



Development and validation of a GeoGebra classroom–integrated interactive e-module for enhancing students’ conceptual understanding of integral calculus

Rina Susilowati ^{*}, Aska Muta Yuliani, Nur Farida

Department of Mathematics Education, STKIP Paracendekia NW Sumbawa, West Nusa Tenggara, Indonesia

^{*} Correspondence: rinasusilowati7@gmail.com

© The Author(s) 2026

Abstract

Technology-based e-modules can facilitate interactive learning by actively engaging students in constructing mathematical understanding. GeoGebra Classroom is a digital platform that supports it by enabling interactive activities, real-time monitoring, and immediate feedback. This study aimed to develop and validate an interactive e-module integrated with GeoGebra Classroom to support students' conceptual understanding of integrals. The research method employed is research and development using a modified 4-D model limited to three stages: define, design, and develop. The research subjects were 21 undergraduate students from the mathematics education program at STKIP Paracendekia NW Sumbawa. Data were collected through questionnaires, observations, interviews, and tests and analyzed using descriptive qualitative and quantitative techniques. The results indicated that the developed e-module achieved a very valid category, with an average score of 90.11% from material and media experts. Students' responses showed that the e-module was very practical (86.21%). The effectiveness evaluation demonstrated potential effectiveness based on an average score of 80.83 in the concept understanding ability test. These findings indicate that the GeoGebra Classroom–integrated interactive e-module is feasible for use as a learning resource to support students' conceptual understanding of integral calculus and has the potential to facilitate interactive and independent learning.

Keywords: conceptual understanding; development; e-module; GeoGebra classroom; integral

How to cite: Susilowati, R., Yuliani, A. M., & Farida, N. (2026). Development and validation of a GeoGebra classroom–integrated interactive e-module for enhancing students’ conceptual understanding of integral calculus. *Jurnal Elemen*, 12(2), 409-427. <https://doi.org/10.29408/jel.v12i2.32431>

Received: 28 September 2025 | Revised: 14 December 2025

Accepted: 20 January 2026 | Published: 30 April 2026



Introduction

Teaching materials are subject matter used in learning with a systematic content structure, consisting of printed and non-printed materials (Lestari, 2018). Teaching materials can be in the form of teaching modules, which have the advantage of flexibility; namely, modules can be accessed anytime and anywhere, which makes it easier to learn the material (Aziz & Noer, 2022). Electronic modules are learning resources that align with technological developments, presenting materials, methods, limitations, and evaluation techniques designed systematically and attractively to achieve competencies at various levels of complexity. They can be accessed electronically and supported by the internet or websites (Hidayatulloh, 2016; Luritawaty & Sumartini, 2025; Rifa'i & Nisa', 2020). Interactive teaching modules can use technology such as video, audio, and software (Rachmawati & Listiani, 2022). Software in mathematics learning includes GeoGebra, MATLAB, and others.

GeoGebra has been widely used in mathematics learning to support conceptual understanding through dynamic visualization and the integration of algebraic and graphical representations (Ziatdinov & Valles, 2022). Its use has been shown to enhance students' learning achievement, motivation, problem-solving fluency, and higher-order thinking skills by enabling active exploration of mathematical concepts (Arbain & Shukor, 2015; Nzaramyimana, 2021; Susilowati & Julkarnain, 2022; Uwurukundo et al., 2020; Yorganci, 2018). In classroom settings, GeoGebra promotes active and constructive learning, supporting students' problem-solving fluency, accuracy, and collaborative skills, while fostering independence in solving non-routine tasks (Albaladejo & López, 2024). The GeoGebra Classroom feature further extends these benefits by facilitating interactive learning through structured activities, real-time monitoring, and immediate feedback, allowing lecturers to observe students' learning progress and support more focused and effective mathematics instruction in both face-to-face and online settings (Rosyidi et al., 2024). Through GeoGebra Classroom, student interactions with applets, responses to questions, and learning progress can be systematically observed, enabling more focused and structured learning activities.

Conceptual understanding can be improved using GeoGebra integrated with a multi-teaching approach (Baye et al., 2021). Interactive modules assisted by GeoGebra Classroom in learning can help visualize concepts and procedures for solving integral problems clearly and attractively; for example, GeoGebra can display the curve of a function and the graph of an indefinite integral, solve the problem of the area under the curve, and visualize it. GeoGebra Classroom can create virtual classes, share interactive activities, quizzes, or mathematical simulations, monitor student progress, and interact directly.

Learning mathematics requires the development of several skills, one of which is the conceptual understanding ability. This ability is very important because it serves as a strong foundation for learning mathematics, which provides procedural knowledge and fosters a more profound understanding of mathematical concepts. Conceptual understanding is a person's ability that is characterized by the ability to explain concepts and relate them to the procedure for solving problems, and explain the relationship between the two (Usman et al., 2025). The use of concepts in solving mathematical problems is necessary to avoid errors in procedures,

algorithms, and solutions (Fitria, 2022; Nahdi & Jatisunda, 2020). The indicator of understanding concepts is an elaboration of indicators developed by Benjamin Bloom, namely translation, interpretation, and extrapolation (Siki et al., 2021). The indicators include restating concepts, identifying and creating examples and non-examples of a concept, presenting concepts in various forms of mathematical representation, developing necessary or sufficient conditions of a concept, using and selecting certain procedures for extrapolation, and applying problem-solving concepts or algorithms (Hastuti et al., 2024; NCTM, 2000; Nurfad et al., 2024). This indicator is used as a reference in developing e-modules.

Integral calculus is a compulsory course for mathematics education procedures and mathematics education students. Classroom learning is presented by lecturers through material presentations or learning resources from the internet. Based on the results of observations and interviews, lecturers have not developed teaching modules that can be used by students in developing conceptual understanding skills. In addition, the results of the study show that students have difficulty in interpreting problem information and connecting it with integral concepts and mathematics education concepts; the solution steps taken are still wrong and do not match the question requests, indicating the need for further understanding of theory and its applications (Septiani & Harisman, 2025). This difficulty is caused by students carrying out a procedure without knowing what and why the procedure is carried out to solve the problem, thus making students lose the opportunity to think about understanding the problem, share ideas to solve the problem concepts, and communicate them (Tasman & Ahmad, 2017). Understanding the concept of integrals is needed in solving value accumulation problems; practical applications of integrals are widely used in the fields of physics, economics, and computer science and are useful in everyday life (Neldiana & Harisman, 2024).

Research on the development of GeoGebra-assisted problems and GeoGebra-assisted e-modules has been conducted, the majority of which are developed on geometry, algebra, and calculus materials. The e-modules developed include GeoGebra e-modules, learning modules in Moodle, e-modules using the Sigil application, and flipbooks (Aspriyani & Suzana, 2020; Meilasari & Khotimah, 2022; Pramana et al., 2022). Other teaching materials developed include web-based worksheets designed to make students active, creative, and independent during the learning process in discovering and exploring plane geometry concepts (Muchlis et al., 2021). These worksheets require access to GeoGebra-assisted access, such as a username and password, so they cannot be accessed publicly. Learning using GeoGebra access, GeoGebra can be used as an alternative in an effort to improve students' understanding of mathematical concepts, where the material is interactive, interesting, and appropriate to cognitive levels and provides opportunities for students to build their own understanding (Nyoman et al., 2021).

