical Problem Solving for Civil Enginering Students

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Abstract. This research seeks to create contextual mathematics teaching materials utilising artificial intelligence focused on integral concepts, and to evaluate the efficiency of these materials in enhancing students' mathematical problem-solving abilities. This study is classified as Research & Development (R&D) utilising a one-group pretest-posttest design. The efficacy of the generated teaching materials was evaluated in two trials: a small group trial and a large group trial. The Paired Sample t-test results (sig.2-tailed < 0.05) indicate a significant difference in learning outcomes before and after students are instructed using artificial intelligence-based contextual mathematics teaching materials on integral concepts, attributable to the impact of the developed teaching materials in structured mathematics learning activities. The effectiveness test results utilising the normalised N-Gain indicate that the application of instructional materials in small group assessments yielded a 59.12% improvement, while large group assessments achieved a 72.31% enhancement in students' mathematical problem-solving abilities.

Keywords: Artificial Intelligence, Development, Integral.

1 Introduction

Integrals are a branch of the scientific discipline of calculus. Integral has a vital role in various fields, including civil engineering. Integrals in civil engineering are usually used to calculate the area and volume of a building area. Integrals are needed to make problem-solving more accessible, for example, to calculate the centre of gravity and moment of inertia of a plane. For planes with simple shapes, such as rectangular planes, the plane's centre of gravity will be easier to determine, namely its location at the intersection of the diagonals of the rectangle. However, determining the plane's centre of gravity for curved planes takes work. To calculate the centre of gravity, you must be able to calculate the plane's area and the plane's area; there is no general formula, so calculating the plane's centre of gravity will also be challenging. In other words, by using integrals, one can easily calculate a plane's area and centre of gravity (either a plane

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bounded by a straight line or a curved curve). Therefore, integral material is essential to the Civil Engineering Study Program for students to master.

However, the difficulty of solving students' integral problems is still a problem that must be overcome. The reality in the field states that students' problem-solving abilities in integral material still need to improve. This low problem solving ability dramatically affects students' mathematics learning outcomes. The following is data on mathematics learning outcomes for students from the Civil Engineering Study Program at Medan State University in the 2023/2024 academic year.

Table 1. Basic Mathematics Learning Results for Civil Engineering Study Program Students at Medan State University.

No	Materi	Test	Average	Average		*Grade*
				Remedial 1	Remedial 2	
1	Real Number System	Midterm Exam	73.04	78.25	-	B
2	Limits and Continuous Functions					
3	Derivative Concept and Its Applications					
4	Integrals and Engineering Integration	Final Exam	43.83	52.03	64.67	E
5	Integral Applications (Area, Volume, Surface Area of Rotating Objects, Arc Length, Moment of Inertia, Center of Gravity, and Center of Mass)					

Based on the results of interviews with several students from different classes in the Civil Engineering study program, information was obtained that the majority of students thought that integral material was challenging to understand, so they could only solve some problems given. This aligns with the results of expert research, stating that students think integral material is rigid [1],[2].

From the results of direct observations and interviews with 15 students, several things are thought to cause students' low mathematical problem-solving abilities, including the learning materials used. The learning materials used only partially support improving mathematical problem-solving abilities. Based on observations, integral calculus learning prioritizes direct learning, and the learning materials used are translated textbooks that are not explicitly constructed according to students' needs. Solving the problem of low mathematical problem-solving abilities requires using learning materials specifically designed based on students' needs, namely contextual teaching materials. Contextual teaching materials are all used in holistic learning that link the learning material and the context of students' daily lives so that students gain direct experience, making the learning more meaningful [3], [4], [5] .

Experts are continually advancing artificial intelligence (AI) technologies to facilitate its rapid development. H. A. Simon asserts that artificial intelligence (AI) is a domain enabling computers to execute activities that surpass human capabilities [6]. Artificial intelligence can deliver tailored educational experiences based on individual student requirements. AI enables instructors to deliver more tailored instruction, accommodating students' learning styles, proficiency levels, and interests. The integration of AI-based contextual mathematics textbooks will facilitate independent learning and enhance students' engagement in developing their problem-solving skills.

