Jurnal Gantang IX (2) (2024): 229-242

JURNAL GANTANG

e-ISSN: 2548-5547
p-ISSN: 2503-0671

http://ojs.umrah.ac.id/index.php/gantang/index

# Development of an interactive E-Module based on realistic mathematics education (RME) to enhance students' mathematical reasoning skills on parallel lines and angles

**Scristia[1], Tatang Herman[1]*, M. Nuur'aini Sholihat[2], Novita Sari[3]**

[1]Universitas Pendidikan Indonesia, Bandung, Jawa Barat, 40154, Indonesia
[2]Universitas Sebelas April, Sumedang, Jawa Barat, Indonesia
[3]Universitas Islam Nusantara Al-Azhaar Lubuklinggau, Sumatera Selatan, Indonesia
*Corresponding Author: tatangherman@upi.edu

Submission: December 1st, 2024; Accepted: December 24th, 2024; Published: December 31st, 2024
DOI: https://doi.org/10.31629/jg.v9i2.7629

**Abstract**

This study aimed to develop an interactive e-module based on the RME approach, focusing on parallel lines and angles. The e-module was designed using a development studies approach with two main stages: preliminary and formative evaluation. These included self-evaluation, expert review, one-to-one trials, small group trials, and field tests. Data were collected through validation sheets, student response questionnaires, pretests, and posttests. The e-module was deemed valid and practical, with average validation scores from experts and students of 4.4 and 4.89, respectively. Furthermore, the effectiveness of the e-module was measured using T-Test and N-Gain analysis, which showed a significant improvement of 38% in students' mathematical reasoning skills. The findings demonstrate that the RME-based interactive e-module is an effective teaching tool for enhancing mathematical reasoning skills, particularly on parallel lines and angles. This e-module provides an alternative solution for teachers to facilitate interactive, context-based, and independent learning, aligning with the demands of 21st-century education. Future research could explore integrating virtual laboratories or GeoGebra software into the e-module and applying it to other mathematical topics, such as angles in polygons.

*Keywords*: interactive e-module; mathematical reasoning; parallel lines and angles; RME

**How to cite:** Scristia, Herman, T., Sholihat M. N., & Sari, N., (2024). Development of an interactive E-Module based on realistic mathematics education (RME) to enhance students' mathematical reasoning skills on parallel lines and angles. *Jurnal Gantang*, *9*(2), 229 – 242. https://doi.org/10.31629/jg.v9i2.7629

## I. Introduction

Mathematics education has seen major changes with the rise of digital technology. This shift has made learning easier and more engaging for students while preparing them to navigate the challenges of a rapidly evolving, interconnected world. By integrating technology into education, students can develop essential skills like critical thinking and problem-solving, which are crucial for success in the Industry 4.0 era. Among these, mathematical reasoning is a vital skill that helps students think logically, understand problems, and find systematic solutions (Habibi & Suparman, 2020; Jeannotte & Kieran, 2017; Reiss et al., 2008).

Despite these advancements, many Indonesian students still struggle with mathematical reasoning. According to the Program for International Student Assessment (PISA), Indonesia ranks lower in mathematical literacy than other countries. This indicates that Indonesian students possess relatively weak mathematical reasoning abilities. These findings are consistent with previous research, revealing that Indonesian students struggle to develop mathematical reasoning skills (Cook et al., 2023; Sari et al., 2020; Scristia et al., 2023). This reflects a gap in students' ability to reason mathematically, often due to outdated teaching methods that fail to connect mathematics to real-life contexts. Additionally, there is a lack of engaging and contextual learning materials (Bal & Seckin Kapucu, 2022). These challenges make it hard for students to understand abstract mathematical concepts and apply logical thinking to solve problems.

Mathematical reasoning is not just about solving problems; it is about identifying patterns, understanding relationships, and building deeper insights into our world. Furthermore, Hendriana et al, (2018) stated that mathematical reasoning is an essential thinking pattern for solving problems, drawing conclusions, and generating new statements based on existing information. For example, reasoning allows students to see how numbers and shapes relate to the real world, form hypotheses, and validate their ideas through logical proof. This process strengthens their understanding and builds a foundation for lifelong learning in mathematics (Hanna, 2000; Stylianides, 2007; The National Council of Teachers of Mathematics, 2000).

One effective approach is Realistic Mathematics Education (RME), which emphasizes using real-world contexts to teach mathematical concepts, making learning more meaningful for students (Bal & Seckin Kapucu, 2022; Dinglasan et al., 2023). Using real-world contexts aligns well with the challenges posed by students' low achievement in mathematical reasoning. Students often find abstract mathematical concepts difficult to grasp, which can hinder their ability to reason mathematically. By embedding these concepts within familiar and tangible contexts, RME reduces cognitive load and helps students see the relevance of mathematics in everyday life, thereby fostering a deeper understanding and better reasoning skills.

Research supports the effectiveness of RME in improving mathematical reasoning. For example, (Saleh et al., 2018) demonstrated that students taught using RME significantly enhanced their ability to construct logical arguments and justify their solutions. Similarly, Heriyadi and Prahmana (2020) highlighted that RME's emphasis on real-world scenarios enables students to approach problems systematically and engage more actively in learning. Such findings underscore the potential of RME to address the persistent issue of low achievement in mathematical reasoning, offering both a theoretical and practical foundation for enhancing students' skills in this critical area.

