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Development of a multi-representation-based calculus e-module to improve students' mathematical literacy skills

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Abstract:
The study aims to develop a multi-representation-based calculus e-module and to examine its effectiveness in improving students' mathematical literacy skills. The research method employed was research and development (R&D) using the DDD-E model. The effectiveness of the e-module was tested through a quasi-experimental design with a pretest-posttest control group design and analysed using ANCOVA based on students' pretest and posttest scores. The subjects were 62 first-semester students of the Civil Engineering Department at Mandalika University of Education, consisting of 32 students in the experimental class and 30 students in the control class. The results indicated that the developed e-module was validated by subject-matter, learning, and design experts and was effective in improving students' mathematical literacy skills. The ANCOVA results showed a significance value of $p < 0.001$, which is less than 0.05, indicating a significant difference between the class that received treatment using the multi-representation-based e-module and the control class. The average posttest score of the experimental class (70.19) was higher than that of the control class (55.77), indicating that the use of a multi-representation-based calculus e-module had a positive impact on students' mathematical literacy skills. In addition, the effect size value was 0.868, which was categorised as a large effect size**.** This result indicates that the developed e-module had a strong effect on improving students' mathematical literacy skills. These findings suggest that the multi-representation-based calculus e-module is effective in improving students' mathematical literacy skills and is suitable for implementation in calculus learning, particularly in the civil engineering program.

Keywords: E-module; Calculus; Multi-Representation; Mathematical Literacy.

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Introduction

Mathematical literacy is an important skill that enables students to understand, analyze, and apply mathematical concepts in Different situations and real-life contexts

(Mestanza-Ramón et al., 2023; Sarimsakova, 2022; Verma, 2024). This skill enables students to think critically, reason mathematically, analyze problems, and do mathematical modeling (Lara-Porras et al., 2019; Li, 2020; Meti et al., 2024; Muhaimin et al., 2024). However, students' preparedness in mathematics learning is often still limited, which can prevent their academic development and achievement (Croft et al., 2022). In addition, many students still have difficulties in understanding mathematical concepts and solving mathematical problems (Gafoor & Kurukkan, 2015; Langoban, 2020; Permata et al., 2021; Sreylak et al., 2022; Yulita & Ain, 2021). This condition indicates that students' mathematical literacy skills still need improvement.

This situation is supported by the relatively low level of students' mathematical literacy in Indonesia Evidence from the 2022 PISA indicates a decline in Indonesia's overall mathematics literacy performance, placing it among the lowest within the ASEAN region. Indonesia recorded a mathematics literacy score of 366, which remains substantially below the global average of 472 (OECD, 2024). Although PISA assesses secondary school students, these findings indicate that mathematical literacy remains an important issue in education and may continue to affect students at the higher education level. In addition, research has found that many students still struggle to understand and use basic mathematical concepts and have underdeveloped thinking skills (Agustina et al., 2021; Putra et al., 2020; Satiti et al., 2021).

Low levels of mathematical literacy were driven by several factors, including the limited capacity of educators to effectively develop these competencies, the suboptimal use of instructional models and learning media, and the lack of thorough and methodically organized guidance. In addition, students tend to approach mathematical problem-solving predominantly through theoretical and procedural methods rather than through contextual and reflective reasoning processes (Yenzi et al., 2023; Isnani et al., 2023; Kandaga et al., 2024; Risdiyanti et al., 2024). These conditions indicate the need for learning media that can support students in understanding mathematical concepts through various forms of representation.

Similar conditions were also found among students of Civil Engineering at Mandalika University of Education, Mataram. Interviews with several lecturers in the research program revealed that many students still lack adequate mathematical literacy skills. This is evident in their lack of ability to apply mathematical concepts, from simple to more complex, to everyday problems, particularly those related to engineering.

This situation indicates the necessity for students to have mathematical literacy skills to solve more complex and broader mathematical problems (Schoenfeld, 2020). One effort that can be made is by familiarizing students with calculations and mathematical analysis related to civil engineering. One relevant topic that plays a crucial role in civil engineering is calculus.

Calculus is a compulsory subject in higher education, especially for students majoring in mathematics, science, technology, and engineering (Turner & Mendoza, 2021). Calculus courses emphasize an understanding of functions, limits, derivatives, and integrals (Barniol et al., 2024). Many aspects of civil engineering require calculus. For example, differentiation and integration are used for addition and optimization, and both are highly useful in everyday problems related to civil engineering (Verma & Mahajan, 2021). Thus, mathematical literacy is important for Civil Engineering students to understand, interpret, and apply calculus concepts in solving engineering-related problems.

In civil engineering, mathematical concepts and problem solving are always intertwined. A good understanding of mathematical concepts will enable students to solve civil engineering problems. However, many students still struggle to understand mathematical concepts, particularly in calculus. Research by Banos (2023) indicates that civil engineering students' problem-solving skills are generally low. Interviews with civil engineering students revealed that many students find it difficult to understand and present mathematical problems, as well as to connect mathematical concepts with other courses. This situation is caused by the lack of mathematical foundations of students, difficulty understanding abstract and complex concepts, errors in mathematical notation, lack of practice, and a lack of easily understandable instructional resources.