According to the aforementioned description and issues, as well as the stipulations of the Republic of Indonesia Law Number 12 of 2012 regarding higher education, Article 41, paragraph 1 mandates that learning resources in higher education institutions must be supplied, facilitated, or possessed by universities in relation to the study program being developed. This research was conducted to create AI-driven contextual mathematics teaching materials for integral disciplines within the Civil Engineering Study Program at the Faculty of Engineering, Medan State University.

2 Research Method

This study pertains to research and development (R&D) based on the Rowntree development model (Rowntree, 1994). Rowntree's approach has deficiencies in product evaluation; hence, this research will integrate Borg & Gall's formative evaluation (Adapted from Gall, D., Meredith D., Joyce, P. Gall., Walter, R. Borg. 2007:590) [7]. The subsequent flow diagram illustrates the research techniques for creating contextual mathematics teaching materials utilising artificial intelligence for integral content, as depicted in Figure 1.

The research trial site for contextual mathematics teaching materials utilising artificial intelligence on integral concepts was undertaken at the Department of Building Engineering Education, Faculty of Engineering, Medan State University, North Sumatra. The participants of the feasibility experiment (expert test) were specialists from Medan State University (Unimed). Experts are deliberately chosen based on their competence, communicative ability, and relevant experience in their domains.

The participants for evaluating the efficacy of the research product were students enrolled in the Civil Engineering department at Medan State University, specifically those undertaking engineering mathematics courses. The engineering mathematics course has 30 participants and one lecturer studying mathematics.

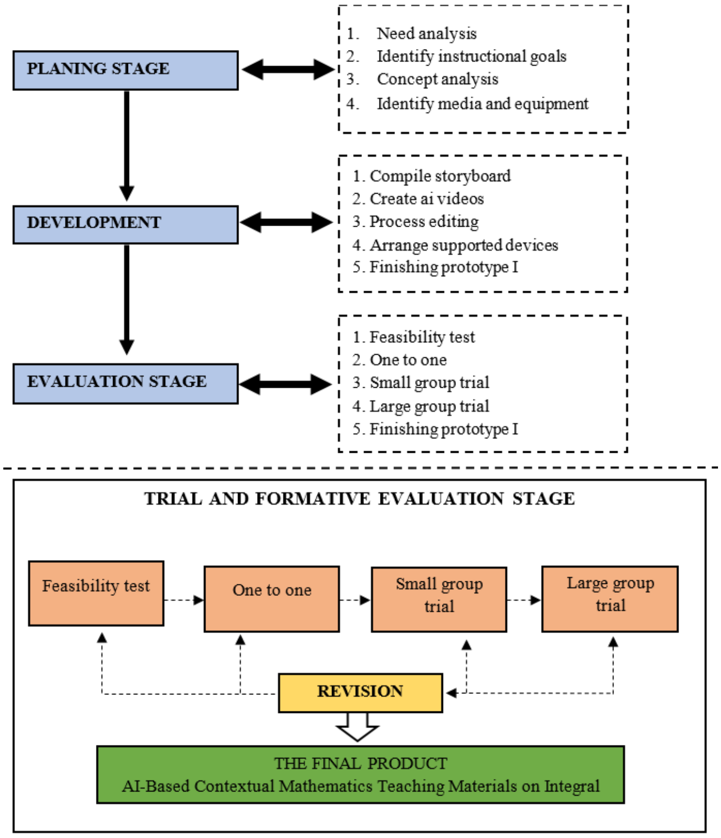

Fig 1. Research Implementation Procedure

3 Result and Discussion

The efficacy of contextual mathematics instructional materials utilising artificial intelligence for integral topics is assessed by their influence on cognitive learning outcomes. The outcomes of efficacy assessments, in both restricted and extensive trials, demonstrate that these indicators satisfy the efficacy standards. Evaluation of product efficacy on learning impact metrics, namely student learning outcomes derived from the post-test. Data analysis employs SPSS tools to conduct statistical assessments for normality and homogeneity tests [8], [9]. The outcomes of normality and homogeneity assessments in both small and large group trials indicated significant values exceeding 0.05. The analysis is reported to fulfil statistical criteria. Table 2 presents an overview of the normality and homogeneity test results for learning outcomes data derived from both small and large group trials.