Although GeoGebra-assisted learning materials have been widely developed, most focus on standalone applications that emphasize visualization and lack integration with GeoGebra Classroom. Consequently, support for real-time monitoring, structured interaction, and formative feedback to enhance students' conceptual understanding of integral calculus remains limited, indicating the need for GeoGebra Classroom–integrated e-modules. The material in the module is quite comprehensive, covering indefinite integrals, definite integrals, and integral applications. In addition, the development of this e-module refers to indicators of the ability to

understand mathematical concepts. The electronic module was developed with the assistance of Classroom, so that each student can know the learning activities carried out and what material will be studied, conduct simulations, and evaluate what they have learned so that it can help in building the ability to understand the concept of integral material. Lecturers can observe the more structured student learning activities and access them at any time and location for free.

From the description above, it is necessary to develop an interactive e-module that is able to facilitate students in improving their understanding of integral concepts, where the module is assisted by GeoGebra Classroom. Therefore, this study aims to develop an interactive e-module integrated with GeoGebra Classroom and to examine its validity, practicality, and potential effectiveness in supporting students' conceptual understanding of integral calculus.

Methods

The type of research used is development research, practical research, or Research and Development (R&D) research, with reference to the 4D development model developed by Thiagarajan et al. (1974). This development model includes Define, Design, Develop, and Dissemination (Sugiyono, 2017). Meanwhile, for this research only 3D (Define, Design, and Develop). The subjects of this study were 21 mathematics education development students at STKIP Paracendekia NW Sumbawa with a convenience sampling technique, as they consisted of students who enrolled in the integral calculus course during the study period. Although this technique allows practical access to participants, it may limit the generalizability of the findings; therefore, the results are interpreted as preliminary evidence within a development research context.

The research flowchart is presented in the following figure.

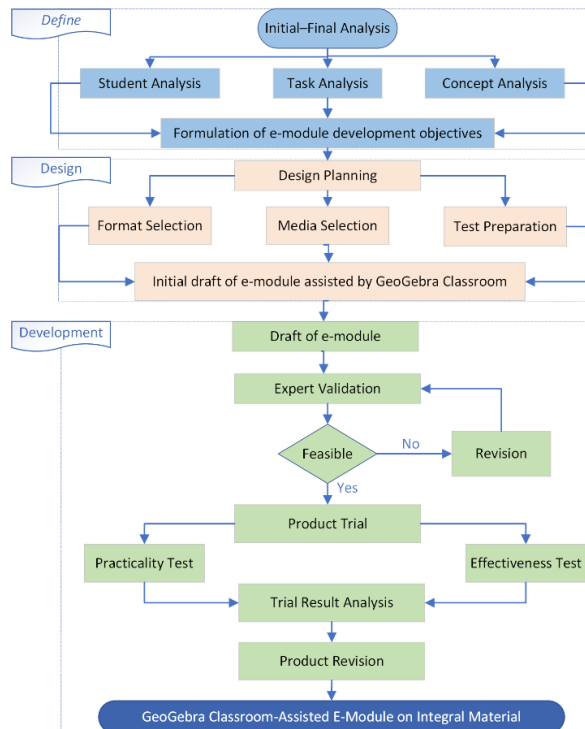


Figure 1. Research flow diagram

The first stage, namely define, begins with conducting observations and interviews with lecturers and students. At this stage, researchers conduct initial data analysis by identifying products that are appropriate to student abilities, mathematics education abilities, and learning objectives; identifying tasks needed to achieve objectives; and identifying learning content or materials. These results will later serve as a reference in compiling plans for developing interactive e-modules assisted by GeoGebra. In the second stage, namely design, the aim is to design and produce interactive e-modules assisted by GeoGebra to improve students' conceptual understanding abilities by looking at the materials and learning activities that have been planned.

Next, experts tested the initial product draft for feasibility and validity using a validation questionnaire. If there were suggestions and input from the validator, the product was revised. The revised and declared valid product was trialed for use by students in learning and tested for practicality using a response questionnaire filled out by the students as users. Furthermore, the effectiveness evaluation focused on determining the potential effectiveness of the developed prototype rather than making causal comparisons, as this study did not involve experimental or control groups, and was evaluated using a conceptual understanding test in the form of fill-in-the-blank questions. The test results were analyzed quantitatively based on predetermined effectiveness criteria, in which the e-module was considered to demonstrate potential effectiveness if at least 75% of students achieved the established benchmark score. The use of a 75% mastery threshold is consistent with the principle of mastery learning and classical completeness, which is widely adopted in mathematics education research and instructional evaluation (Khoiriah et al., 2024; Nyoman et al., 2021)

Data collection techniques included observation, interviews, questionnaires, and tests. The questionnaire was used to analyze initial needs and to determine students' responses to the use of the e-module. The validation sheet was used to determine the level of feasibility in terms of product validity, as assessed by experts based on aspects of content quality and objectives, instructional quality, and technical quality. The test instrument was used to test the effectiveness of the product by observing the ability to understand concepts regarding integral material.

The validity and practicality questionnaire data analysis was conducted using a Likert scale, and the scores were then converted into qualitative criteria. The validity and practicality scores were calculated by assigning percentages based on the following formula (Muchlis et al., 2021).

$$Percentage = \frac{Score\ obtained}{Total\ score} \times 100\% \quad (1)$$

The e-module validity percentage criteria can be seen in Table 1 below.

Table 1. E-module validity criteria

Interval	Category
81% – 100%	Very valid
61% - 80%	Valid
41% - 60%	Quite valid
21% - 40%	Less valid
0% - 20%	Invalid

An interactive e-module assisted by GeoGebra Classroom is considered valid based on expert assessment if the results are at least in the valid category. Furthermore, the practicality score data obtained from the student response sheets was converted into qualitative form with the following interpretation. The criteria for the e-module's practicality percentage can be seen in Table 2 below.

Table 2. Practicality criteria of e-modules

Interval	Category
81% – 100%	Very practical
61% - 80%	Practical
41% - 60%	Quite practical
21% - 40%	Less practical
0% - 20%	Not practical

An interactive e-module assisted by GeoGebra Classroom is considered practical if the results are at least in the practical category. This research will produce a product in the form of an e-module assisted by GeoGebra Classroom that can be accessed on the website and can be used in learning, containing learning activities such as materials, simulations, and practice questions. The product will be tested for validity, practicality, and effectiveness in improving conceptual understanding, making it suitable for general use.