Teaching calculus requires a learning approach that is tailored to student needs. One alternative is to have e-modules in which multiple representations are based. The e-module is an electronic learning media that is systematically, interestingly, easily understood, and can be accessed anytime and anywhere(Mahardika & Wicaksono, 2023; Purwanti et al., 2023; Sadji et al., 2024). E-modules function as independent learning tools that can be applied in both theoretical and practical learning and as a learning medium for effectively acquiring material (Aninditto et al., 2024; Resmanti et al., 2024; Sidiq & Suhendro, 2021). Multi-representation refers to the presentation of learning material in various forms of written information, including verbal, visual, and symbolic information (Adelia et al., 2023; Alwi et al., 2024). In keeping with this definition, an e-module that employs several representations, including text, tables, graphs, equations, and images, to help students grasp mathematical topics is called a multi-representation-based e-module. Gulkilik et al. (2020) stated that students need multiple representations in learning activities to develop each individual's mathematical understanding.

Several previous studies have discussed the use of e-modules and multi-representation approaches in mathematics learning. However, studies focusing on the development of a multi-representation-based calculus e-module to improve students' mathematical literacy skills in higher education, particularly among Civil Engineering students, are still limited. In addition, previous studies have generally focused more on conceptual understanding and learning outcomes rather than on students' mathematical literacy skills. Therefore, this study focuses on developing a multi-representation-based calculus e-module and examining its effectiveness in improving students' mathematical literacy skills among Civil Engineering students.

The use of a multi-representation-based calculus e-module is expected to provide a solution for a more effective and innovative learning process, encourage student engagement, and facilitate students' comprehension of calculus concepts. Furthermore, this research also focuses on its impact on improving students' mathematical literacy skills.

Research Methods

This investigation adopted a Research and Development (R&D) approach with an emphasis on the systematic process of product development. The study also employed a quasi-experimental approach to examine the effectiveness of the developed product in improving students' mathematical literacy skills. The principal aim of the study was to design and produce a calculus e-module grounded in multi-representation-based Learning, as well as to evaluate its effectiveness in enhancing students' mathematical literacy skills.

The model used in the development of the e-module is the DDD-E (Decide, Design, Develop, Evaluate) model proposed by Ivers and Barron (2002). The DDD-E model was selected because it provides systematic and structured stages for developing interactive digital learning media, from identifying learning needs to evaluating the developed product. In addition, this model facilitates the integration of learning objectives, instructional materials, and various forms of representation in the developed e-module. The DDD-E model was also considered suitable for this study because it allows evaluation and refinement at each stage of development, thereby supporting the development of a valid, feasible, and effective calculus e-module for improving students' mathematical literacy skills.

Beginning with the first stage, Decide, initial observations were conducted regarding learning issues faced by students and interviews with lecturers related to module development, as well as deciding what should be included in the e-module. The output of this stage included the identification of students' mathematical literacy problems, course learning outcomes, indicators of mathematical literacy skills, and the selection of calculus materials relevant to Civil Engineering students.

The second stage, Design, involved designing the e-module's structure and content in compliance with the relevant curriculum, including learning goals, learning outcomes, and the subject matter to be covered in the e-module, which was part of the second stage. The output of the Design stage included the preparation of the e-module framework, learning activities, learning evaluation, and multi-representation components adapted to the objectives of calculus learning and students' mathematical literacy skills.

The creation of the multi-representation-based calculus e-module was the focus of the subsequent stage, Develop. The output of this stage was a completed multi-representation-based calculus e-module integrated with text, tables, graphs, equations, and images to support students' understanding of calculus concepts. Expert validation was carried out throughout the development phase to guarantee the e-module's viability. A subject-matter expert validator, a learning expert validator, and a design expert validator were all engaged. If the average score from all validators fell into the "feasible" range, the e-module was deemed suitable for use in educational activities. The Sugiyono (2017) score conversion, which is summed up in Table 1, served as the basis for the feasibility criteria used to assess the e-module's viability.

Table 1. E-module Feasibility Categories

Category	Score Range
Very Feasible	80 – 100
Feasible	60 – 79
Moderately Feasible	40 – 59
Less Feasible	20 – 39
Not Feasible	0 – 19

The final stage is Evaluate. This stage involved evaluation during and after the implementation of the developed e-module. Evaluation during the learning process was conducted through observation and question-and-answer sessions with students to identify their responses and difficulties while using the e-module. At the end of the learning process, students were given essay-type test questions to evaluate their

mathematical literacy skills after using the developed e-module. The test questions were developed based on indicators of mathematical literacy skills, including mathematical representation, reasoning, problem solving, and the interpretation of mathematical information.

To examine and characterize the influence of a multi-representation-based calculus e-module on the enhancement of students' mathematical literacy, an experimental procedure was implemented by integrating the e-module into the learning process. The research used a pretest and posttest control group design in a quasi-experimental manner, with two groups receiving various instructional interventions. The first group was the experimental class, while the second group was the control group. Throughout the instructional period, the experimental class was exposed to learning activities supported by the multi-representation-based calculus e-module, whereas the control class received conventional instruction without the integration of the e-module. At the outset, both groups were administered a pretest to assess baseline competencies and to account for potential differences in initial ability. Upon completion of the intervention, growth of the students' mathematical literacy skills in both groups was assessed and compared using a posttest .

The study's participants were first-semester students enrolled at Mandalika University of Education's Civil Engineering department during the 2025–2026 academic year. Sampling was conducted using cluster random sampling, as the samples were already organized into class groups. The sample consisted of 32 students from semester IA and 30 students from semester IB. Semester IA was assigned as the experimental class, while semester IB served as the control class.

