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Development of a Microlearning-based e-Module to Improve Seventh-Grade Students' Understanding of Triangle and Quadrilateral

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Abstract: Understanding concepts in learning mathematics, especially triangles and quadrilaterals, is crucial. However, students often struggle with this material due to invalid and impractical teaching resources. This research aimed to develop valid and practical microlearning-based e-modules using a 3-D research model to improve students' understanding of triangles and quadrilaterals. Conducted at a junior high school in Sei Suka, Batu Bara Regency, North Sumatra Province, data were collected through interviews and questionnaires, utilizing instruments such as interview guides, expert validation sheets, and practicality test questionnaires. Data analysis included qualitative methods to reduce interview data and quantitative likert scale calculations. The developed e-modules were rated very valid by media and material experts and very practical by teachers. Testing on students showed that e-modules were quite practical on a small scale and very practical on a large scale. The effectiveness test revealed a significant improvement in students' understanding, with a gain score of 0.79, categorized as high. These results confirm that the microlearning-based e-module is valid, practical, and effective in enhancing students' understanding of triangles and quadrilaterals.

Keywords: E-modul, microlearning, triangle and quadrilateral.

▪ INTRODUCTION

Mathematics is fundamental in education, providing students with essential logical reasoning and problem-solving skills. Within mathematics, geometry is particularly significant due to its practical applications in engineering, architecture, and design. In the seventh grade, students are introduced to basic geometric concepts, focusing on triangles and quadrilaterals. Geometry is an outstandingly wealthy range of information, not only for its incredible differing qualities and grouping but also for its commonsense applications such as visual introductions, computer liveliness, virtual reality, and medication (within the range of therapeutic imaging, which is driven to considerable modern comes about in areas such as geometric tomography), mechanical technology, geometric demonstrating (counting plan, adjustment and the make of cars and planes, within the development of buildings, etc.) and computer-aided plan (CAD) (Viseu, 2022). Mastery of these topics is crucial, as they serve as foundational knowledge for more advanced mathematical concepts in higher grades. When students study geometry, they think analytically (Özerem, 2012). However, research indicates that students often face challenges in understanding these geometric concepts, which can hinder their overall mathematical development (Gal, 2010).

Studies have shown that students frequently struggle with visualizing and comprehending the properties and relationships of geometric shapes, leading to difficulties in solving related problems. For instance, students may find it challenging to grasp the hierarchical relationships between different types of quadrilaterals or to apply the properties of triangles in various contexts. These challenges are often attributed to

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traditional teaching methods that may not effectively engage students or facilitate deep conceptual understanding (Juman, 2022).

To address these issues, innovative instructional approaches are necessary. Integrating technology into geometry education has shown promise in enhancing students' understanding and engagement. Incorporating digital technologies into the teaching and learning process is an innovative method for teaching mathematics that encourages student motivation, fosters more significant achievement, and enhances overall performance (Mensah & Nabie, 2021; Tay & Mensah-Wonkyi, 2018). Tools such as dynamic geometry software can provide interactive and visual representations of geometric concepts, aiding in developing spatial reasoning skills. Incorporating collaborative learning strategies can encourage students to discuss and explore geometric ideas, further reinforcing their comprehension. Improving students' understanding of triangles and quadrilaterals is vital for their success in mathematics and their ability to apply geometric reasoning in real-world situations. By adopting effective teaching strategies and leveraging technological tools, educators can help students overcome learning obstacles and build a strong foundation in geometry, preparing them for future academic and professional endeavours.

One way to improve students' understanding of triangles and quadrilaterals is by enhancing the quality of their learning resources. Learning modules are an effective resource; however, traditional modules often have limitations regarding illustrations and visual appeal, which can reduce their effectiveness in conveying complex geometric concepts. To address these issues, more interactive and engaging instructional materials are necessary. According to Klančar et al. (2019), incorporating digital technologies into teaching and learning facilitates the creation of enriched learning environments by utilizing diverse digital resources and tools, including simulations, animations, and applets. Ayan and Isiksal Bostan (2016) suggest that incorporating digital technologies into mathematics instruction allows students to actively and effectively tackle complex problems. Thus, developing modules integrating technology and interactive learning approaches presents a practical solution to improving students' mastery of triangle and quadrilateral topics.