Results

The development model used in this study is a 3D model developed by Thiagarajan et al., which consists of three stages: define, design, and develop. The research results for these three stages are explained below.

Define

At this stage, a preliminary-final analysis was conducted to identify the problems in the calculus learning process in the Mathematics Education study program of STKIP Paracendekia NW Sumbawa. The analysis included student analysis, assignment analysis, and concept analysis. The student analysis was obtained based on the results of classroom observations and interviews with students and lecturers. The results showed that students found it difficult to understand the concept of integral material well, visualize, and apply integral concepts in problem solving. In addition, the delivery of integral material used PowerPoint presentations; there was no optimal use of learning media. The limited availability of learning modules that can help students understand abstract material. The teaching materials used previously were not interactive, thus not providing space for students to do repeated exercises or self-evaluation. The unavailability of digital modules that can create active, effective, and enjoyable learning further emphasizes the need for the development of more innovative teaching materials.

Next, assignments and concepts were analyzed through literature studies and interviews with the lecturers to obtain information on the scope of the material to be developed in the e-module. Based on the conceptual analysis, the researcher determined the learning outcomes

(CPMK) and sub-CPMK that students must master, as shown in the following table. The researcher also analyzed the tasks required to achieve each sub-CPMK of integral.

Table 3. CPMK and sub-CPMK of integral material

CPMK	Sub-CPMK
1. Able to analyze related indefinite integrals (antiderivatives)	1) Students can understand the method of indefinite integrals (antiderivatives) 2) Students can analyze indefinite integral problems
2. Able to analyze related definite integrals	3) Students can examine and solve area problems using Riemann sums. 4) Students can to relate the material on Riemann sums to the concept of definite integrals. 5) Students can understand and solve problems using the first and second fundamental theorems of calculus and the substitution method.
3. Able to solve problems related to the use of integrals	6) Students can apply the concept of integrals in determining the area of a flat plane, the volume of a solid object, and the length of a curve.

The development of this GeoGebra Classroom-assisted e-module is also adapted to the research objective of improving students' conceptual understanding abilities. The activities in the e-module are arranged with reference to indicators of conceptual understanding abilities, namely: (1) restating concepts, (2) identifying examples and non-examples of a concept, (3) presenting concepts in various forms of mathematical representation, (4) developing necessary or sufficient conditions of a concept, (5) using and selecting specific procedures, and (6) applying concepts or problem-solving algorithms (NCTM, 2000; Nurfad et al., 2024).

The collection of information and references related to the research on the development of e-modules assisted by GeoGebra obtained the results that e-modules will be able to improve the ability to understand mathematical concepts (Anggraeni et al., 2021; Nasrullah et al., 2023; Sutopo & Ratu, 2022; Triana Safitri et al., 2023). Based on the analysis that has been done, this research is on the development of e-modules assisted by GeoGebra Classroom on integral material that can improve students' conceptual understanding abilities, can visualize the material, and can be used for student independent learning.

Design

The design phase includes format selection, media selection, and test development. The e-module is designed using the GeoGebra Book format, presenting the material in a structured manner that includes text, images, questions, and GeoGebra applets. The e-module is then implemented through GeoGebra Classroom by distributing class codes to students.

This format was chosen because GeoGebra books facilitate conceptual understanding through visualization and can increase learning interest through engaging and interactive technology. GeoGebra Classroom, on the other hand, facilitates classroom management, monitors student activity in real time, provides immediate feedback on completed answers, and promotes active engagement in the learning process (Oliveira et al., 2023).

The selected media was a web-based interactive e-module (HTML5) with JavaScript support, integrating the GeoGebra applet on the module page containing the material. This allows the e-module to be accessed directly via mobile phone or laptop. Next, the researcher typed the material, examples, exercises, and tests sourced from the Calculus book (Varberg et al., 2006). The designed GeoGebra Book display is presented in the following image.

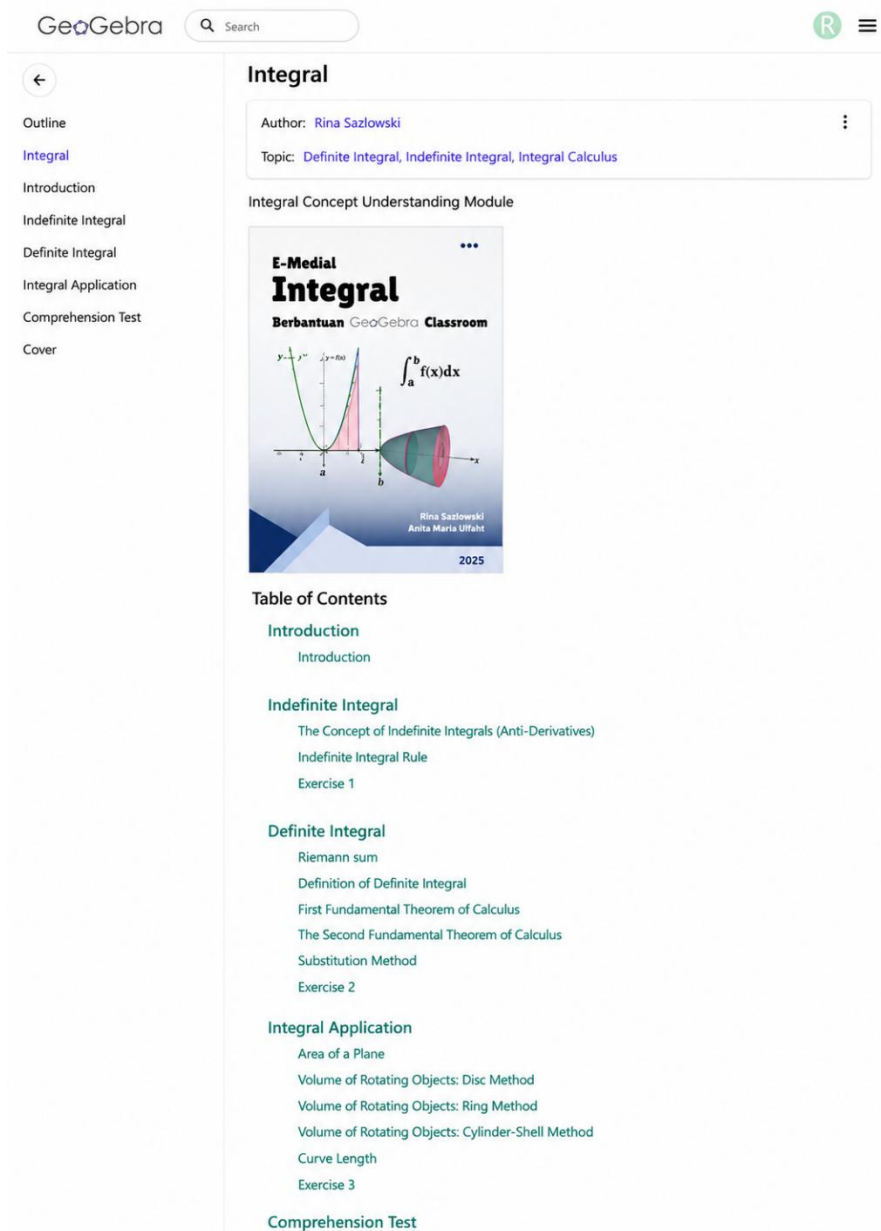


Figure 2. GeoGebra book display

The design of this interactive e-module, assisted by GeoGebra Classroom, contains a systematically arranged description of integral material accompanied by activities and example questions presented through the GeoGebra applet, as well as exercises on each sub-material and a test of understanding at the end. The activities in this e-module were developed to improve students' conceptual understanding, for example restating the concept of integrals through explanations of integral definitions accompanied by graphical illustrations, identifying examples and non-examples of functions that can be integrated with the help of simulations,