Before the treatment was administered, an equivalence test was conducted using pretest data to ensure that both classes had comparable initial abilities. The results of the normality and homogeneity tests indicated that the data were normally distributed and homogeneous. Furthermore, the Independent Sample t-Test showed a significance value of 0.634 ($p > 0.05$), indicating that there was no significant difference in the initial abilities of the two classes. Therefore, both classes were considered equivalent prior to the implementation of the treatment.

Regarding the research data, the data collection techniques comprised observation, interviews, and tests. Observations were carried out during the instructional process in both the experimental and control groups, with the aim of assessing students' engagement throughout learning activities. Interviews were conducted with students in the experimental group to explore and identify their responses to instruction utilizing the multi-representation-based calculus e-module. To evaluate improvements in mathematical literacy skills, students were administered a posttest.

The test instrument initially consisted of 10 essay-type questions developed based on indicators of mathematical literacy skills. Before being used in the study, the instrument was validated by experts and tested on 32 students. Based on the results of validity, reliability, discrimination index, and difficulty level analyses, seven questions met the criteria of good items. Of these, five questions were selected and used as the research instrument. The indicators of the instrument were adapted from mathematical literacy skill indicators, including mathematical representation, reasoning, problem solving, interpretation, and mathematical communication. One example of the mathematical literacy test item used in this study involved a Civil Engineering context in

which students were required to determine the maximum height of a road embankment and identify the position of the maximum point based on a given function.

The students' scores were used as indicators of their mathematical literacy skills. The categorization of students' mathematical literacy skills referred to the standards and indicators proposed by the National Council of Teachers of Mathematics (2000) and the mathematical literacy framework developed by the Programme for International Student Assessment (OECD, 2013). The categorization of students' mathematical literacy skills is presented in Table 2.

Table 2. Categories of Mathematical Literacy Skills

Category	Score Range
Very High	85 – 100
High	70 – 84
Moderate	55 – 69
Low	40 – 54
Very Low	0 – 39

For the purpose of providing a general overview of the results, descriptive statistics were utilized in the data analysis. Inferential statistical tests using one-way analysis of covariance were also used to test the data. After adjusting for the impact of pretest results as a covariate, this research sought to ascertain the effect of using a multi-representation-based calculus e-module on students' mathematical literacy skills. Following the completion of all necessary tests, including those for normality, homogeneity of variance, linearity, and homogeneity of regression coefficients, the examination was carried out.

Results and Discussions

Research result

The study outcomes, which relate to the development of a multi-representation-based calculus e-module and the effects of its implementation on improving students' mathematical literacy skills, are presented according to the stages of the DDD-E model.

Decide Stage

During the decision-making phase, observations and interviews were carried out to determine the challenges that Civil Engineering students had while studying mathematics. The results of the observations and interviews indicated that common issues encountered by students included difficulties in understanding the material, ineffective learning processes, and limited learning time.

In the curriculum, calculus is a prerequisite course for other civil engineering courses. Therefore, students should have a solid understanding of calculus concepts. However, in practice, many students experience difficulties in comprehending calculus concepts due to the abstract and complex nature of the material. Furthermore, calculation errors frequently occur due to students' limited prior knowledge and difficulties in reading mathematical symbols, notation, and equations. Another impact of these conditions is that students' inability to apply mathematical formulas and methods

to contextual problems related to civil engineering cases. These findings indicate that students require interactive and easily accessible visual learning media.

Observations of learning activities revealed that the learning process remained ineffective. Learning tended to be passive and monotonous, with limited student engagement. Usually, students listened to what their teachers said without asking questions or talking about how to solve problems directly. Students' dependence on lecturers' explanations resulted in low levels of active participation limited independent learning habits, and low motivation to attempt or solve mathematical problems independently. Overall, these conditions hindered students' ability to understand and apply mathematical concepts effectively. This situation demonstrates the need for more active and participatory learning innovations.

Another issue identified was limited instructional time. Calculus is an abstract subject that includes complex topics, including functions, limits, derivatives, and integrals. Sufficient time and practice are essential for a thorough understanding of these concepts. However, students find it challenging to develop a thorough conceptual grasp due to the restricted contact hours. This restriction impacts students' ability to apply mathematical ideas to civil engineering issues. This time constraint also contributes to suboptimal classroom learning, as it limits question-and-answer sessions, discussions, and independent practice. Therefore, students need additional learning resources, such as e-modules, that they can access at any time to support their independent learning outside of formal classroom instruction.

In addition to observations and interviews with students, the researchers also conducted interviews with lecturers in other civil engineering courses related to mathematics. Generally, the problems identified by lecturers were that students frequently made errors in selecting and applying mathematical concepts, resulting in incorrect solutions. Many students made errors in formula use, performed algebraic operations incorrectly, failed to distinguish between variables and constants, made errors in determining derivatives and calculating integrals, and made errors in reading and interpreting graphs. Based on these findings and the interviews with lecturers, it was identified that students needed learning resources, such as e-modules, to support them in understanding and interpretation mathematical concepts in civil engineering problems.