Enhancing the quality of educational modules by incorporating technology transforms them into e-modules—digital versions of printed materials accessible via computers or smartphones, designed using specialized software. The use of technology in developing teaching materials that present information by combining several media such as text, images, video, or audio given to students shows many positive results. Students learn fluently through effective teaching materials by combining text-based, video, or audio media compared to retrieving data only through text-based or audio-based teaching materials (Alkhateeb & Al-Duwairi, 2019). Therefore, developing e-modules that integrate such technological tools is expected to improve students' comprehension of geometric concepts, including triangles and quadrilaterals.

In today's digital era, technology plays a pivotal role in education, especially considering students are closely connected to devices like smartphones. The rapid advancement of technology has led to the proliferation of social media applications accessible via smartphones, featuring short videos, photos, and posters—elements that align with the concept of microlearning. Microlearning involves delivering specific knowledge in concise, well-structured segments, making it suitable for presentation on handheld devices, emails, and web browsers. Microlearning defines how to deliver a certain amount of knowledge and information in a short, defined, well-defined, and related chapter structure. Microcontent refers to information whose length is determined by a single topic, content that covers a single idea or concept, is accessed through a single URL, and is suitable for presentation on handheld devices, email, and web browsers (Giurgiu, 2017). Previous studies have also shown that microlearning can increase students' learning ability by up to 18% (Mohammed, Wakil, & Nawroly, 2018).

Many previous studies have developed e-modules with geometry content to enhance students' abilities in learning mathematics. However, these studies did not incorporate the concept of microlearning in developing the e-modules. For instance, a study by Murdikah et al. (2021) developed a spatial geometry e-module based on the Vee heuristic strategy. This e-module effectively trained students' mathematical representation skills, which are crucial for a deeper understanding of geometric concepts. Additionally, a study by Faizah et al. (2023) developed a geometry transformation e-module with the assistance of GeoGebra software. The results showed that this e-module was valid and practical for learning, helping students better understand the concept of geometric transformations. For this reason, the researchers want to develop a microlearning-based e-module as a renewal of previous research to improve students' understanding of triangular and quadrilateral shape material. More technically, the methods associated with these ideas are discussed in the next section.

▪ METHOD

Participants

The sample is part of the number and characteristics possessed by the population. Information obtained in-depth, detailed, and efficient about a group of individuals or not a population by only taking a small part (sample) from a population can be interpreted as a sampling technique (Sugiyono, 2019). The sampling technique used in this study is purposive sampling because the research requires explicitly subjects with specific characteristics relevant to developing and implementing the microlearning-based electronic module. The required characteristics for this study are 1) grade VII students, 2) students who have not yet studied the topic of triangles and quadrilaterals, and 3) classes that have not previously received instruction using e-modules. A brief interview was conducted with the school administration and teachers to ensure these characteristics are met. Based on the interview results, two classes were identified that meet these characteristics to serve as the control and experimental classes.

Research Design and Procedures

This Research and Development (R&D) study uses Thiagarajan's 4D development model (Thiagarajan, Semmel, Semmel, 1974) modified to 3D due to time constraints. The following are the stages of the development model used in this study.

Diagram 1. 4-D stages modification (Thiagarajan et al., 1974)

In the first stage, a defining stage was conducted to define the problems in learning, also known as the needs analysis stage. This stage consisted of four steps. The first was front-end analysis, which was done to determine the actual conditions in the school. Then, student analysis was done to see the needs of students during the learning process. These two steps were generated by interviewing students at the school. The third was task analysis, which was done to determine the basic competencies, indicators, materials, and submaterials used. The fourth was concept analysis, which identified important parts of forming a solution to overcome problems based on previous analyses.