Teaching materials have become increasingly important in the learning process in the digital era. As a form of digital teaching material, E-modules provide flexibility for students to learn independently and interactively. Then, E-modules designed with the RME approach can help students understand mathematical concepts within real-world contexts and develop their reasoning skills (Aulia & Prahmana, 2022). Although prior studies have developed RME-based e-modules for various mathematical topics (Aulia & Prahmana, 2022; Farida et al., 2022; Putri et al., 2020), few have focused on parallel lines and angles and their role in mathematical reasoning. While previous research has extensively explored mathematical reasoning, such as the reasoning types used in proofs and descriptive reasoning abilities, the limited focus has been on tools to enhance reasoning skills. Research specifically utilizing RME-based e-modules to facilitate reasoning and meet the "Reasoning and Proof" standard set by NCTM remains scarce.

Previous studies have shown that the RME approach effectively enhances students' mathematical reasoning skills. For instance, (Heriyadi and Prahmana, 2020) found that students taught using RME demonstrated significantly improved reasoning abilities compared to those taught using conventional methods. Similarly, (Hilaliyah et al., 2019) highlighted that using real-world contexts in RME helped students better understand mathematical concepts and develop reasoning skills.

However, while ample research exists on RME in mathematics education, studies developing interactive RME-based e-modules for parallel lines and angles are limited. Most prior research has focused on other mathematical topics, such as numbers and algebra (Sudarman & Vahlia, 2019; Zakiyah et al., 2019). Based on a literature review, several research gaps need to be addressed. First, despite the proven effectiveness of RME, few studies have integrated it into interactive e-modules for parallel lines and angles. Second, previous research has primarily focused on improving general mathematical understanding, with limited attention to enhancing reasoning skills in this specific topic. Third, there is a growing need for interactive and contextual digital teaching materials to support learning in the digital era. However, the development of e-modules meeting these needs remains limited (Aulia & Prahmana, 2022; Zakiyah et al., 2019).

This study aims to develop an interactive e-module based on the Realistic Mathematics Education (RME) approach for parallel lines and angles that is valid, practical, and effective in enhancing the mathematical reasoning skills of eighth-grade students. Specifically, the objectives of this study are: (1) To design an interactive RME-based e-module aligned with the curriculum and students' needs; (2) To test the validity and practicality of the developed e-module through expert validation and student trials; and (3) To measure the effectiveness of the e-module in improving students' mathematical reasoning skills through pretests and posttests.

This research is expected to provide significant theoretical and practical contributions. Theoretically, it will enrich the literature on RME-based teaching materials and their use in mathematics education. The findings are expected to guide teachers in developing and using effective interactive e-modules to enhance students' reasoning skills. Moreover, the developed e-module can serve as an alternative teaching material for online learning, supporting adaptation to changes and challenges in digital-era education. This study also aims to address the low levels of mathematical reasoning skills among Indonesian students, contributing to overall improvements in mathematics education quality. Therefore, the development of this RME-based interactive e-module is anticipated to significantly impact students' mathematical skills and prepare them to face future challenges.

## II. Research Methods

This study applied a design research method in the form of development studies, which consisted of two main stages: preliminary and formative evaluation. These stages included self-evaluation, expert review, one-to-one trials, small-group trials, and field tests (Tessmer, 1998). Figure 1 illustrates the development flow of the e-module.

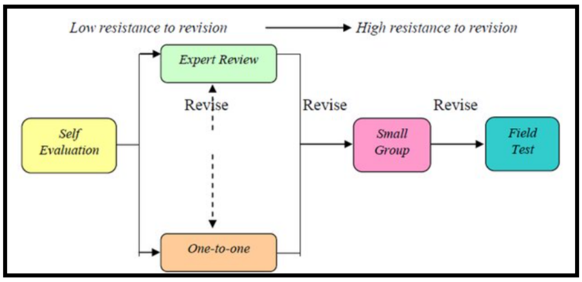

Figure 1. Formative evaluation design flow

This research was conducted during the second semester of the 2023/2024 academic year at SMP Negeri 3 Lubuklinggau, involving two groups of subjects: 35 students from class VII.1 (10 male and 25 female students) and 8 students from class VII.2 (4 male and 4 female students).

The data collection instruments included validation sheets for content and media experts, student feedback questionnaires, pretest questions, and posttest questions. The validation sheets assessed the e-module's validity, while the student feedback questionnaires gathered responses regarding students' experiences after using it. The pretest and posttest questions were designed to measure the potential impact of the e-module on improving students' mathematical reasoning skills.

The e-module was deemed valid and practical if the average score met at least the "good" criteria. To evaluate the product's potential impact, the pretest and posttest scores of students' mathematical reasoning abilities were analyzed using the T-Test and N-Gain test with Ms. Excel and SPSS v.26. The analysis employed the Paired Sample T-Test, which examines the effects of a specific intervention on the same group at two different points in time. The e-module was considered to have a significant impact if the Paired Sample T-Test result was less than 0.05, indicating a meaningful difference between the average pretest and posttest scores before and after using the e-module. Another indicator of its effectiveness was an improvement in students' mathematical reasoning skills, as reflected by an N-Gain score of at least 0.3, which is categorized as moderate (Bao, 2006; Hake, 1998): $g \geq 0{,}70$ (tinggi); $0{,}30 \leq g < 0{,}70$ (sedang); and $g < 0{,}30$ (rendah).