Drawing on observations, interviews, and the previously mentioned findings, a learning approach that promotes students' active participation in both independent and collaborative learning is required. The solution adopted in this study was the development of a calculus e-module. The decision to create an e-module for calculus stemmed from students' demand for organized, methodical learning materials that are always available. Additionally, to help students grasp mathematical ideas, this calculus e-module was organized using a multi-representation-based method that included descriptions, tables, graphs, equations, and pictures. It is anticipated that the availability of a calculus e-module based on many representations would facilitate more efficient learning. The findings of several earlier investigations justify the choice to create this e-module. The use of multi-representation-based e-modules successfully and favourably improves student learning outcomes, according to Irfan's study findings (Syam & Louise, 2023). Additionally, Alfisyahr (Indraswari et al., 2024) reported that using multi-representation-based e-modules may enhance students' metacognitive abilities and be a useful tool for educational activities.

Decide Stage

During the design phase, the e-module's development concentrated on creating the material structure and idea presentation while using a variety of representation techniques. This design aimed to ensure that the resulting e-module would facilitate students' understanding of the abstract and complex calculus concepts. The design flow of a multi-representation-based e-module is illustrated in the following figure.

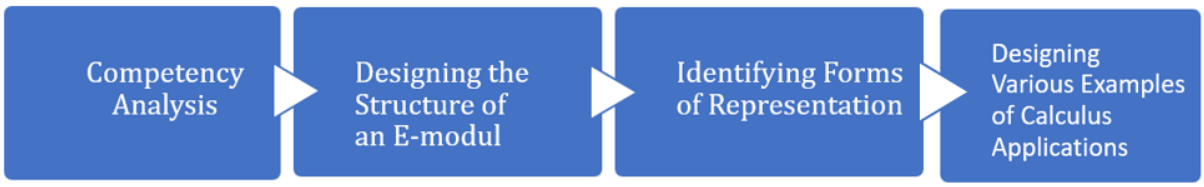


Figure 1. Design Flow of E-module Development

As seen in the figure above, the initial step in e-module design began with a competency analysis, which includes the objectives, learning outcomes, and study materials. The following table details the competency analysis for the first semester calculus course in the Civil Engineering Study Program at Mandalika University of Education, Mataram.

Table 3. Competency Analysis of the Calculus Course

Objective	:	The students are expected to understand the definitions, types and properties of single variable functions, master the technique of derivation and integral function, and their application in the field of civil engineering.
Learning Outcomes	:	An ability to apply knowledge of mathematics, science, and engineering in civil engineering fields.
Topics discussed	:	1. Real numbers and rectangular coordinate system 2. Functions and limits 3. Derivatives and its applications 4. Integration and its applications 5. Logarithmic 6. Exponential 7. Tanscendental functions 8. L'Hopital rule

Referring to Table 3, the material contained in the e-module consists of real numbers, limit functions, logarithms, exponentials, derivatives, and integrals. After determining the e-module topics, designing the construction of the e-module was the following stage. The subjects of the e-module were arranged in this design exercise into chapters and subchapters that include ideas, theories, exercises, and summaries. The subsequent step involved identifying the forms of representation used in each chapter or subchapter. The forms of representation in question included descriptions, tables, graphs, equations, and images. This activity aimed to facilitate students' ability to recognize various forms of representation, enabling them to present and relate one form of representation to another. The final stage in designing the e-module was to develop

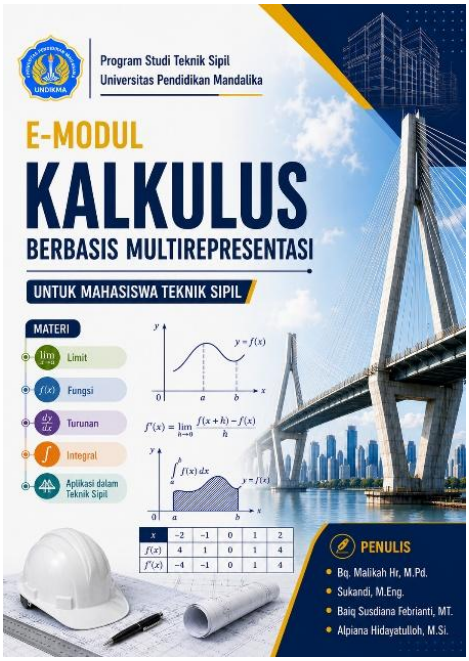
various examples of calculus applications in the real world. In the developed e-module, a chapter was presented that contained examples of calculus applications in real life. This design aimed to train students to connect theoretical learning with real-life situations, especially those related to civil engineering.

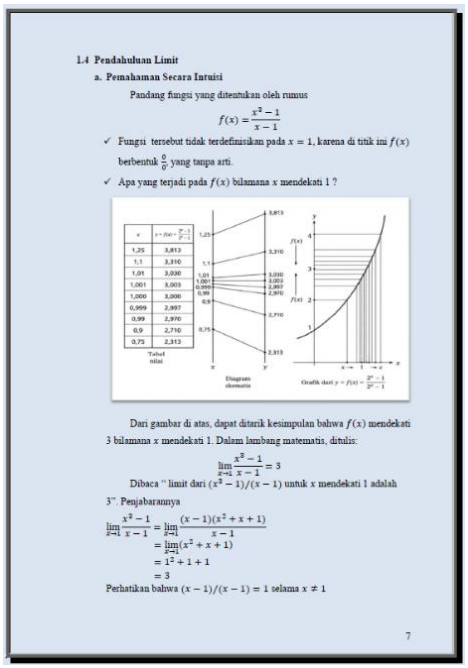
Develop Stage

This Stage represents a refinement of the previous stage. The development process began with the creation of a comprehensive calculus e-module, including the organization of content in each chapter, accompanied by example problems and exercises. Each topic was integrated with various appropriate forms of representation. The calculus e-module, which also used trustworthy and relevant sources for the calculus course, was developed using the design from the previous stage.