The second stage in this research was designing a product developed to overcome student problems. This stage includes three steps, the first of which is the selection of instructional materials, which is carried out to select the type of instructional materials to be developed. The second was format selection, the step in preparing the product design based on the curriculum's core and basic competencies. It includes it in a short, concise, and precise form by the concept of microlearning. The study focuses on students' competencies relating to perimeter and area formulas for various quadrilaterals (squares, rectangles, rhombuses, parallelograms, trapezoids, kites) and triangles. Key indicators include classifying triangles, describing properties of quadrilaterals, deriving perimeter and area formulas, and solving contextual problems. By mastering these skills, students gain a deeper understanding of geometric principles and their real-life applications.

Furthermore, the last was the initial design, which was a description of the design of the teaching materials to be developed and was in the form of a cover, table of contents, basic competencies, how to use teaching materials and triangular and quadrilateral materials.

The final stage was development. This stage consists of three steps, the first of which was validation by media material experts and material experts. This validation was done to determine whether the developed materials were valid.

Instruments

The validation tool used was a Likert scale questionnaire with the following criteria: According to Bonne (2012), the Likert scale for validation consists of five criteria with corresponding scores. A score of 1 indicates "Very Suitable," a score of 2 represents "Suitable," a score of 3 signifies "Quite Suitable," a score of 4 corresponds to "Less Suitable," and a score of 5 indicates "Not Suitable." This scale is used to evaluate the suitability of an item based on respondents' opinions. The questionnaire blueprint for material expert validation covers four main aspects: material suitability, material presentation, language aspect, and usability aspect.

For the material suitability aspect, the evaluated indicators include the alignment of the material with Basic Competencies, the clarity of the formulation of learning objectives, the alignment of the material with learning indicators, and the alignment of the material with learning objectives. The assessment statements for this aspect include, "the material presented is by Basic Competencies" and "the learning objectives are formulated."

In the material presentation aspect, the evaluated indicators include the clarity of material presentation, the systematic delivery of material, the attractiveness of material presentation, and the completeness of the material. Examples of assessment statements for this aspect are 1) the material is presented clearly, 2) the material is delivered systematically or coherently, 3) the material is packaged attractively, and 4) the material presented in the media is complete. This aspect ensures that the learning material is well-structured and appealing to students.

Additionally, the language aspect plays an essential role in the questionnaire blueprint. The evaluated indicators for this aspect include adherence to EYD (Enhanced Spelling System) rules and the ease of understanding the material flow through language. The assessment statements for this aspect include, "the material writing complies with EYD rules" and "the use of language supports the ease of understanding the material flow." This ensures that the language used in the material is clear and easy for students to understand.

Lastly, the usability aspect evaluates the effectiveness of the material in supporting the learning process. The indicators for this aspect include the ability of the material to encourage student curiosity, support for independent learning, and the ability to increase student knowledge. Examples of assessment statements include: 1) The teaching materials encourage student curiosity, 2) The teaching materials support students in independently learning the triangle and quadrilateral material, and 3) The teaching materials enhance students' knowledge of triangle and quadrilateral material.

The questionnaire blueprint for material expert validation also includes teaching materials' display and content aspects and the previously mentioned aspects of material suitability, material presentation, language, and usability. For the display aspect, the evaluated indicators focus on the appropriateness of display elements, such as color selection, font type, font size, and the attractiveness and balance of the images used. Assessment statements for this aspect include: 1) The font used is appropriate and attractive, 2) The font size is suitable for the design, 3)The images used are attractive and not distracting, and 4) The image proportion follows the design. This aspect ensures that the visual elements of the teaching material enhance its appeal and clarity without causing distractions.

For the content aspect of teaching materials, the evaluated indicators include the design attractiveness, the suitability of animations, the accuracy of visual and audio presentation, and the quality of sound and video. Assessment statements for this aspect include: 1) The teaching material design is interesting, 2) The animations used in the material are easy to understand, 3) The images used in the material are accurate and appropriate, 4) the sound/audio presentation is appropriate, and 5) the video display is of good quality. These indicators ensure that the teaching material content is informative, engaging, and accessible for students.