presenting concepts in various forms of mathematical representation by displaying the relationship between graphic symbols and numerical calculations, developing necessary or sufficient conditions of a concept by providing exploration activities, and so on. These activities are carried out with the GeoGebra applet, which can be run directly to visualize and explore the concept of indefinite integrals, definite integrals, and integral applications such as area, volume of rotating objects, and other integral applications.

After producing the initial draft of the e-module, the next step was to develop assessment instruments or tests. The assessment instruments developed by the researchers included validation sheets from material experts and media experts, student response questionnaires, and conceptual understanding test instruments. The conceptual understanding indicators used in this study are shown in the Table 4.

Table 4. Indicators of conceptual understanding test instrument

Number	Conceptual Understanding Indicator	Question Indicator
1	Restating the concept	Restating the definitions of indefinite integrals and definite integrals
2	Identify examples and non-examples of a concept	Identify examples and non-examples of integrable functions
3	Presenting concepts in various forms of mathematical representation	Presenting the concept of the Riemann sum from a picture Presenting the concept of integral applications in graphical form
4	Developing the necessary or sufficient conditions of a concept	Developing conditions for using the substitution rule in definite integrals
5	Using and selecting specific procedures	Using specific procedures in solving definite integrals Selecting the method of solving integral applications on the volume of rotating objects
6	Applying problem-solving concepts or algorithms	Applying the concept of definite integrals to solving problems of the volume of rotating objects

Develop

This stage aims to produce an e-module assisted by GeoGebra Classroom on integral material by testing the validity, effectiveness, and practicality of the developed e-module. The activity carried out at this stage is to conduct a validation process with experts. The two material expert validators are lecturers from the Mathematics Education Study Program, and the two media expert validators are lecturers from the Educational Technology and Informatics Study Programs, respectively. The validation results by the material experts are shown in the Table 5 below.

Table 5. Results of validation of the e-module draft by material experts

Aspect	Total Score		Average Score	Average Percentage
	Validator-1	Validator-2		
Content suitability	22	22	22	91.67%
Presentation suitability	10	11	10.5	87.5%
Language eligibility	22	22	22	91.67%
Conceptual understanding	25	27	26	92.86%
Average Percentage	89.77%	93.18%		91.48%

Table 5 shows that the average percentage of validation results by material experts in all three aspects reached an average of 91.48%. The validity criteria are based on the 82% - 100% interval, which is categorized as very valid based on existing criteria (Widoyoko, 2018). Meanwhile, the validation results by media experts are shown in Table 6 below.

Table 6. Results of validation of the e-module draft by media experts

Aspect	Total Score		Average Score	Average Percentage
	Validator-1	Validator-2		
Presentation	18	17	17.5	87.5%
Interactivity	11	10	10.5	87.5%
Technical	7	8	7.5	93.75%
Average Percentage	90%	87.5%		88.75%

Based on the validation results by media experts, as shown in Table 6, the average percentage for the presentation, interactivity, and technical aspects reached an average of 88.75% and was categorized as very valid. Therefore, the validation results for the e-module draft by both material experts and media experts obtained an average percentage of 90.11% and were categorized as very valid. Several comments and suggestions were submitted by the four validators, as shown in Table 7 below.

Table 7. Suggestions and comments from material experts and media experts

Validator	Comments
Material Experts-1	1. e-modules should be equipped with prerequisite material related to derivatives
	2. There needs to be clear instructions for use
	3. There is no comparison of examples and non-examples of the integral concept presented in the e-module.
	4. Correct typos and appropriateness of symbols used
Material Experts-2	1. Lack of instructions for use
	2. There is no information after filling in
	3. It is necessary to clarify the technical aspects of the activities or activities carried out by students.
Media Experts-1	1. In activity 1.2 and task 20, it can be seen that some of the text is cut off, so that the information is not complete.
	2. Correct typos
	3. There needs to be a presentation of sequential steps for solving practice questions.
	4. Need to provide alternative offline e-module access

Validator	Comments
Media Experts-2	<ol style="list-style-type: none"> 1. Add the year of module compilation on the cover; the integral illustration is less clear 2. Feedback needs to be clarified with activity instructions in the GeoGebra applet.

Next, the researchers made revisions and improvements based on the suggestions, input, and comments provided by the validators, including material experts and media experts. These suggestions served as a reference for improving the designed e-module to ensure its suitability for student use in the learning process. Below are some examples of how the revised e-module looked before and after revisions.

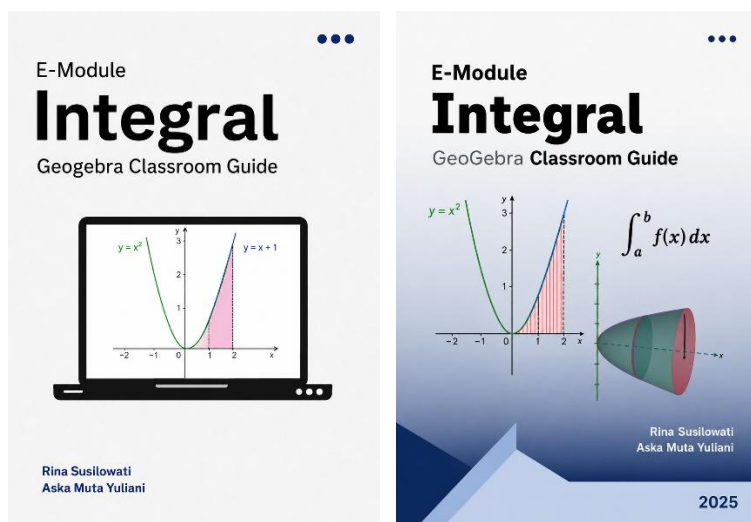


Figure 3. Appearance of the e-module cover before and after revision

Activity 1.2

Determine the answer to the following question.