## III. Results and Discussion

### Result

This study consists of two main stages: the preliminary stage and the formative evaluation stage. Below is a description of each stage.

### Preliminary Stage

This stage begins with an analysis, followed by a product's design based on the needs analysis results. During the analysis phase, the researcher conducted various activities, such as curriculum analysis, student characteristic analysis, and teaching material analysis. These analyses were based on interviews with teachers and student observation sheets.

The needs analysis revealed several key points: (1) SMP Negeri 3 Lubuklinggau uses the Kurikulum Merdeka; (2) the lesson plans (RPP) used by teachers align with the Kurikulum Merdeka and develop learning materials based on Core Competencies, Basic Competencies, and Achievement Indicators; (3) students' mathematical reasoning abilities need improvement; (4) the current teaching materials used by teachers are not effective in enhancing students' mathematical reasoning; (5) teachers require teaching materials that actively involve students in the learning process to reduce teacher-centeredness, enabling students to become more independent; and (6) based on student characteristics, teaching materials accessible via smartphones and self-learning-friendly, such as e-modules, are needed to facilitate learning and increase interactivity when studying parallel lines and angles.

Based on observations and coordination with mathematics teachers, class VII.2 students were selected as test subjects for the one-to-one and small group stages, while class VII.1 students, consisting of 35 students with varying levels of ability, were chosen as test subjects for the field test stage. The researcher then designed solutions for the issues identified during the analysis. An e-module based on Realistic Mathematics Education (RME) and oriented toward improving students' mathematical reasoning skills was designed for the topic of parallel lines and angles in grade VII. The e-module includes content, mind mapping, learning trajectories, learning objectives, prerequisite materials, interactive student activities, interactive worksheets, and assessments to measure student understanding. Additionally, research instruments were designed, such as content expert validation sheets, media expert validation sheets, student response questionnaires, and pretest and posttest questions.

## Formative Evaluation

At this stage, the researcher carried out several sequential steps, including self-evaluation, expert review, one-to-one, small group, and field tests.

## Self-Evaluation

The researcher assessed the e-module and research instruments regarding content, structure, and language in this phase. Based on the self-evaluation, several significant changes were made. Improvements included adding prerequisite materials that students need to master, adding instructional videos to assist students struggling with prerequisite materials, and revising activities to become interactive using Articulate Storyline software. The results of this self-evaluation phase were referred to as Prototype 1.

## Expert Review

During the expert review phase, the process began with validating the research instruments, followed by product validation of Prototype 1. The validated research instruments included both non-test and test instruments. The non-test instruments validated consisted of content expert validation sheets, media expert validation sheets, and student response questionnaires. The reviewers for non-test instruments were Muhammad Rizal Usman, M.Pd., a Mathematics Education lecturer at Makassar University (February 26, 2024), and Elika Kurniadi, M.Sc., a Mathematics Education lecturer at Sriwijaya University (February 27, 2024). Validation was conducted online via Zoom and email. The evaluation results indicated that the instruments were valid in content, structure, and language, concluding that they were usable with revisions.

The validated test instruments consisted of pretest and posttest questions, each containing five essay questions. Validation was conducted by Dr. Meryansumayeka, M.Sc., and Weni Dwi Pratiwi, M.Pd., Mathematics Education lecturers at Sriwijaya University. Validation was conducted online via WhatsApp and email. The validation results showed that both pretest and posttest questions were usable with revisions. After revisions, the pretest and posttest questions were piloted on 17 students outside the research class on May 6, 2024. The pilot results were analyzed using IBM SPSS Statistics 32, with pretest validity results in Table 1.

Table 1. Pretehsenst results

| N | r table | r count | | | | |
|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q5 |
| **17** | 0.532 | 0.553 | 0.553 | 0.539 | 0.740 | 0.649 |

Table 1 shows that questions 1 to 5 are valid because the r count exceeds the r table (Mohsen, 2011). The pretest reliability test yielded a Cronbach's alpha value of 0.871, indicating that the pretest questions are reliable (0.871 > 0.6). Similarly, posttest validity testing was conducted, with results shown in Table 2.

Table 2. Posttest results

| N | r table | r count | | | | |
|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q5 |
| **17** | 0.532 | 0.543 | 0.533 | 0.647 | 0.623 | 0.623 |

Table 2 indicates that questions 1 to 5 are valid because the r count exceeds the r table (Mohsen, 2011). The reliability test for the posttest yielded a Cronbach's alpha value of 0.812, confirming reliability (0.812 > 0.6).

Subsequently, the researcher conducted validation of the e-module on Prototype 1 that had been previously developed, and it was then submitted to experts for validation. Content experts and media experts carried out the e-module validation. The content validators in this study were Syaiful Hamzah Nasution, M.Pd., a Mathematics Education lecturer at Universitas Negeri Malang, on April 22, 2024, and David, M.Pd., a middle school mathematics teacher, on April 23, 2024.

The media validator was Dr. Meryansumayeka, M.Sc., a lecturer in instructional media at the Mathematics Education program of Universitas Sriwijaya, who conducted the validation process on April 27, 2024. The e-module validation was conducted both in person and via the WhatsApp online platform. The results of the validation by the content experts, including comments and suggestions, are presented in Table 3.