Then, after validation by materials and media experts, design improvements were made, that was, improvements to the original design through input from materials and media experts. The last step was product testing, which helped test the practicality of the developed teaching materials. The tests carried out were teacher tests and student tests on a small scale consisting of six students in grade VII-7 and on a large scale consisting of 26 students in grade VII-1. The practicality instrument used was a likert scale. The Likert scale for practicality is categorized into five levels based on the scores (Boone, 2012). A score of 1 corresponds to the criterion "Very Suitable," indicating the highest level of practicality. A score of 2 represents "Suitable," while a score of 3 is labelled as "Quite Suitable," signifying a moderate level of practicality. A score of 4 corresponds to "Less Suitable," suggesting limited practicality, and finally, a score of 5 indicates "Not Suitable," representing the lowest level of practicality (Bonne, 2012). Based on user feedback, this scale assesses the practicality of a particular instrument or material.

The practicality test for the microlearning-based e-module is conducted using assessment items that evaluate various aspects of the module's usability and appeal. These items cover key points such as the attractiveness of the module's external appearance (cover) and content, the appropriateness of the animations used, and the ease of understanding the language. Additional items include 1) modules that can be easily used, 2) that help students learn, and 3) the appropriate writing size and type."

The assessment also considers whether "the module can be easily understood," "the overall appearance of the e-module is attractive," and whether "learning with modules is fun." These statements aim to measure the practical effectiveness of the e-module in engaging students and supporting their learning process, ensuring that the design and content meet user-friendly standards.

Last, to evaluate the effectiveness of the developed e-module, an assessment was conducted using a test instrument consisting of 4 essay questions. These questions are designed to assess students' understanding of geometry concepts through indicators of mathematical concept comprehension. The first indicator, which involves restating a concept, is assessed through question 1, where students are asked to explain the differences between a square, a rhombus, and a parallelogram regarding their sides, angles, and diagonals. Next, the second indicator, which focuses on presenting a concept in different mathematical representations, is measured through question number 2, where students are required to draw a right triangle with perpendicular sides of 9 cm and 12 cm and then calculate the length of its hypotenuse using the Pythagorean theorem.

The third indicator, which involves using, applying, and selecting specific procedures or operations, is assessed through question number 3, where students are tasked with calculating the area of a trapezoidal garden with parallel sides of 12 m and 18 m and a height of 10 m, as well as determining the length of the fence needed around the garden. Finally, the fourth indicator, which involves applying concepts or algorithms to solve problems, is assessed through question number 4, where students are asked to calculate the remaining area of triangular land after a rectangular pond is constructed in the middle. The triangle has a base of 24 m and a height of 16 m, while the pond has a length and width of 12 m and 8 m, respectively.

Data Analysis

Data analysis is an activity that is performed after collecting all respondents or data sources obtained through interviews or questionnaires. The data analysis technique used in this development research is a qualitative and quantitative descriptive analysis technique.

Qualitative descriptive analysis is a data processing technique that groupes information from the obtained data, such as input, criticism, or suggestions in the questionnaire. This data will be used to make improvements to the developed module. Qualitative descriptive analysis is a data processing technique that is carried out by systematically compiling the form of numbers and percentages regarding an object under study. According to Arikunto (2010), the validity of an e-module can be categorized based on percentage scores as follows: 1) A percentage of $80\% < V \leq 100\%$ is categorized as "Very Valid/Practical." 2) A percentage of $60\% < V \leq 80\%$ falls under the "Valid/Practical" category. 3) $40\% < V \leq 60\%$, the e-module is considered "Quite Valid/Practical." 4) $20\% < V \leq 40\%$ is categorized as "Less Valid/Practical," 5) $0\% \leq V \leq 20\%$ indicates "Not Valid/Practical." This scale is used to assess the degree of validity and practicality of the e-module based on evaluation results.