Is $g(x) = x^2$ integral of $f(x) = 2x$?
 Yes No
 Correct answer

Is $h(x) = x^2 + 2$ integral of $f(x) = 2x$?
 Yes No
 Wrong answer

Is $p(x) = x^2 + 3$ integral of $f(x) = 2x$?
 Yes No
 Wrong answer

Is $q(x) = x^2 + 4$ integral of $f(x) = 2x$?
 Yes No
 Correct answer

Figure 4. Revised display of feedback after students input their answers

In addition, there are also revisions by adding instructions to the activities in the module, and activities to compare examples and non-examples in the integral concept, which is one of the indicators of the ability to understand mathematical concepts, as shown in the following image.

Activity Instructions 1.1

1. Enter your answer in the box provided and press Enter, then feedback will appear from the answer given. 2. Reset button to delete feedback and re-enter the answer. 3. Select one of the answers "Yes" or "No", if it is green then it is correct and red then it is wrong.

In Activity 2.2, you can move the P value slider and observe the changes that occur in the image.

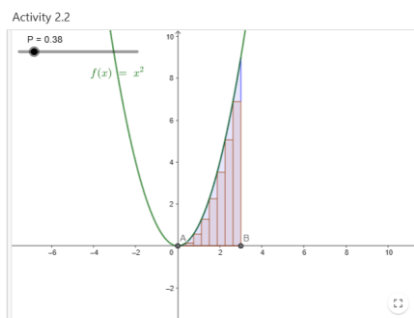


Figure 5. Revised additional activity instructions

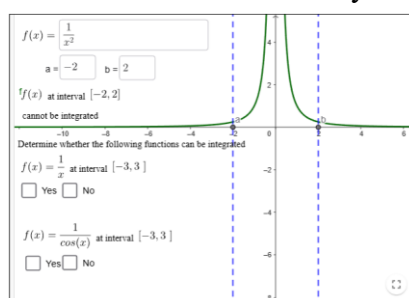


Figure 6. Revision of the addition of activities comparing examples and non-examples in the integral concept

The e-module that has been declared valid was tested in the field for use in Calculus learning in the Mathematics Education Study Program at STKIP Paracendekia NW Sumbawa for four meetings in July 2025. The field test involved 21 students. The following is a display of class participants in the GeoGebra Classroom.

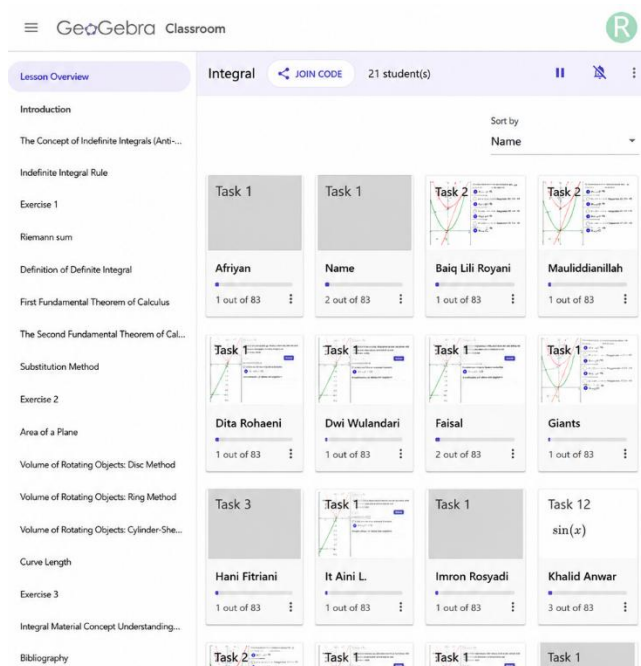


Figure 7. GeoGebra classroom participants

The effectiveness of the e-module was determined based on an effectiveness test using descriptive questions. Before use, the test instrument was validated by a validator, with a validity percentage of 90.91%, categorized as very valid. The results of the students' test on the ability to understand the concept of integral material obtained an average value of 80.83. These results indicate that the interactive e-module assisted by GeoGebra Classroom demonstrated potential effectiveness in supporting students' understanding of mathematical concepts, because as many as 16 people, or 76.19% of students, were able to achieve a score of more than 75.

Furthermore, the practicality test of the e-module was obtained based on the results of the student response questionnaire after using the e-module. The results of the student response questionnaire are shown in the following figure.

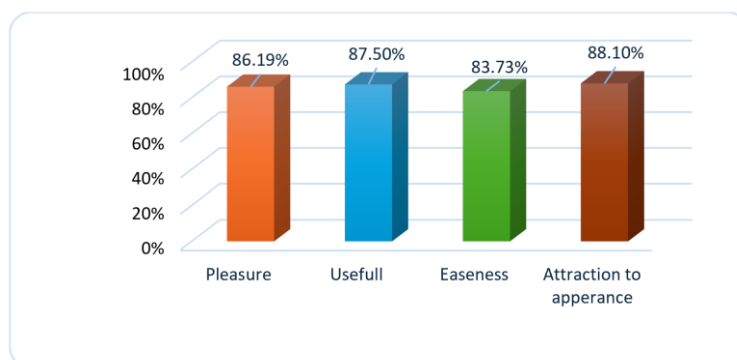


Figure 8. Diagram of student response questionnaire results for the e-module

Figure 8 shows that the results of the student questionnaire responses on the aspects of enjoyment, usefulness, ease of use, and interest in the display reached percentages of 86.19%, 87.5%, 83.73%, and 88.1%, respectively. So, the average percentage of the student questionnaire response results was 86.21% and was categorized as very practical.

Discussion

The results of the study indicate that the developed interactive e-module assisted by GeoGebra Classroom meets the criteria of being valid, practical, and demonstrated potential effectiveness in improving students' understanding of integral concepts. Validity is demonstrated through expert assessments of material and media, which are in the very valid category. The integration of dynamic visualization and symbolic representations in GeoGebra facilitates conceptual understanding by allowing students to link abstract integral concepts with visual interpretations, consistent with previous studies highlighting GeoGebra's role in supporting conceptual learning (Takači et al., 2015; Ziatdinov & Valles, 2022).

Practicality is seen from students' positive responses to the use of the e-module, while effectiveness is reflected in the improvement in the results of the integral concept understanding test. In this developmental research, the effectiveness of the e-module was determined based on predetermined success criteria, rather than by comparing experimental and control groups. The results showed that most students achieved the minimum achievement standards, indicating that the developed e-module has the potential to support students' conceptual understanding.

Compared to standalone GeoGebra applications, GeoGebra Classroom offers a more structured learning environment by integrating classroom management, guided activities, and lecturer monitoring. This structure encourages students to remain focused on learning tasks while still allowing flexibility for exploration, which is consistent with previous findings that interactive and well-organized digital learning environments enhance student engagement and learning efficiency (Albaladejo & López, 2024; Badriyanto & Qohar, 2022).