To provide a clearer illustration of the developed product, several displays of the multi-representation-based calculus e-module are presented in Figure 2. The e-module was developed by integrating various forms of representation, including verbal explanations, mathematical symbols, tables, graphs, and contextual problems related to Civil Engineering. These components were intended to support students in understanding calculus concepts and improving their mathematical literacy skills.

After the e-module was developed, it was validated by three expert validators to assess its feasibility. The three validators consisted of a content expert validator, who was a mathematics lecturer with over five years of experience teaching calculus to civil engineering students; a media expert validator, who was a mathematics education specialist with knowledge in instructional material creation, and a learning expert validator, who was a mathematics education lecturer with competence in instructional material development. The following table displays an overview of the validators' evaluations.




1.4 Pendahuluan Limit

a. Pemahaman Secara Intuisi

Pandang fungsi yang ditentukan oleh rumus

$$f(x) = \frac{x^3 - 1}{x - 1}$$

✓ Fungsi tersebut tidak terdefinisikan pada $x = 1$, karena di titik ini $f(x)$ berbentuk $\frac{0}{0}$ yang tanpa arti.

✓ Apa yang terjadi pada $f(x)$ bilamana x mendekati 1 ?

Dari gambar di atas, dapat ditarik kesimpulan bahwa $f(x)$ mendekati 3 bilamana x mendekati 1. Dalam lambang matematis, ditulis:

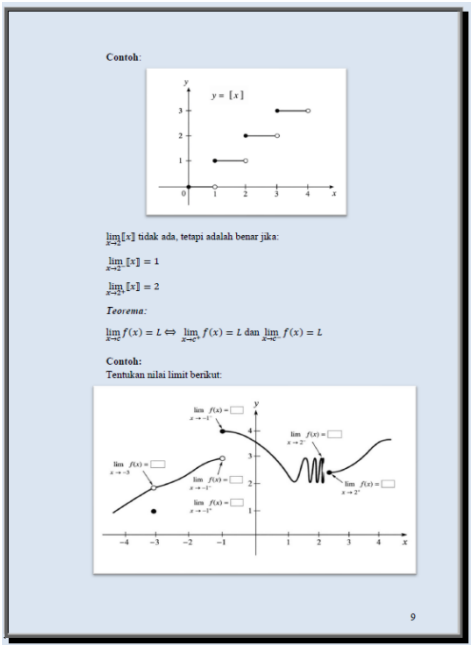
$$\lim_{x \to 1} \frac{x^3 - 1}{x - 1} = 3$$

Dibaca " limit dari $(x^3 - 1)/(x - 1)$ untuk x mendekati 1 adalah 3". Penjabarannya

$$\lim_{x \to 1} \frac{x^3 - 1}{x - 1} = \lim_{x \to 1} \frac{(x - 1)(x^2 + x + 1)}{x - 1}$$
$$= \lim_{x \to 1} (x^2 + x + 1)$$
$$= 1^2 + 1 + 1$$
$$= 3$$

Perhatikan bahwa $(x - 1)/(x - 1) = 1$ selama $x \neq 1$

7



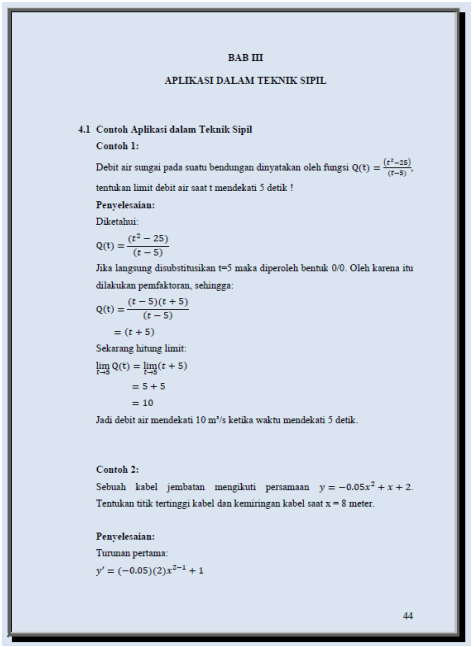


Figure 2. Display of the developed multi-representation-based calculus e-module

Table 4. Summary of Validator Assessments on the Feasibility of the E-Module

Assessment Aspect	Subject Matter Expert (0-100)	Learning Expert (0-100)	Media Expert (0-100)	Average
Alignment of content with the curriculum	91.75			
Correctness and accuracy of content concepts	83.25			86.65
Ease of content comprehension	91.75			
Utilization of multiple representations	83.25			
Learning activities and evaluation	83.25			
Appropriateness of learning methods		91.75		
Integration of multiple representations		91.75		88.35
Learning activities and interactions		83.25		
Evaluation and feedback		83.25		
Ease of use and learning motivation		91.75		
Layout and typography			91.75	
Visualization and graphic design			83.25	
Multimedia and interactivity			75.00	85.00
Consistency and design coherence			83.25	
Accessibility and user-friendliness			91.75	
Average score				**86.67**

The findings of the validators' evaluation of the produced multi-representation-based calculus e-module's viability are summarized in Table 4. The assessment was conducted using a score range of 0-100 across several aspects, which were grouped according to the expertise of each validator. Overall, based on the average scores from the three validators, the e-module achieved a mean score of 86.67, demonstrating that it can be used in the learning process in a very viable way.