▪ RESULT AND DISSCUSSION

Define

Students' concept understanding of triangle and quadrilateral material was still very poor. This was because the teaching materials used by students in learning the material were still inadequate based on the interviews conducted with students in the front-end analysis, which was the first step of the design stage. The result was that the teaching materials used by teachers in teaching were difficult to understand because they used textbooks that did not provide a complete explanation. Then, the teacher sometimes does not provide other teaching materials besides the textbook used by the students. This aligns with research by Karalı (2022), which states that classroom teachers face significant challenges in teaching mathematics due to a lack of adequate teaching materials and resources. This insufficiency negatively impacts students' learning experiences and outcomes. In addition, teachers often ask questions without explanation, so students often have difficulty learning.

In addition, the researchers conducted a student analysis, which was the second step in the definition, to find out more about the student's needs for teaching materials that they will use to support their understanding of the concepts of triangles and flat buildings. The result was that students wanted interesting teaching materials so that they did not experience boredom during the teaching and learning activities, then they also said that they needed diverse teaching materials, which means they contain a variety of media and teaching materials that have a complete explanation. Teaching materials such as PowerPoint presentations, video clips, and activity sheets have proven to be effective tools for teaching mathematics in today's modern context. This effectiveness is linked to students' predominant learning styles and performance, reflecting how they approach and engage in the learning process (Bearneza, 2023).

The third step of the define stage was task analysis, the result of which was that the school used the 2013 curriculum in 2022, so the preparation of the teaching materials that the researchers developed guided by the core competencies, basic competencies, indicators, materials and sub-materials contained in the curriculum. Then, the last step of the define stage was the concept analysis, which produced a concept for developing teaching materials in the form of an e-module based on microlearning, taking into account the results of the previous analyses.

Design

The second stage was designing teaching materials to become valid using the analysis results in the previous stage. The first step in designing teaching materials was selecting teaching materials. Seeing the analysis results at the defined stage, the researchers chose teaching materials as an e-module that would be developed into a microlearning-based e-module. The next step was format selection. The format used in the teaching materials developed was by the core competencies and basic competencies in the curriculum and contained microlearning-based so that the material was presented in a short, concise, and clear format. The last step of this stage was the initial design. The initial design of this teaching material consists of a cover, table of contents, a brief introduction to core competencies and basic competencies, how to use module, triangle, and quadrilateral material, and practice questions.

Develop

The last stage was development. After the teaching materials were developed in the form of a microlearning-based e-module, material experts and media experts validated them to see the validity of the teaching materials that had been developed. The validation results from material experts indicate that the microlearning-based e-module developed in this study is of high quality. Validator 1 scored 93.85%, categorizing the module as very valid. Validators 2 and 3 each gave a score of 80%, classifying the module as valid. These results confirm that the e-module meets the required standards in terms of content and design, ensuring its effectiveness for use in teaching and learning processes.

Based on the results of the validation by material experts that have been carried out, it was found that teaching materials in the form of modules developed based on microlearning can be used with a percentage of 93.85% with very valid criteria by validator 1. He also commented that the developed module could be used for product development. Then, the results of the next validation by validator two and the mathematics teacher get a percentage of 80% with valid criteria.

Furthermore, after material experts validated the microlearning-based e-module, media experts validated it. The following presents the validation results from media experts. The validation results from media experts indicate that the microlearning-based e-module has been developed with a high-quality standard. Validator 1 provided a percentage score of 95.56%, classifying the module as very valid. Validator 2 scored 80%, categorizing it as valid. Validator 3 assessed the module with a percentage of 94.44%, also categorizing it as valid. These evaluations confirm that the e-module's media aspects, including design, usability, and functionality, are highly quality and suitable for effectively supporting the learning process.

While the validation was done by a media expert, before validator 1 gave the validation results, he gave little input in the first phase of product revision. The things that were revised were the table of contents, display of basic competencies and core competencies, consistency in the use of backgrounds and fonts, and including captions and sounds in videos. After the researcher revised according to the suggestion, the researcher showed again the revision results, which obtained validation results with a percentage of 95.56% with very valid criteria by the validator 1, and commented that the modules that have been developed can be used for product development.