GeoGebra is typically used individually without centralized control and monitoring, making it difficult for instructors to understand students' thinking processes. GeoGebra Classroom, on the other hand, is more effective in teaching because it provides a structured, interactive, and organized learning environment. Lecturers can quickly identify and correct student errors thanks to formative assessment tools, guided activities, and real-time monitoring, while also supporting deeper conceptual understanding.

This e-module is proven to be able to create more interesting learning, facilitate students in visualizing abstract integral concepts, and encourage active involvement through practice and direct feedback. Its use can be accessed online and is widely used to explore mathematical concepts and ideas (Hidayat et al., 2024). These findings show that students not only memorize procedures but are also able to construct the meaning of integral concepts through symbolic and graphical representations. The results of this study are in line with the findings (Tatar & Zengin, 2016) that GeoGebra can create a fun and interesting environment with dynamic learning, providing visualization and opportunities for learning through practice and exercises, enabling a thorough understanding and explanation of skills, and paving the way for conceptual learning, not just memorizing. The study by (Bedada & Machaba, 2024; Gurmu et al., 2024; Owusu et al., 2023) findings showed that GeoGebra technology had a greatly stronger effect on students' conceptual understanding. Besides that, (Sur, 2020) and (Sari et al., 2024) confirm that the use of GeoGebra in calculus learning has great potential in improving conceptual understanding, especially in the visualization of function graphs and integral concepts, visualization of integral conditions that help in building abstract integral concepts, so that visual and symbolic representations can be combined mathematically.

These findings indicate that the role of GeoGebra Classroom is not merely as a visualization medium, but also as a means that allows students to construct knowledge through active exploration and interaction. This is in line with the principles of constructivism, namely the view that knowledge is actively constructed by students, not simply transferred from lecturers. According to Piaget (1972), constructivism emphasizes the processes of assimilation and accommodation in building cognitive structures, while Vygotsky (1978) emphasized the importance of social interaction and scaffolding in the zone of proximal development. Both of these theories are reflected in the use of GeoGebra Classroom, where students can learn independently through simulations and exercises, but still receive direct guidance through feedback from lecturers and discussions with peers.

The novelty of this research lies in the development of an e-module integrated with GeoGebra Classroom, not just assisted by Ge(Aspriyani & Suzana, 2020; Meilasari & Khotimah, 2022)(Aspriyani & Suzana, 2020; Meilasari & Khotimah, 2022). This integration provides added value in the form of the ability to manage virtual classes, monitor student progress, and

provide immediate feedback on answers worked on. This is in accordance with the view (Oliveira et al., 2023; Rosyidi et al., 2024) that GeoGebra Classroom can increase student engagement through technology-based interactive activities. This research implies that the development of interactive digital teaching materials can be an important strategy in improving the quality of calculus learning, because interactive e-modules assisted by GeoGebra Classroom provide opportunities for students to learn independently while receiving interactive guidance from lecturers. The success of this research opens up opportunities for the development of similar e-modules on other mathematical materials, such as derivatives, geometry, or differential equations, as well as their integration with innovative learning models.

Conclusion

The interactive e-module assisted by GeoGebra Classroom meets the criteria of being valid and practical, and demonstrates potential effectiveness. The validity of the e-module is demonstrated through the results of the assessment of material and media experts, which are the very valid category. The practicality of the e-module is reflected in positive student responses indicating that the module is easy to use, interesting, enjoyable, and helpful for learning. The potential effectiveness of the e-module is indicated by the results of the conceptual understanding test. These findings suggest that the GeoGebra Classroom-assisted e-module is feasible to be used as an alternative teaching material to support students' conceptual understanding of integral material, particularly within the context of development research.

This study has limitations in that the field trial involved a relatively small sample size of 21 students and used a research and development (R&D) design without a control group to determine the effectiveness of the developed e-module. Therefore, the effectiveness of the e-module was based on predetermined achievement criteria for the prototype, rather than experimental comparisons. The results provide sufficient preliminary evidence of the potential effectiveness of the GeoGebra Classroom e-module and can serve as a basis for further experimental or large-scale studies. The duration of the implementation was relatively short, which may not fully capture the long-term impact of the e-module on students' conceptual understanding.

Theoretically, this study reinforces previous findings that understanding of mathematical concepts can be enhanced through the integration of visualization-based technology supported by a clear pedagogical structure. Practically, the developed e-module can be utilized as an alternative learning resource in integral calculus learning, particularly in face-to-face and blended learning contexts. For further research, it is recommended to use experimental or quasi-experimental designs with a wider sample size and application to other mathematics topics to strengthen the generalizability of the findings.

Acknowledgment

The Authors would like to express his gratitude to the parties who have assisted in this research, including research members, both lecturers and students, the Author and editor of the GeoGebra

applet in the developed module, namely Ade Rahmad Sutami, students of the Mathematics Education Study Program at STKIP Paracendekia NW Sumbawa as respondents, and other parties who cannot be mentioned one by one.

Declarations

- Conflicts of Interest : The authors declare no conflict of interest.
- Generative AI Statement : Generative AI tools, such as Grammarly, were employed solely for language editing and minor phrasing enhancements. All conceptualization, analysis, and scholarly content were independently developed and verified by the authors.
- Funding Statement : This work was supported by the Ministry of Higher Education, Science, and Technology of Republic of Indonesia which is a research grant under the 2025 “Penelitian Dosen Pemula” scheme [grant number 129/C3/DT.05.00/PL/2025].
- Author Contributions : **Rina Susilowati:** Conceptualization, writing - original draft, editing, software and visualization, supervision; **Aska Muta Yuliani:** Writing - review & editing, formal analysis, validation and methodology; **Nur Farida:** Writing - editing, investigation.

References

- Albaladejo, I. M. R., & López, M. del M. G. (2024). Mathematical attitudes transformation when introducing GeoGebra in the secondary classroom. *Education and Information Technologies*, 29(8), 10277–10302. <https://doi.org/10.1007/s10639-023-12085-w>
- Anggraeni, E. R., Ma'rufi, & Suaedi. (2021). Pengembangan media pembelajaran matematika berbasis GeoGebra untuk meningkatkan kemampuan pemahaman konsep siswa [Development of GeoGebra-based mathematics learning media to improve students' conceptual understanding abilities]. *Proximal: Jurnal Penelitian Matematika Dan Pendidikan Matematika*, 4(1), 43–55. <https://doi.org/10.30605/proximal.v4i1.503>
- Arbain, N., & Shukor, N. A. (2015). The effects of GeoGebra on students achievement. *Procedia - Social and Behavioral Sciences*, 172, 208–214. <https://doi.org/10.1016/j.sbspro.2015.01.356>
- Aspriyani, R., & Suzana, A. (2020). Pengembangan e-modul interaktif materi persamaan lingkaran berbasis realistic mathematics education berbantuan Geogebra [Development of an interactive e-module for circle equation material based on realistic mathematics education assisted by Geogebra]. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 9(4), 1099–1111. <https://doi.org/10.24127/ajpm.v9i4.3123>
- Aziz, A. A., & Noer, S. H. (2022). Analisis pembelajaran berbasis kemampuan pemecahan masalah dan kebutuhan e-modul berbantuan flipbook maker [Analysis of problem-solving ability-based learning and e-module needs assisted by flipbook maker]. *JNPM (Jurnal Nasional Pendidikan Matematika)*, 6(4), 788–801. <https://doi.org/10.33603/jnpm.v6i4.7330>
- Badriyanto, B., & Qohar, A. (2022). Developing Interactive Learning Media of Worksheets based on Geogebra Classroom. *JIPM (Jurnal Ilmiah Pendidikan Matematika)*, 11(1), 233. <https://doi.org/10.25273/jipm.v11i1.14094>
- Baye, M. G., Ayele, M. A., & Wondimuneh, T. E. (2021). Implementing GeoGebra integrated with multi-teaching approaches guided by the APOS theory to enhance students'