Evaluate Stage

The evaluation stage's primary goal was to determine the e-module's efficacy. The aims of this stage ware to determine and describe the effect of the multi-representation-based calculus e-module on improving students' mathematical literacy skills. The evaluation was conducted by administering pretests and posttest to both the experimental and control classes. The distribution of pretest and posttest data in this study is presented in the following descriptive statistics table.

Table 5. Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Experimental pretest	32	42	33	75	51.19	12.060
Experimental posttest	32	40	47	87	70.19	11.721
Control pretest	30	44	29	73	52.67	12.291
Control posttest	30	45	37	82	55.77	13.114

Table 5 provides a detailed summary of both the pretest and posttest outcomes for the control and experimental groups. There was a wide variety of students starting skills in the experimental group, as their pretest scores varied from 33 to 75, with an SD of 12.060 and an average of 51.19. The posttest scores ranged from 47 to 87, with an SD of 11.721 and an increase to 70.19 on average after the multi-representation-based calculus e-module was implemented. After including the multi-representation-based calculus e-module into the learning process, students' mathematical literacy significantly improved, as shown by the upward shift in the mean score.

In the control group, the mean pretest score was 52.67 with an SD of 12.291, and the scores ranged from 29 to 73. These findings indicate that students' initial abilities in the control group were also heterogeneous and relatively comparable to those in the experimental group. However, the posttest results revealed only a modest increase, with the mean score reaching 55.77, an SD of 13.114, and a score range between 37 and 82. Compared to the experimental class, the score improvement in the control class was lower. Overall, these descriptive statistical data indicate both classes had similar initial abilities, but the experimental class experienced a greater improvement in mathematical skills.

Table 6 provides further information by describing the percentage gain in students' mathematical literacy abilities in both the experimental and control groups.

Table 6. Description of the Improvement in Students' Mathematical Literacy Skills

Level of Mathematical Literacy Ability		Experimental Class				Control Class			
		Pre-test		*Posttest*		*Pre-test*		*Posttest*	
Category	Score	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Very High	85 – 100	-	-	2	6%	-	-	-	-
High	70 – 84	3	9%	15	47%	1	3%	6	20%
Medium	55 – 69	10	31%	11	34%	12	40%	9	30%
Low	40 – 54	13	41%	4	13%	12	40%	12	40%
Very Low	0 – 39	6	19%	-	-	5	17%	3	10%

Based on Table 6, the pretest data from the experimental class show that six students had very low mathematical literacy skills and thirteen students were categorized as low. This indicates that more than 50% of the students initially had relatively low mathematical literacy skills. With almost 85% of the students attaining medium-level mathematical literacy skill, the experimental class demonstrated a substantial increase in mathematical literacy when compare to the posttest results. Twelve students were classified as having poor mathematical literacy abilities, and five students had extremely low mathematical literacy skills, according to pretest outcomes for the control group. This indicates that over half of the students in the control group also had comparatively poor levels of mathematical literacy. The control group likewise showed improvement as compared to the posttest results, however, it was not as pronounced as in the experimental class, as 50% of students remained in the low mathematical literacy category.

Referring to Tables 5 and 6, the experimental group exhibited a more substantial improvement in mathematical literacy compared to the control group. These outcomes explain the application of a multi-representation-based calculus e-module is more effective in enhancing students' mathematical literacy than conventional instructional approaches, as reflected in the shift of a greater proportion of students into higher performance categories. Nevertheless, to rigorously ascertain the effect of the e-module while accounting for students' initial abilities, these descriptive findings require further verification through inferential analysis using ANCOVA.

The table displays the outcomes of the tests conducted for normality, homogeneity of variance, linearity, and homogeneity of regression coefficients that were carried out prior to doing the ANCOVA.

Table 7. Tests of Normality

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Residual for Posttest	.111	62	.058	.964	62	.068

The Shapiro-Wilk normality test was used in this investigation. The posttest residual data's Shapiro-Wilk normality test yielded a significance value (Sig.) of 0.068. It may be inferred that the residual posttest data are normally distributed since the significance value in this test is higher than the 0.05 significance threshold. As a result, the normality test's assumption is satisfied.

Table 8. Levene's Test of Equality of Error Variances[a]

F	df1	df2	Sig.
2.181	1	60	0.145

Levene's Test of Equality of Error Variances findings indicate that the significance value (Sig.) was 0.145. Since this value is greater than 0.05 significance level, it can be concluded that the variances of the experimental and control classes are homogeneous. Therefore, the assumption of homogeneity is satisfied.