Table 3. Suggestions and feedback from content experts

| **Suggestions for Improvement** |
|---|
| Validator 1 |
| ▪ **Conclusion slide on Opposite Angles**: The notation in the red circle indicates an angle. It is recommended that the symbol for angle measurement (m in front) be included. Angles and angle measurements are different. Angle measurements use the equals sign, while angles use the congruence sign.<br>▪ **Slide on Opposite Angles:** Provide activities for students to demonstrate that opposite angles are equal, such as manually tracing, cutting, and pasting angles.<br>▪ **Transversal Line Section:** Ensure it is shown that the transversal line does not intersect at two points on lines m and n, and observe how students respond.<br>▪ Clearly define acute angles as less than 90° or between 0° and 90°.<br>▪ Use GeoGebra and insert it into the Articulate Storyline to illustrate the conditions of two intersecting or parallel lines.<br>▪ Clearly distinguish between line segments, lines, and rays.<br>▪ Differences between angle points and vertices can confuse middle school students.<br>▪ Pay attention to the angles formed by a transversal line on two non-parallel lines. In English, they are called "corresponding angles," while in Indonesia, they are referred to as sudut sehadap. The condition of corresponding angles remains valid for non-parallel lines, but the difference with parallel lines lies in their measurements. According to the theorem, if l // m, then $m\angle A = m\angle B$. |
| **Validator 2** |
| ▪ **Context of Daily Life:** The daily life problems used are too complex for grade VII middle school students. Consider using examples like road intersections or railway tracks that show angles formed by two parallel lines and a transversal.<br>▪ **Activities on Angles Formed by a Transversal**: For manual activities, use paper, scissors, and glue. For instance, angle A1 can be traced using plain paper, cut, and pasted on angle B1, showing that A1 and B1 are equal, referred to as *sudut sehadap* (corresponding angles). The same applies to opposite angles. These activities can be converted into virtual activities.<br>▪ **Virtual Activities:** Create manual activities in virtual form to ensure the e-module effectively demonstrates technology utilization.<br>▪ **Measuring Angles**: Add materials about measuring angles using rays. For example, provide patterns to illustrate how the sum of angles divided by a ray works.<br>▪ **Prerequisite Materials:** Add prerequisite materials about the relationships between two lines (intersecting, parallel, and coinciding). |

Meanwhile, Table 4 presents the results of the media expert validation, including comments and suggestions.

Table 4. Comments and suggestions from media experts

| **Dr. Meryansumayeka, M.Sc.** |
|---|
| ▪ The source of the video used from YouTube must be included.<br>▪ The activity for discovering opposite angles should be interactive, allowing students to fill in step-by-step proofs.<br>▪ Many arrows at the bottom are still locked, preventing transitions to the next slide.<br>▪ The sound in the video has not yet appeared.<br>▪ The researcher should record the results of students' work in the evaluation section.<br>▪ Add animated images to enhance the appearance of the e-module. |

After completing the product validation, the researcher made revisions based on feedback and suggestions from content and media experts. Some of the revisions can be seen in the following images. The learning activities (materials) section improvements included adding explanations and statements encouraging students to think critically and reason, as shown in Figure 2.

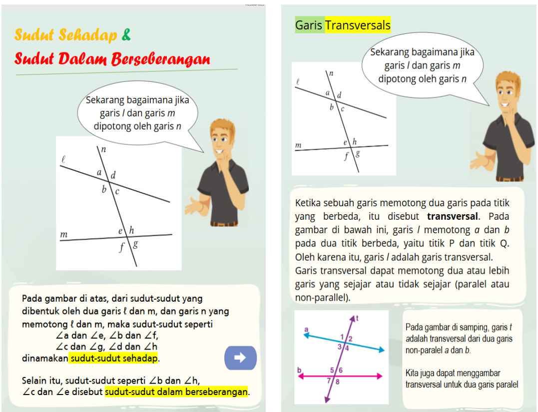

Figure 2. Before revision (left) and after revision (right)

Revisions were also made to the context used, replacing the railroad context with an activity where students are invited to engage in interactive tasks to solve the given problem, as shown in Figure 3 below.

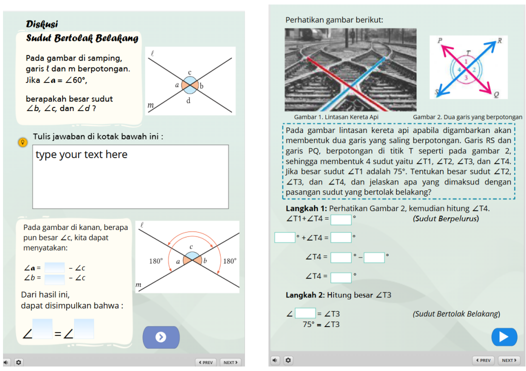

Figure 3. Before revision (left) and after revision (right)

Meanwhile, improvements to the media included adding instructions for each activity that students must complete, as shown in Figure 4 below.