- conceptual understanding of limit in Ethiopian Universities. *Heliyon*, 7(5). <https://doi.org/10.1016/j.heliyon.2021.e07012>
- Bedada, T. B., & Machaba, M. F. (2024). The development of the cycle model and its effect on mathematics learning using GeoGebra mathematical software. *Education Inquiry*, 15(4), 503–526. <https://doi.org/10.1080/20004508.2022.2137260>
- Diković, L. (2009). Applications geogebra into teaching some topics of mathematics at the college level. *Computer Science and Information Systems*, 6(2), 191–203. <https://doi.org/10.2298/CSIS0902191D>
- Fitria, M. (2022). Kemampuan pemahaman konsep mahasiswa dalam penyelesaian soal integral berdasarkan teori APOS [Students' conceptual understanding ability in solving integral problems based on APOS theory]. *Dharmas Education Journal (DE Journal)*, 1(1), 48–54. <https://doi.org/10.56667/dejournal.v1i1.59>
- Gurmu, F., Tuge, C., & Hunde, A. B. (2024). Effects of GeoGebra-assisted instructional methods on students' conceptual understanding of geometry. *Cogent Education*, 11(1). <https://doi.org/10.1080/2331186X.2024.2379745>
- Hastuti, S. S., Labudasari, E., & Jannah, W. N. (2024). Analisis kemampuan pemahaman konsep matematika melalui model contextual teaching and learning [Analysis of mathematical concept understanding ability through contextual teaching and learning model]. *JRPD (Jurnal Riset Pendidikan Dasar)*, 7(2), 148–156. <https://doi.org/10.26618/jrpd.v7i2.15165>
- Hidayat, R., Noor, W. N. W. M., Nasir, N., & Ayub, A. F. M. (2024). The role of GeoGebra software in conceptual understanding and engagement among secondary school student. *Infinity Journal*, 13(2), 317–331. <https://doi.org/10.22460/infinity.v13i2.p317-332>
- Hidayatulloh, M. S. (2016). Pengembangan e-modul matematika berbasis problem based learning berbantuan geogebra pada materi bilangan bulat [Development of a mathematics e-module based on problem-based learning assisted by GeoGebra on the topic of integers]. *AKSIOMA: Jurnal Matematika Dan Pendidikan Matematika*, 7(2), 24–31. <https://doi.org/10.26877/aks.v7i2.1416>
- Lestari, I. (2018). Pengembangan bahan ajar matematika dengan memanfaatkan Geogebra untuk meningkatkan pemahaman konsep [Development of mathematics teaching materials by utilizing GeoGebra to improve conceptual understanding]. *GAUSS: Jurnal Pendidikan Matematika*, 01(01), 26–36. <https://doi.org/10.30656/gauss.v1i1.634>
- Luritawaty, I. P., & Sumartini, T. S. (2025). Pengembangan e-modul Geogebra berbasis problem-based learning untuk meningkatkan kemampuan spasial matematis [Development of GeoGebra e-modules based on problem-based learning to improve mathematical spatial abilities]. *Ar-Riyadhiyyat: Journal of Mathematics Education*, 5(2), 44–56. <https://doi.org/10.47766/ariyadhiyyat.v5i2.5054>
- Meilasari, V., & Khotimah, K. (2022). Pengembangan e-modul berbantuan Geogebra pada mata kuliah kalkulus integral lipat [Development of GeoGebra-assisted e-modules for the subject of folded integral calculus]. *SIGMA: Kajian Ilmu Pendidikan Matematika*, 8(1), 1–7. <https://doi.org/10.53712/sigma.v8i1.1533>
- Muchlis, E. E., Priatna, N., & Dahlan, J. A. (2021). Development of a web-based worksheet with a project-based learning model assisted by GeoGebra. *Jurnal Riset Pendidikan Matematika*, 8(1), 46–60. <https://doi.org/https://doi.org/10.21831/jrpm.v8i1.40985>
- Nahdi, D. S., & Jatisunda, M. G. (2020). Conceptual Understanding and Procedural Knowledge: A Case Study on Learning Mathematics of Fractional Material in Elementary School. *Journal of Physics: Conference Series*, 1477(4), 1–5. <https://doi.org/10.1088/1742-6596/1477/4/042037>
- Nasrullah, A., Umalihayati, U., & Mubarika, M. P. (2023). Pemanfaatan Geogebra Terhadap Peningkatan Kemampuan Pemahaman Konsep pada Pembelajaran Matematika Ekonomi.

- AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 12(2), 1789.
<https://doi.org/10.24127/ajpm.v12i2.7098>
- NCTM. (2000). *Principles and Standards for School Mathematics*. The National Council of Teachers of Mathematics, Inc.
- Neldiana, R., & Harisman, Y. (2024). Peranan Integral dan Diferensial Terhadap Kalkulus. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, 09, 273–284.
<https://doi.org/10.31004/cendekia.v9i1.3853>
- Nurfad, Indriana, & Julian, F. (2024). Students' Mathematical Conceptual Knowledge. *Jurnal Mercumatika: Jurnal Penelitian Matematika Dan Pendidikan Matematika*, 8(2), 3–7.
<https://doi.org/https://doi.org/10.26486/jm.v8i2.3414>
- Nyoman, N., Darma Putri, W., Puja Astawa, W., & Ardana, I. M. (2021). Improving Students' Conceptual Understanding Through Geogebra-Assisted "5E" Learning Cycle: Is It Effective? *Jurnal Pendidikan Dan Pengajaran*, 54, 170–180.
<https://doi.org/https://doi.org/10.23887/jpp.v54i1>
- Nzaramyimana, E. (2021). Effectiveness of GeoGebra towards Students' Active Learning, Performance and Interest to Learn Mathematics. *International Journal of Mathematics and Computer Research*, 09(10). <https://doi.org/https://doi.org/10.47191/ijmcr/v9i10.05>
- Oliveira, M. P. de S., Hall, A., Bastos, N. R. O., Seabra, D., Assunção, E., & Barroso, M. J. (2023). The Geogebra Book: A Tool to Engage Students. *EDULEARN23 Proceedings*, 2149–2157. <https://doi.org/10.21125/edulearn.2023.0645>
- Owusu, R., Bonyah, E., & Arthur, Y. D. (2023). The Effect of GeoGebra on University Students' Understanding of Polar Coordinates. *Cogent Education*, 10(1).
<https://doi.org/10.1080/2331186X.2023.2177050>
- Pramana, B. W. A., Susanto, Suwito, A., Lestari, N. D. S., & Murtikusuma, R. P. (2022). Pengembangan e-modul berbantuan Geogebra pada materi transformasi geometri SMA [Development of GeoGebra-assisted e-modules on high school geometric transformation material]. *GAUSS: Jurnal Pendidikan Matematika*, 5(2), 1–14.
<https://doi.org/10.30656/gauss.v5i2.5694>
- Rachmawati, & Listiani, W. (2022). Pengembangan bahan ajar komputasi matematika dan implementasinya pada maple soft untuk pembelajaran jarak jauh [Development of mathematical computational teaching materials and their implementation on maple soft for distance learning]. *Jurnal Jendela Pendidikan*, 02(01), 110–116.
<https://doi.org/https://doi.org/10.57008/jjp.v2i01.134>
- Rifa'i, M., & Nisa', R. (2020). Pengembangan e-modul kalkulus berbasis Geogebra dengan dukungan website Moodle [Development of GeoGebra-based calculus e-modules with Moodle website support]. *Math Didactic: Jurnal Pendidikan Matematika*, 5(3), 259–268.
<https://doi.org/10.33654/math.v5i3.780>
- Rosyidi, A. H., Sari, Y. M., Fardah, D. K., & Masriyah, M. (2024a). Designing mathematics problem-solving assessment with GeoGebra Classroom: proving the instrument validity. *Journal of Education and Learning*, 18(3), 1038–1046.
<https://doi.org/10.11591/edulearn.v18i3.21191>
- Sari, N. H. M., Ayusman, M. H., Agus, M., & Nahdi, A. L. (2024). Pemanfaatan Geogebra dalam pembelajaran kalkulus: systematic literature review [Utilization of Geogebra in calculus learning: systematic literature review]. *SANTIKA: Seminar Nasional Tadris Matematika*, 429–438.
<https://proceeding.uingusdur.ac.id/index.php/santika/article/view/santika42434>
- Septiani, R. D., & Harisman, Y. (2025). Studi pemahaman kalkulus: uji kemampuan mahasiswa pendidikan matematika dalam perhitungan integral dan diferensial [Calculus comprehension study: a test of mathematics education students' abilities in integral and

- differential calculations]. *Jurnal Riset Pembelajaran Matematika Sekolah*, 9(1), 28–42. <https://doi.org/10.21009/jrpms.091.04>
- Siki, D., Djong, K. D., & Jagom, Y. O. (2021). Profil pemahaman konsep matematika siswa SMP dalam menyelesaikan masalah matematika [Profile of junior high school students' understanding of mathematical concepts in solving mathematical problems]. *Leibniz : Jurnal Matematika*, 1(1), 36–43. <https://doi.org/10.59632/leibniz.v1i1.55>
- Sugiyono. (2017). *Metode penelitian kuantitatif, kualitatif dan R&D [Quantitative, qualitative and R&D research methods]*. CV. Alfabeta.
- Sur, W. A. A. (2020). Mathematical Construction of Definite Integral Concepts by Using GeoGebra. *Mathematics Education Journal*, 4(1), 37. <https://doi.org/10.22219/mej.v4i1.11469>
- Susilowati, R., & Julkarnain, M. (2022). Pengembangan applet GeoGebra pada materi distribusi peluang khusus [Development of a GeoGebra applet on the special probability distribution material]. *JINTEKS (Jurnal Informatika Teknologi Dan Sains)*, 4(4), 346–352. <https://doi.org/10.51401/jinteks.v4i4.2044>
- Sutopo, N. A., & Ratu, N. (2022). Pengembangan media pembelajaran geogebra classroom sebagai penguatan pemahaman konsep materi translasi siswa SMP kelas IX [Development of GeoGebra Classroom learning media to strengthen the understanding of translation material concepts for grade 9 junior high school students]. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, 06(01), 10–23. <https://doi.org/10.31004/cendekia.v6i1.971>
- Takači, D., Stankov, G., & Milanovic, I. (2015). Efficiency of learning environment using GeoGebra when calculus contents are learned in collaborative groups. *Computers and Education*, 82, 421–431. <https://doi.org/10.1016/j.compedu.2014.12.002>
- Tasman, F., & Ahmad, D. (2017). Pemahaman mahasiswa terhadap integral sebagai anti turunan, suatu desain riset pada kalkulus integral [Students' understanding of integrals as antiderivatives, a research design in integral calculus]. *JURNAL EKSAKTA PENDIDIKAN (JEP)*, 1(1), 9–16. <https://doi.org/10.24036/jep/vol1-iss1/28>
- Tatar, E., & Zengin, Y. (2016). Conceptual Understanding of Definite Integral with GeoGebra. *Computers in the Schools*, 33(2), 120–132. <https://doi.org/10.1080/07380569.2016.1177480>
- Triana Safitri, S., Darminto, B. P., & Purwaningsih, W. I. (2023). Pengembangan media pembelajaran matematika berbasis web berbantuan Geogebra untuk meningkatkan pemahaman konsep siswa SMP [Development of web-based mathematics learning media assisted by GeoGebra to improve junior high school students' conceptual understanding]. *Jurnal Gammath*, 08(01), 39–46. <https://doi.org/10.32528/gammath.v8i1.276>
- Usman, Aiyub, & M. Hasbi. (2025). Students' conceptual understanding of limit of functions reviewed from mathematical beliefs. *Jurnal Elemen*, 11(3), 515–532. <https://doi.org/10.29408/jel.v11i3.29144>
- Uwurukundo, M. S., Maniraho, J. F., & Tusiime, M. (2020). GeoGebra integration and effectiveness in the teaching and learning of mathematics in secondary schools: A review of literature. *African Journal of Educational Studies in Mathematics and Sciences*, 16(1), 1–13. <https://doi.org/https://doi.org/10.4314/ajesms.v16i1.1>
- Varberg, D., Purcell, E., & Rigdon, S. (2006). *Calculus (Ninth)*. Prentice Hall.
- Yorganci, S. (2018). A study on the views of graduate students on the use of Geogebra in mathematics teaching. *European Journal of Education Studies*, 4(8), 63–78. <https://doi.org/10.5281/zenodo.1272935>
- Ziatdinov, R., & Valles, J. R. (2022). Synthesis of modeling, visualization, and programming in GeoGebra as an effective approach for teaching and learning STEM topics. *Mathematics*, 10(3), 1–16. <https://doi.org/10.3390/math10030398>