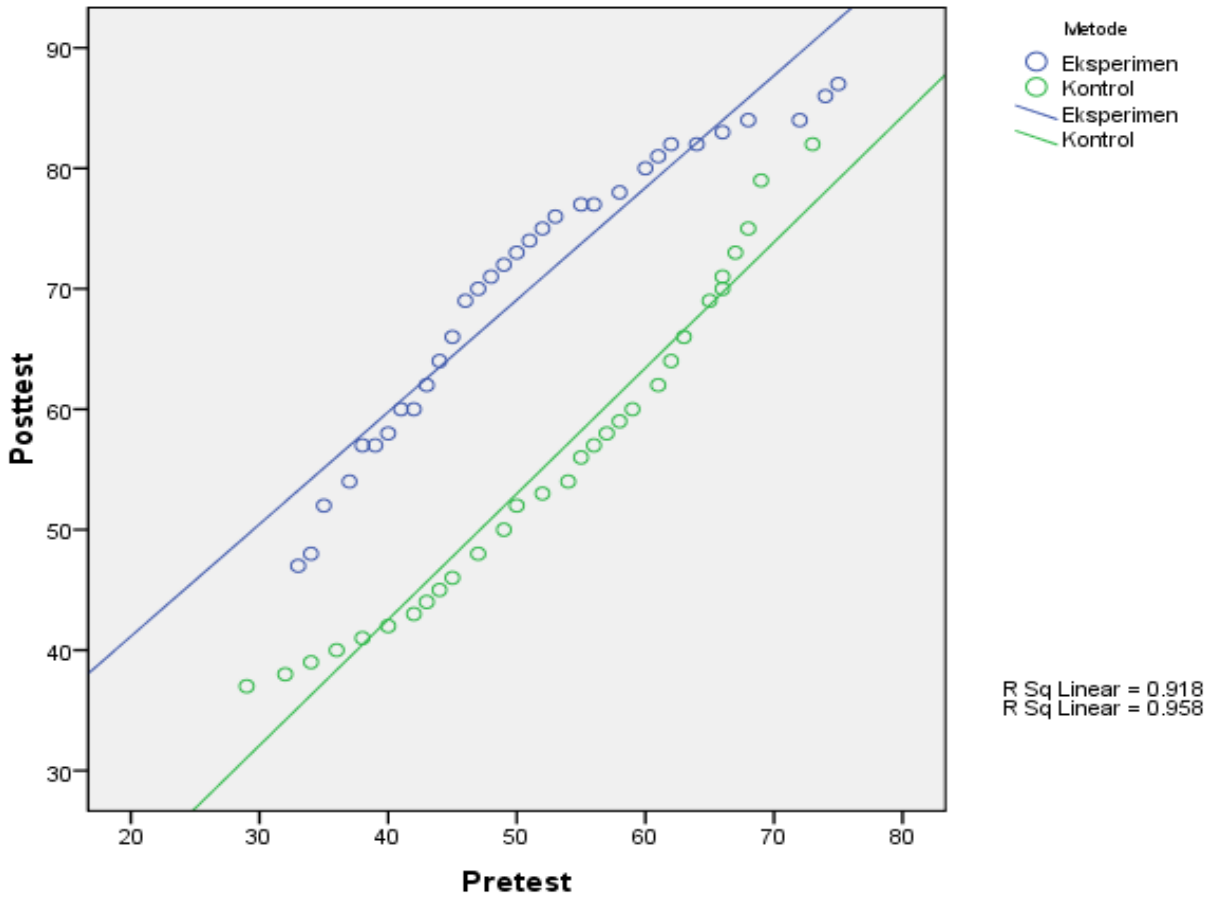


Figure 3. Linear Regression Plot of Pretest and Posttest Scores

Figure 3 shows the correlation between the experimental and control classes' pretest and posttest results. It can be inferred that there is a substantial linear link between pretest and posttest scores regarding the development of mathematical literacy

abilities in both classrooms since the scatter plot displays a linear trend. As a result, the linearity assumption is met.

Table 9. Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11905.617[a]	3	3968.539	410.545	0.000
Intercept	424.442	1	424.442	43.908	0.000
Method	370.347	1	370.347	38.312	0.000
Pretest	8669.614	1	8669.614	896.871	0.000
Method * Pretest	28.503	1	28.503	2.949	0.091
Error	560.657	58	9.667		
Total	260185.000	62			
Corrected Total	12466.274	61			

Table 9 shows that the interaction between the learning technique and the pretest had a significant value (Sig.) of 0.091. The regression coefficients for both groups are homogenous as the significance value is higher than 0.05. As a result, the regression coefficients' homogeneity condition is met.

As all prerequisite assumptions have been met, the analysis can be continued using a one-way analysis of covariance with the following hypothesis formulation:

H_0 : There is no significant difference in students' mathematical literacy skills between the class taught using the multi-representation-based calculus e-module and the class taught using the conventional method, after controlling for pretest scores

H_A : There is a significant difference in students' mathematical literacy skills between the class taught using the multi-representation-based calculus e-module and the class taught using the conventional method, after controlling for pretest scores

Table 10. Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11877.114[a]	2	5938.557	594.702	.000
Intercept	430.942	1	430.942	43.156	.000
Pretest	8657.082	1	8657.082	866.942	.000
Method	3890.073	1	3890.073	389.562	.000
Error	589.160	59	9.986		
Total	260185.000	62			
Corrected Total	12466.274	61			

The outcomes of the ANCOVA presented in Table 10, the value Sig. for the instructional method factor is $p < 0.001$, which is below the 0.05 threshold. This discovery suggests that the H_a is accepted and H_0 is rejected. After considering students pretest scores, can be summarized as follows the mathematical literacy skills of students taught using the multi-representation-based calculus e-module differ significantly from those taught using conventional methods. The experimental group averaged 70.19 on the posttest, whereas the control group average 55.77, according to the comparison of the mean scores. The multi-representation-based calculus e-module is more successful in improving students' mathematical literacy, as this difference shows. Furthermore, the average score within the experimental group rose significantly from 51.19 on the pretest to 70.19 on the posttest, suggesting a notable improvement. Taken as a whole, these findings show that students' mathematical literacy is much enhanced when a calculus e-module on multi representations-base is used.