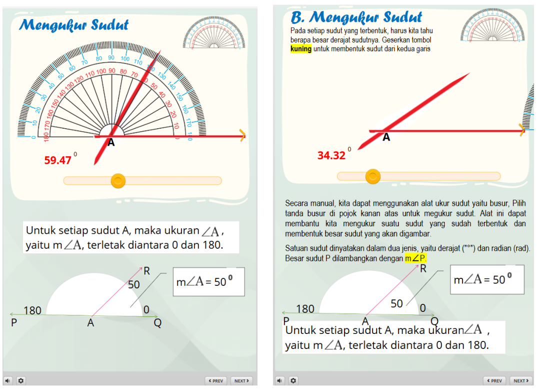

Figure 4. Before revision (left) and after revision (right)

## One-to-One

During the one-to-one stage, the product was tested on two students from class VII.3 at SMP Negeri 3 Lubuklinggau, who had diverse abilities. This activity was conducted on May 4, 2024. The purpose was to obtain general feedback from students regarding the learning activities within the e-module. Comments and suggestions from students at this stage did not indicate significant changes. Therefore, the researcher decided to proceed to the small group stage. During the one-to-one stage, students' activities were carried out following the instructions provided by the researcher via WhatsApp. The implementation of the one-to-one activities is shown in Figure 5.

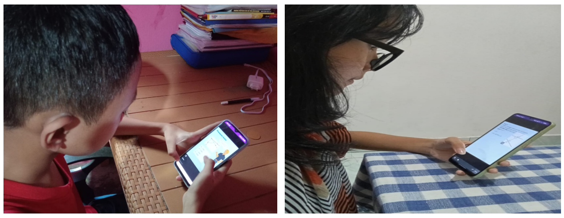
Figure 5. Students participating in the one-to-one stage

## Small Group

At this stage, Prototype 2 was tested on six students from class VII.2 at SMP Negeri 3 Lubuklinggau. The small group activities were conducted on May 7, 2024. During this stage, students were asked to use the e-module. The purpose was to observe students' responses to the practicality of the e-module before it was tested on a larger scale. The results of the student's responses are shown in Table 5.

Table 5. Scores of student responses in the small group stage

| Student | Score | Criteria |
|---|---|---|
| S1 | 89 | Good |
| S2 | 85 | Good |
| S3 | 82 | Good |
| S4 | 78 | Fair |
| S5 | 80 | Good |
| S6 | 82 | Good |
| **Total Score** | 496 | - |
| **Average Score** | 82,67 | Good |

Based on the student response scores in Table 5, the average score obtained was 82.67, categorized as good. This indicates that the RME-based e-module is considered practical. At this stage, students were also asked to provide comments as input for improving Prototype 2 before it was tested in the field test stage. The comments and suggestions from students during the small group stage are presented in Table 6.

Table 6. Comments and suggestions from small group

| Comments and Suggestions |
|---|
| ▪ The system marked incorrect answers as wrong, even though the correct answers were given. |
| ▪ Learned a lot about angles through this e-module, making it easier to understand. |
| ▪ The e-module did not explain acute, right, and obtuse angles; only videos were provided. |
| ▪ The section for filling out opposite angles was confusing, as there were no instructions on where to input the answers. |
| ▪ Seeing the protractor that can measure angles and movable lines made it more interesting and engaging. |
| ▪ When dragging corresponding angles, I was confused about where to click, as no instructions were provided. |

Significant improvements were made to Prototype 2 based on the comments and suggestions from students during the small group stage. These included adding instructions for each activity, providing explanations about types of angles, revising correct answers in the evaluation questions, and ensuring that all buttons function interactively for students. The revised prototype at this stage was referred to as Prototype 3. The next step involved testing Prototype 3 in the field test stage to examine the potential effects of the e-module on students' mathematical reasoning skills. The implementation of the small group stage is shown in Figure 6.

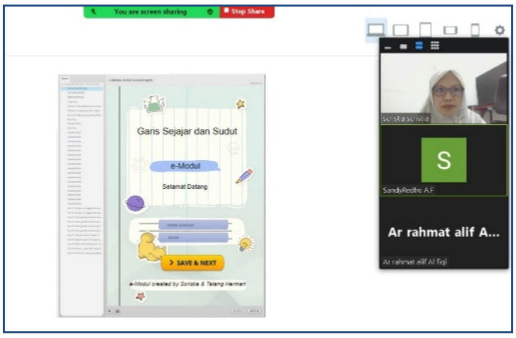


Figure 6. Discussion activities with the small group regarding feedback and suggestions for e-module improvements

**Field Test**

Prototype 3 of the e-module was tested during the field test stage on class VII.1 students at SMP Negeri 3 Lubuklinggau, who were the research subjects. The teacher conducted the learning activities using the e-module in class VII.1, which consisted of 35 students. In the first meeting, the researcher provided a pretest to assess students' mathematical reasoning skills before using the e-module. The pretest consisted of five essay questions.

For two subsequent meetings, the class VII.1 students used the e-module to study the topic of parallel lines and angles. The teacher recorded the learning activities to ensure no steps in the e-module were skipped, starting with prerequisite materials. As an introduction, the learning began with presenting a context in which students observed problems related to parallel and intersecting lines. Then, they used models from the problems to represent them mathematically. Students were asked to write down the solutions and ideas they derived through construction. Interactivity was present within the e-module and in the classroom, where students discussed with their peers and teachers whenever they faced difficulties. Finally, using connections, students could relate the material they had learned. This teaching approach aligns with the principles of RME developed by De Lange (van den Heuvel-Panhuizen, 2020).

In the fourth meeting, the researcher administered a posttest to evaluate the students' reasoning skills after using the e-module during the learning process. Students were also asked to complete a questionnaire regarding their responses to the e-module. The questionnaire results from class VII.1 students indicated a high level of e-module practicality, with an average score of 87 out of 35 student responses.