Validator 2 obtained 80% of the validation results with valid criteria. She also gave some suggestions for developing this module so that it can be used and become even better. The advice from her was consistency in the background, adding voice explanations to the video, and giving different colors to something important. The results of the validation by the computer science lecturer amounted to 94.45%, with a comment saying that this microlearning-based digital module was suitable and feasible to use for learning.

The validated module can now be used for trial testing with students. Research has shown that validated modules can improve students' learning outcomes. For example, Max (in Balasundaram, 2024) conducted a randomized controlled trial to assess the impact of microlearning on students, finding that those who participated in microlearning modules had notably better learning outcomes than those who received traditional lecture-based teaching. Similarly, Eden et al. (2020) used a quasi-experimental approach to explore the effects of microlearning on students, and their findings indicated that students who engaged with microlearning modules scored significantly higher on the final exam than those who received conventional lecture-based instruction.

After getting some input from the validators, the microlearning-based e-module teaching materials were improved in several parts. The following are improvements to microlearning-based e-module teaching materials on triangle and quadrilateral materials.

1. Consistency in the Use of Backgrounds and Fonts

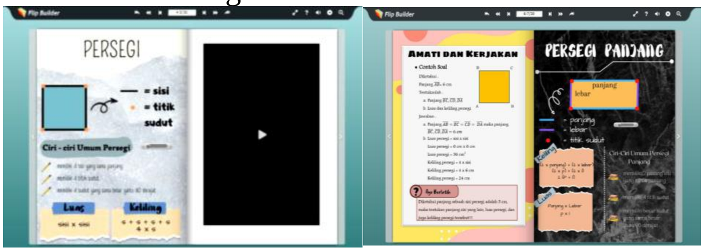

Figure 1. The background before revision

Figure 2. The background after revision

2. Writing Core Competences and Basic Competences

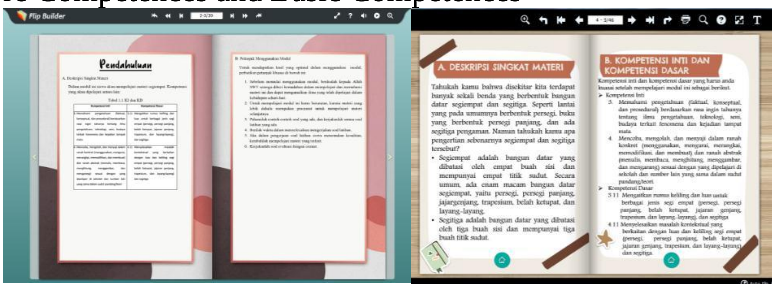

Figure 3. The core and basic competences before and after revision

3. Table of Contents

Figure 4. Table of contents before and after revision

4. Adding Video Captions and Sound

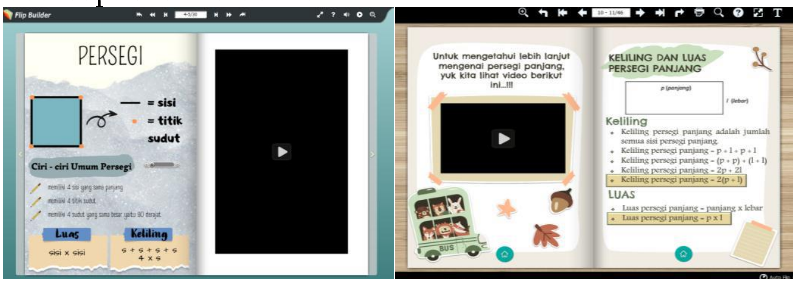

Figure 5. Video before and after revision

Practicality Test

The e-module that has been improved according to the validator's suggestions was then tested on teachers and students to see the practicality of the e-module. The following presents the results of the trial conducted with the teacher.