To determine the magnitude of the effect of the developed e-module on students' mathematical literacy skills, an effect size analysis was conducted based on the ANCOVA results presented in Table 10. The effect size analysis was used to examine the extent to which the implementation of the multi-representation-based calculus e-module influenced the improvement of students' mathematical literacy skills after the learning process. The results of the effect size analysis are presented in Table 11.

Table 11. Effect Size Analysis Based on ANCOVA Results

Component	Value
SS Method	3890.073
SS Error	589.160
Partial Eta Squared (η_p^2)	0.868
Category	Large

Based on Table 11, the obtained Partial Eta Squared value was 0.868, which is categorized as a large effect size. This result indicates that the implementation of the multi-representation-based calculus e-module had a strong effect on improving students' mathematical literacy skills. The effect size value also strengthens the ANCOVA results presented in Table 10, which showed a significant difference between the experimental and control classes after controlling for students' initial abilities.

Discussion

This research demonstrated positive results in the development of the multi-representation-based calculus e-module, making it suitable for use by students in learning activities. This e-module is deemed appropriate because it underwent a thorough assessment and testing process. Three validators with different areas of expertise validated the e-module during the assessment process. Additionally, the development process incorporated several suggestions from the validators to ensure that the teaching materials were both appropriate and practical. According to the evaluation findings from the three validators, the multi-representation-based calculus e-module is well-suited for educational activities.

The findings of this research also showed that the implementation of the multi-representation-based calculus e-module had a significant effect on improving students' mathematical literacy skills. The ANCOVA analysis demonstrated significant differences between the experimental and control classes after controlling students' initial abilities. In addition, the effect size analysis showed a Partial Eta Squared (η^2_p)value of 0.868, which indicates a large effect size category. These findings suggest that the developed e-module contributed strongly to the improvement of students' mathematical literacy skills. This finding is consistent with the study conducted by Chusni (2022), which reported that the use of multi-representation-based e-modules provides better learning outcomes compared to conventional learning.

The improvement in students' mathematical literacy skills may occur because the multi-representation approach enables students to understand mathematical concepts through various forms of representation. Through graphs, equations, tables, verbal explanations, and contextual applications, students were able to connect mathematical ideas with problem situations more effectively. This condition supports students in interpreting information, representing mathematical ideas, solving problems, and communicating mathematical reasoning during the learning process.

These findings are in line with previous studies reporting that multi-representation-based learning can improve students' understanding and literacy skills in mathematics learning. Rahmawati et al. (2022) demonstrated that the use of multi-representation-based e-modules facilitates independent learning and is suitable for online learning. Prahastiwi & Zain (2023) also reported that the varied presentation of e-module content enhances students' motivation to learn. Furthermore, Uslima et al. (2018) found that providing multi-representation-based e-modules is more effective and can be utilized without limitations of time and place. Additionally, Aulia (2022) discovered that the use of e-modules based on multiple representations might improve students' scientific literacy. These findings strengthen the results of the present research, which showed that the implementation of the multi-representation-based calculus e-module had a positive effect on improving students' mathematical literacy skills.

The findings of this research also support previous studies showing that the use of contextual and interactive learning materials can improve students' understanding of mathematical concepts and learning engagement. However, this research specifically contributes to the development of a multi-representation-based calculus e-module designed for Civil Engineering students by integrating calculus concepts with contextual applications in engineering. This integration becomes one of the distinctive contributions of this research because the developed e-module emphasizes conceptual understanding and facilitates students in connecting calculus learning with real problems related to their field of study.

Practically speaking, these results imply that the multi-representation-based calculus e-module may be a useful substitute learning tool, especially for students studying Civil Engineering. Lecturers can employ the e-module to implement diverse learning strategies, especially when explaining the relationships between abstract concepts that students often find challenging. Moreover, the multi-representation-based e-module allows students to learn independently, interactively, and flexibly, thereby potentially enhancing their motivation, engagement, and independence in learning.

Conclusions and Suggestions

Conclusions

The multi-representation-based calculus e-module developed in this research was categorized as very feasible for use in learning activities based on the validation results from content, learning, and media experts. The e-module integrates verbal explanations, mathematical symbols, graphs, tables, images, and contextual applications related to Civil Engineering to support students' understanding of calculus concepts. The findings of this research also showed that the implementation of the developed e-module significantly improved students' mathematical literacy skills. The ANCOVA analysis indicated significant differences between the experimental and control classes, while the effect size analysis demonstrated a large effect category. These findings indicate that the multi-representation-based calculus e-module contributed strongly to improving students' mathematical literacy skills.

This research contributes theoretically by strengthening the use of multiple representations in supporting mathematical literacy development in calculus learning. Practically, this research contributes through the development of a validated calculus e-module specifically designed for Civil Engineering students by integrating contextual engineering applications into calculus learning. Therefore, the developed e-module can be used as an alternative learning resource to support more meaningful, interactive, and independent learning in higher education.

Suggestions

This recommended the multi-representation-based calculus e-module be employed as a learning aid, as it can help students gain a clearer understanding of concepts. Lecturers can use the e-module in delivering course material, while media developers are encouraged to continue refining its features. Future research could expand the sample to include multiple study programs to provide a more comprehensive assessment or apply the e-module in other courses to evaluate the consistency of its effectiveness. Additionally, further studies could incorporate other variables, such as motivation or higher-order thinking skills, to more holistically assess the effect of the e-module on learning outcomes.

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