Subsequently, the potential effects of the e-module on students' mathematical reasoning skills were analyzed using the T-Test and N-Gain tests. The normality test results showed a normal distribution for the pretest and posttest scores of students' mathematical reasoning skills. The results of the Paired Sample T-Test showed a significant difference between the average pretest and posttest scores. Additionally, based on the N-Gain test, there was a 38% improvement in students' mathematical reasoning skills after using the e-module. This confirms the potential of the RME-based e-module to enhance students' mathematical reasoning skills on the topic of parallel lines and angles.

**Discussion**

The findings of this study demonstrate that the e-module based on the Realistic Mathematics Education (RME) approach is valid, practical, and effective in enhancing students' mathematical reasoning skills. This aligns with the study's original objective to create an interactive and contextual learning tool that addresses students' difficulties in understanding abstract mathematical concepts. By integrating RME principles, the module contextualized these abstract concepts, making them relatable and easier to understand. The results showed a significant 38% improvement in students' mathematical reasoning abilities, as indicated by the N-Gain test. This improvement confirms the module's effectiveness in fulfilling the study's objective to enhance reasoning skills through contextualized and interactive learning.

The significant improvement in students' reasoning skills can be attributed to the RME approach, which emphasizes connecting mathematics to real-world contexts. For instance, including GeoGebra-based activities allowed students to visualize and manipulate geometric representations, fostering deeper conceptual understanding. This approach aligns with De Lange's principles of RME, which emphasize guided reinvention and active student engagement (van den Heuvel-Panhuizen, 2020; Warsito et al., 2018). Interactive elements, such as drag-and-drop tasks and instructional videos, enhanced the learning experience by encouraging active participation and self-directed exploration. The findings are consistent with previous research on the effectiveness of RME in improving mathematical reasoning skills. (Tumangger et al., 2024) Reported that RME-based interventions significantly enhance students' ability to connect mathematical concepts with real-world applications. Similarly, (Falah and Komaro, 2016; Samura et al., 2022) highlighted the role of interactive and contextual learning materials in fostering critical thinking and problem-solving skills. However, this study extends the existing literature by demonstrating the potential of RME-based e-modules specifically for parallel lines and angles. This area has received limited attention in prior research.

This study contributes to the field by addressing a specific gap: the lack of interactive e-modules designed to teach parallel lines and angles using the RME approach. Unlike traditional teaching materials that rely on rote memorization, this e-module emphasizes understanding through exploration and discovery. Integrating technology, such as GeoGebra and Articulate Storyline, adds a layer of interactivity that sets this research apart from previous studies. Additionally, the systematic validation process involving expert reviews and iterative revisions ensures the module's robustness and applicability in real classroom settings. The results of this study have broad implications for mathematics education. They underscore the importance of incorporating technology and real-world contexts into teaching materials to make learning more engaging and effective. Furthermore, the study highlights the potential of RME to address persistent challenges in mathematical reasoning, particularly in topics that students find abstract and complex.

Future research could explore the application of RME-based e-modules to other mathematical topics or grade levels to assess their generalizability. Additionally, longitudinal studies could examine the long-term impact of such modules on students' reasoning abilities and overall mathematical proficiency. Another promising avenue for future research is investigating the integration of artificial intelligence into e-modules to provide personalized feedback and adaptive learning experiences.

In conclusion, this study demonstrates that the RME-based e-module effectively enhances students' mathematical reasoning skills by addressing their conceptual difficulties and fostering active engagement. The findings support the growing evidence supporting contextual and interactive learning approaches in mathematics education. By offering a practical and innovative solution to challenges in teaching parallel lines and angles, this research paves the way for further advancements in the field.

**Understanding the Concept of Parallel and Transversal Lines**

Students' difficulties in understanding the definition of parallel and transversal lines were a major concern for the researcher in revising the e-module. For example, during an activity involving a slider to demonstrate that the distance between lines *m* and *n* remains constant, students did not recognize this as a property of parallel lines. They needed to understand that parallel lines are two lines on the same plane that never meet. An additional GeoGebra activity addressed students' difficulties in understanding parallel lines. In this activity, students used a slider to adjust the slope of the lines and observed what happens to point *C* when the slope of one line is different from the other.

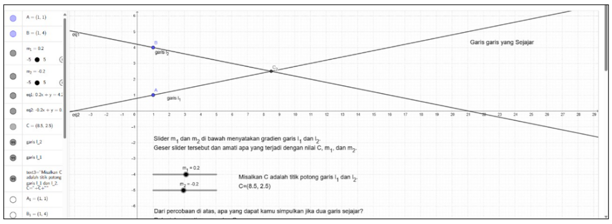

Figure 7. Student activity to understand the properties of parallel lines

Students also struggled to identify that a transversal line intersects two parallel lines at different points. The line cannot be considered a transversal if this condition is not met. This difficulty stemmed from a lack of information about the definition of a transversal. To address this issue, the e-module included additional information on the transversal slide as follows:

"*When a line intersects two lines at different points, it is called a transversal. In the diagram below, line l intersects a and b at two points, P and Q. Therefore, line l is a transversal. A transversal can intersect two or more lines, whether parallel or non-parallel."*

Another issue arose during discussions about parallel lines and angles, where students struggled to arrive at the following conclusion:

"*Line segment AB serves as a transversal to XY and PQ, and angles X and Y are corresponding angles of equal measure. Therefore, XY and PQ are parallel line segments."*

Prototype 2 was validated and deemed appropriate for use by incorporating these revisions. It was then tested during the small group stage, where six students used a student response questionnaire as the assessment tool to evaluate its practicality. The evaluation results indicated that the e-module met the criteria for practicality. After incorporating feedback from the small group stage, Prototype 3 was developed and subsequently tested during the field test stage.