The results of product testing conducted with mathematics teachers indicate that the microlearning-based e-module is highly practical. Mathematics Teacher 1 scored 92.73%, while Mathematics Teacher 2 scored slightly higher 96.37%. Both evaluations classify the e-module as very practical, highlighting its ease of use, effectiveness, and potential to support teaching practices in the classroom. These results confirm the practicality of the e-module in real educational settings, particularly for teaching triangle and quadrilateral concepts.

Based on the results of the trials conducted on teachers, a percentage of 92.73% and 96.37% were obtained with very practical criteria. After the teacher trial was conducted, a small-scale trial of six students was conducted. The students' achievement percentages vary from 60% to 75%. Student A achieved the highest percentage, around 75%, followed by Student B and Student F, who scored close to 70%. Meanwhile, Student C and Student E showed the same result, approximately 65%, while Student D recorded the lowest percentage, slightly below 65%. This data indicates fluctuations in the students' achievement percentages, with relatively minor differences. Based on the results of small-scale trials, the average percentage results are 80% with practical criteria, so microlearning-based digital modules can be tested in the main grade as large-scale trials.

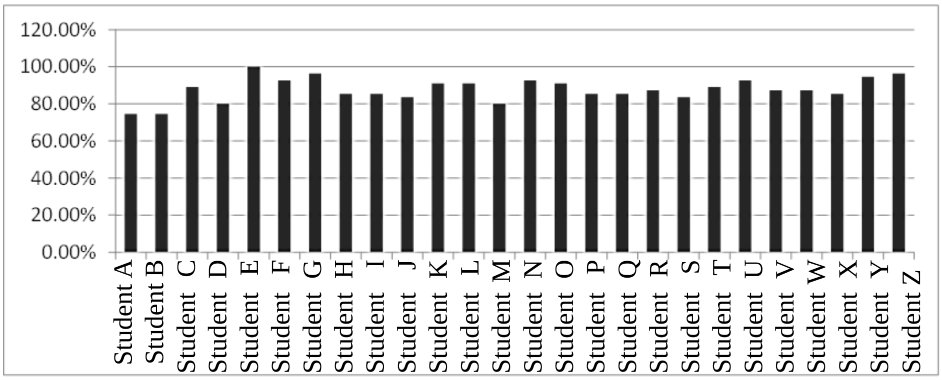

Figure 6. Large-scale trial results

Based on the large-scale trial results of the digital module tests, the percentage of results was 87.76% with very practical criteria. This means the developed e-module based on microlearning is easy to understand and use.

Based on the results of the practicality test conducted, the microlearning-based e-module to improve students' understanding of the concepts of triangle and quadrilateral for grade VII students received "practical" results in the small-scale trial and "very practical" results in the large-scale trial. Research based on these trials (Murod et al., 2021; Seprina, Sustipa, & Erita, 2022) said that practical e-module can improve student understanding. This says that a practical e-module can improve students' concept understanding of triangle and quadrilateral material.

The Effectiveness of Microlearning-based e-Module to Improve Seventh-Grade Students'

The significant increase in post-test scores reflects the effectiveness of microlearning-based e-module as a learning approach. Here is a bar chart showing the average scores of students' pre-test and post-test results for each question that has been assessed. The chart illustrates the comparison between pre-test and post-test scores, highlighting the improvement in students' understanding of the material after the intervention or learning process.

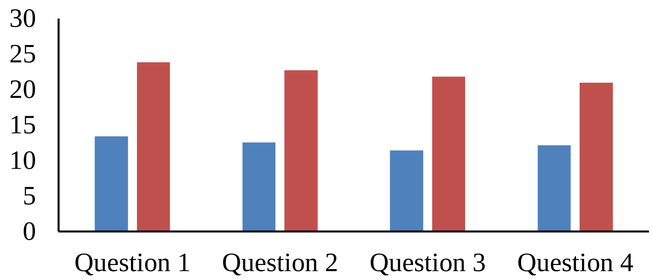

Figure 7. Effectiveness test

The bar chart comparing the pre-test and post-test results for four questions designed according to the indicators of conceptual understanding in mathematics shows a significant improvement in every indicator after using the e-module. The e-module, as an interactive learning medium, allows students to study independently with features that support a deeper understanding of concepts.