Table 2. The Outcomes of Assessing Normality and Homogenity

Test	The Outcome of Small Group Trial		The Outcome of Large Group Trial	
	Normality	**Homogenity**	**Normality**	**Homogenity**
Pre-test	0.149	0.292	0.177	0.200
Post-test	0.200		0.091	

Table 2 presents a summary of the analysis regarding the learning impacts in both small and large-group trials. The degree of student competency mastery is evidenced by the scores achieved in the cognitive domain. Cognitive scores are transformed into numbers between 0 and 100. The objective is to identify pupils' proficiency levels as either competent or incompetent on the final score sheet. The alteration in student learning outcomes post-treatment is evidenced by the disparity in average scores between the pre-test and post-test assessments. The treatment mentioned utilises artificial intelligence-driven contextual mathematics instructional resources for integral components in engineering mathematics educational activities.

Table 3. The Disparities in The Average of Scores

Trials	Average of Scores		Disparities of Average
	Pre-Test	**Post-Test**	
Small-Group	33.98	73.08	39.10
Large-Group	32.22	81.23	49.01

The disparity in mean scores between pre-test and post-test assessments in small-group and large-group trials was highly significant. To verify the validity of the substantial difference, the subsequent analysis employs a paired t-test utilising SPSS. The t-test findings are utilised to determine the disparity in the analysed data, leading to the conclusion that H0 is rejected and Ha is accepted. This was conducted by Siregar, Budiyono, and Slamet (2018) in their study, which examined variations in intelligence levels in mathematical education. If the t-test value is less than 0.05, it is considered that the null hypothesis (H0) is rejected and the alternative hypothesis (Ha) is accepted [10], [11].

The results of this study indicate that the p-value (sig. 2-tailed) for learning outcomes in the cognitive domain is less than the alpha value (5%). The outcomes of the differential test analysis (t-test) conducted are displayed in Table 4 below.

Table 4. The Outcomes of T-Test

Trials	Sig.(2-tailed)	Description
Small Group	0.000	Null Hypothesis (H0) Rejected and
Big Group	0.000	Alternative Hypothesis (Ha) Accepted

The learning impact analysis presented in Table 4 reveals a significance level (2-tailed) in the t-test of less than 0.05, indicating disparities in learning outcomes before and after the instruction of artificial intelligence-based contextual mathematics teaching materials on integral concepts. At a significance level of 5 percent. This indicates that the average learning outcomes of students after utilising artificial intelligence-based contextual mathematics teaching materials on integral topics surpass those of students prior to such instruction, with a measurable difference in each case. The averages were previously provided in Table 3.

The efficacy of contextual mathematics education materials utilising artificial intelligence for integral content can be assessed through the Normalised N-Gain exam concerning cognitive aspects. The normalised N-Gain test is derived by computing the difference between pre-test and post-test results. The N-Gain test outcomes were subsequently compared pre- and post-treatment. The average Gain value is assessed to determine its classification as high, medium, or low. The efficacy criteria in this study pertain to the average normalised Gain value, which is at a minimum in the medium group. The outcomes of the conducted learning impact analysis are displayed in Table 5 below.

Table 5. The Summary of the Average Normalized Gain Value

Trial	**Average**		**N-*Gain***	**Category**
	Pre-Test	***Post-Test***		
Small Group	37.71	73.87	59.12	Medium
Big Group	36.55	81.71	72.31	High

Table 5 indicates that in the small group trials, N-Gain fell within the medium category (30 ≤ N-Gain ≤ 70), however in the large group trials, N-Gain was classified in the high category (N-Gain > 70) [12]. The N-Gain test results from both small-group and large-group trials indicate that the contextual mathematics teaching model, grounded in artificial intelligence and applied to integral material for engineering mathematics, effectively enhances students' mathematical problem-solving skills, which is the desired outcome of mathematics education.

Learning is effective when it meets the specified objectives and maximises student achievements. This research indicates that the use of artificial intelligence-based contextual mathematics teaching materials in integral mathematics can significantly enhance students' mathematical problem-solving abilities, which is the intended learning outcome upon the conclusion of mathematics instruction.

4 Conclusion

Contextual mathematics teaching materials utilising artificial intelligence for integral concepts in the Civil Engineering education program satisfy the criteria for practical application in mathematics instruction, aimed at enhancing students' mathematical problem-solving skills. This aligns with the intended learning outcomes post-mathematics instruction, as evidenced by the attainment of student learning competencies in both small and large group trials.

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