In this stage, the e-module was tested with 35 students to measure its potential effect on students' mathematical reasoning abilities. The analysis showed a significant difference between pretest and posttest scores, with a 38%

improvement in students' mathematical reasoning abilities.

## IV. Conclusion

This study resulted in developing a learning tool that applies the principles of Realistic Mathematics Education (RME) as an interactive e-module focusing on parallel lines and angles. The e-module was designed for implementation with seventh-grade students at public junior high schools in Lubuklinggau City. The RME-based e-module was developed through development studies, which consisted of two main stages: initial and formative evaluation. These stages included self-evaluation, expert review, one-to-one trials, small group trials, and field tests. Validation results from five validators indicated that the RME-based learning tool achieved a high level of validity in the context of the e-module. The feasibility evaluation by users, particularly instructors, yielded an average score of 4.4, indicating that the e-module is highly feasible. Additionally, student evaluations produced an average score of 4.89, indicating high feasibility.

Based on these findings, the developed learning tool effectively facilitates mathematics learning, particularly in parallel lines and angles. The tool has demonstrated its ability to achieve students' learning objectives comprehensively, enhance student engagement during the learning process, and elicit positive student reactions regarding the learning experience. The developed tool can also be applied to teaching angles in polygons. It has shown the capacity to facilitate comprehensive learning outcomes, increase student engagement and participation, and generate positive reactions to using the e-module.

The development of the RME-based learning tool for parallel lines and angles has certain limitations. The trial was conducted on only 17 seventh-grade students from SMPN 3 Lubuklinggau. Further trials involving a larger sample size are needed to evaluate the application of the material presented in this e-module, particularly focusing on angles with a curriculum typically taught in third-grade elementary school. Another limitation lies in the selection of contexts; for SMPN 3 Lubuklinggau, the only context familiar to students was the railway station 600 meters from the school. Additional contexts that effectively illustrate the properties of opposite angles or parallel lines should be considered.

For future research, it is recommended that broader scale development and testing of mathematics learning tools be conducted. Interactive e-modules could be enhanced by directly integrating GeoGebra software and other virtual laboratory tools to allow students to perform discovery experiments. This approach could be extended to angles in polygons as a continuation of parallel lines and angles.

The effectiveness of RME-based learning tools, such as e-modules, has been highlighted in a study by (Ramadhanta et al., 2024; Samritin, 2023), which states that the RME approach improves students' reasoning skills. It enables students to understand and overcome basic mathematical challenges, engage in logic and problem-solving when encountering real-world contexts, process information, solve problems, and make logical decisions. Students also develop more efficient strategies for addressing mathematical problems. Consistent with the analysis of students' scores before and after intervention in this study, the average mathematics score improved from 80.35, indicating a 38% increase in mathematical reasoning skills after using the reasoning-oriented interactive e-module. This demonstrates a significant improvement in students' reasoning abilities following the intervention with the RME-based e-module.

**Acknowledgment**

The authors are grateful to Lembaga Pengelola Dana Pendidikan (LPDP / Indonesia Endowment Fund for Education), part of the Ministry of Finance of the Republic of Indonesia, for supporting our doctoral studies and this publication.

**Reference**

Samura, A. O., Darhim, Dadang Juandi, Arwan Mhd. Said, Karman La Nani, & Maximus Tamur. (2022). Improving the critical thinking ability of junior high school students through realistic mathematics education innovation. *AIP Conf. Proc*, *2577*. https://doi.org/https://doi.org/10.1063/5.0096077

Aulia, E. T., & Prahmana, R. C. I. (2022). Developing interactive e-module based on realistic mathematics education approach and mathematical literacy ability. *Jurnal Elemen*, *8*(1), 231–249. https://doi.org/10.29408/jel.v8i1.4569

Bal, N., & Seckin Kapucu, M. (2022). The effect of realistic mathematics education activities applied in secondary school 7th grade mathematics education on life skills development. *The Eurasia Proceedings of Educational & Social Sciences (EPESS)*.

Cook, J. P., Melhuish, K., & Uscanga, R. (2023). Reasoning productively across algebraic contexts: Students develop coordinated notions of inverse. *The Journal of Mathematical Behavior*, *72*, 101099. https://doi.org/https://doi.org/10.1016/j.jmathb.2023.101099

Dinglasan, J. K. L., Caraan, D. R. C., & Ching, D. A. (2023). Effectiveness of realistic mathematics education approach on problem-solving skills of students. *International Journal of Educational Management and Development Studies*, *4*(2), 64–87. https://doi.org/10.53378/352980

Falah, F., & Komaro, M. (2016). Penggunaan multimedia animasi untuk meningkatkan kemampuan berpikir kritis dalam pembelajaran materi bidang geser. In *Journal of Mechanical Engineering Education* (Vol. 3, Issue 2).