Based on the first question, students are asked to explain the differences between a square, a rhombus, and a parallelogram regarding their sides, angles, and diagonals. After using the e-module, scores increased from 13 in the pre-test to 24 in the post-test. This indicates that the materials in the e-module, designed with text, interactive images, and video explanations, helped students understand the properties of geometric shapes more clearly. A study by Çelen and Baran (2023) emphasized the importance of effective strategies in teaching basic geometric concepts to enhance students' understanding. In this case, the e-module served as an effective strategy to improve students' understanding. Similarly, Haryanti and Saputro (2016) developed a mathematics module using Flipbook Maker to enhance students' conceptual understanding of triangles, showing that such modules effectively improve conceptual understanding.

The second question required students to draw a right triangle and calculate its hypotenuse. The increase from around 13 in the pre-test to 23 in the post-test indicates that interactive visualization features in the e-module, such as animated diagrams or simulation exercises, helped students understand how to translate concepts into visual representations. A study by Ziatdinov and Valles Jr. (2022) supports that using interactive technology in learning modules enhances students' ability to visualize geometric concepts.

The third question required students to calculate the area of a trapezoidal garden and the length of fencing needed. The significant improvement from 11 in the pre-test to 22 in the post-test demonstrates that the e-module provided clear procedural guidance, such as examples and adaptive exercises, enabling students to understand mathematical procedures more effectively. This aligns with research by Sugihartini and Jayanta (2017), which developed e-modules tailored to the syllabus, showing that such modules help students better grasp mathematical procedures.

The last question asked students to calculate the remaining area of triangular land after a rectangular pond was constructed. Scores increased from around 12 in the pre-test to 21 in the post-test. This demonstrates that the e-module, which includes real-world applications of concepts, helped students connect theory with practice. According to Sinurat and Firdaus (2024), an e-module using Flip PDF improves students' understanding of mathematical concepts. The research found that the e-module was valid, practical, and effective in enhancing students' conceptual comprehension.

The effectiveness test results show a significant improvement in students' understanding after using the microlearning-based e-module. The minimum score increased from 40 (pre-test) to 72 (post-test), and the maximum score rose from 59 to 100. The average score improved from 49.58 to 89.27, with an n-gain score of 0.79, categorized as "High," indicating the e-module's effectiveness in enhancing learning outcomes. The e-module successfully improved students’ understanding of triangles and quadrilaterals, aligning with Hug's (2005) findings that microlearning enhances learning by breaking content into manageable units. Mayer's (2005) research further supports this, emphasizing multimedia's role in improving comprehension and retention through interactivity and visualization. Additionally, the e-module's design captures attention and supports independent learning, consistent with Vygotsky's constructivist theory (1978), which highlights interactive media's role in fostering exploration and understanding.

▪ CONCLUSION

The teaching materials in the form of microlearning-based e-modules that have been developed are very valid, according to media expert validators and material experts. According to teachers, microlearning-based e-modules are also very practical to use. Moreover, the modules were deemed highly practical based on practical tests conducted with students. The effectiveness test results further support these findings, showing a significant improvement in students' understanding of triangles and quadrilaterals. The pre-test scores had an average n-Gain score of 0.79, categorized as high. Thus, the microlearning-based e-module developed in this study is valid, practical, and effective in enhancing student engagement and learning outcomes.

This advancement holds significant educational implications, providing a model for leveraging technology to improve learning outcomes, particularly in foundational subjects like geometry, which serve as prerequisites for advanced mathematical concepts. Despite its advantages, the research has certain limitations. The study's implementation was restricted to a single school in a specific region, limiting the generalizability of the findings to other educational contexts or larger populations. Additionally, the research relied on a relatively small sample size for its practicality tests, which may not fully capture a broader student population's diverse learning needs and responses. The study also focused solely on geometry, leaving the potential application of microlearning-based e-modules to other subjects unexplored. Future research could expand the scope to address these limitations and explore broader applications of the findings.

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