Farida, U., Caswita, C., & Sutiarso, S. (2022). Pengembangan bahan ajar berbasis realistic mathematics education berorientasi kemampuan berpikir kritis. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *11*(2), 1563. https://doi.org/10.24127/ajpm.v11i2.4942

Habibi, & Suparman. (2020). *Literasi matematika dalam menyambut PISA 2021 berdasarkan kecakapan abad 21*. *6*(1), 57–64. http://journal.lppmunindra.ac.id/index.php/jkpm/

Hanna, G. (2000). Proof, explanation and exploration: An overview. *Educational Studies in Mathematics*, *97*(1–4), 131–141. https://doi.org/10.1023/A

Hendriana, H., Prahmana, R. C. I., & Hidayat, W. (2018). Students' performance skills in creative mathematical reasoniNG. *Infinity Journal*, *7*(2), 83. https://doi.org/10.22460/infinity.v7i2.p83-96

Heriyadi, H., & Prahmana, R. C. I. (2020). Pengembangan lembar kegiatan siswa menggunakan pendekatan pendidikan matematika realistik. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *9*(2). https://doi.org/10.24127/ajpm.v9i2.2782

Hilaliyah, N., Sudiana, R., & Subhan Pamungkas, A. (2019). Pengembangan modul realistic mathematics education bernilai budaya Banten untuk mengembangkan kemampuan literasi matematis siswa. 2548–8546. https://doi.org/10.24815/jdm.v%vi%i.13359

Jeannotte, D., & Kieran, C. (2017). A conceptual model of mathematical reasoning for school mathematics. *Educational Studies in Mathematics*, *96*(1), 1–16. https://doi.org/10.1007/s10649-017-9761-8

Mohsen, M. A., & Balakumar, M. (2011). A review of multimedia glosses and their effects on L2 vocabulary acquisition in CALL literature. *ReCALL*, *23*(2), 135-159.

Putri, D. A., Dewi Susanti, V., & Apriandi, D. (2020). Pengembangan modul berbasis rme untuk meningkatkan kemampuan literasi matematika siswa kelas XI SMK. *Jurnal Ilmiah Kependidikan*, *1*(2), 138–

146.

Ramadhanta, S. A., Simamora, R. E., & Susanti, D. (2024). Enhancing mathematical creative thinking ability: experimentation with realistic mathematics education by embedding ice breaking in junior high school. *EDU-MAT: Jurnal Pendidikan Matematika*, *12*(1), 47. https://doi.org/10.20527/edumat.v12i1.18693

Reiss, K. M., Heinze, A., Renkl, A., & Groß, C. (2008). Reasoning and proof in geometry: Effects of a learning environment based on heuristic worked-out examples. *ZDM*, *40*(3), 455–467. https://doi.org/10.1007/s11858-008-0105-0

Saleh, M., Prahmana, R. C. I., Isa, M., & Murni. (2018). Improving the reasoning ability of elementary school students through the Indonesian realistic mathematics education. *Journal on Mathematics Education*, *9*(1), 41–53. https://doi.org/10.22342/jme.9.1.5049.41-54

Samritin. (2023). The effectiveness of RME approach to elementary school students' mathematical abilities: A meta-analysis study. *Indonesian Journal Of Educational Research and Review*, *6*(1), 176–186. https://doi.org/10.23887/ijerr.v6i1.59150

Sari, D., Hapizah, & Scristia. (2020). Analysis of student's proof construction on matrix determinants. *Journal of Physics: Conference Series*, *1480*(1). https://doi.org/10.1088/1742-6596/1480/1/012060

Scristia, S., Dasari, D., & Herman, T. (2023). Sentiment analysis of prospective mathematics teacher on reasoning and proof questions using Naïve-Bayes classification. *Jurnal Gantang*, *8*(2), 155–165. https://doi.org/10.31629/jg.v8i2.6591

Stylianides, G. J. (2007). Investigating the guidance offered to teachers in curriculum materials: The case of proof in mathematics. *International Journal of Science and Mathematics Education*, *6*(1), 191–215. https://doi.org/10.1007/s10763-007-9074-y

Sudarman, S. W., & Vahlia, I. (2019). Pengembangan bahan ajar trigonometri dengan pendekatan RME berbasis aplikasi schoology. *Jurnal Derivat: Jurnal Matematika Dan Pendidikan Matematika*, *5*(1), 9–18. https://doi.org/10.31316/j.derivat.v5i1.142

Tessmer, M. (1998). *Planning and conducting formative evaluations*. Kogan Page.

The National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics. the national council of teachers of mathematics, Inc.*

Tumangger, W. R., Khalil, I. A., & Prahmana, R. C. I. (2024). The impact of realistic mathematics education-based student worksheet for improving students' mathematical problem-solving skills. *IndoMath: Indonesia Mathematics Education*, *7*(2), 196. https://doi.org/10.30738/indomath.v7i2.122

Van den Heuvel-Panhuizen, M. (Ed.). (2020). *International Reflections on the Netherlands Didactics of Mathematics*. Springer International Publishing. https://doi.org/10.1007/978-3-030-20223-1

Warsito, Darhim, D., & Herman, T. (2018). Improving students' mathematical representational ability through RME-based progressive mathematization. *Journal of Physics: Conference Series*, *948*(1). https://doi.org/10.1088/1742-6596/948/1/012038

Zakiyah, H., Purnomo, D., PGRI Semarang, U., Kunci, K., Kontekstual, P., & Bulat, B. (2019). Pengembangan E-Modul dengan pendekatan kontekstual pada materi bilangan bulat SMP Kelas VII. *Imajiner: Jurnal Matematika dan Pendidikan Matematika*. *1*(9), 287–293.