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Design and Development of a Realistic Mathematics Education (RME)-Based E-Module on Triangle Concepts

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ABSTRACT

In training students to solve problems logically and systematically, the use of effective learning media is essential. One form of digital learning media that is increasingly relevant is the e-module. Previous studies emphasize that e-module needed in mathematics learning should be closely related to students' daily lives, as emphasized in Realistic Mathematics Education (RME). The purpose of this study was to design, produce, and evaluate an RME-based e-module on triangle concepts for junior high school students**.** The research employed the Richey and Klein Design and Development model consisting of design, production, and evaluation stages and was conducted at a junior high school in Bandung City involving expert validators and students. This study contributes by developing an RME-based e-module on triangle material that integrates contextual problems with interactive digital features, extending previous RME studies that are largely non-digital. The results show that the e-module achieved high feasibility, with expert validation reaching 90.3 percent and student responses 86.9 percent, both categorized as very feasible. These findings indicate that integrating RME into digital e-modules can enhance contextual learning and student engagement. However, this study is limited to feasibility testing in a single school, suggesting the need for further research on learning effectiveness in broader contexts.

Keywords: Design, Development, E-Module, Triangle

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Introduction

Mathematics learning is an important component in education, as it plays a significant role in shaping students' reasoning abilities and supporting learning across disciplines (Atuhurra & Kaffenberger, 2022; Clements et al., 2022; Hamim et al., 2022). Beyond its contribution to knowledge acquisition, mathematics is essential because it fosters critical and analytical thinking skills (Karenina et al., 2019; Montaku, 2011). When solving mathematical problems, students often apply analytical thinking with different characteristics and strategies. This diversity occurs because mathematics not only provides fundamental calculation skills but also trains students to solve problems logically and systematically according to their individual ways of thinking (Maqruf et al., 2023; Wijaya et al., 2023). In this context, the availability of appropriate learning media becomes a crucial factor in supporting students' ability to learn mathematics meaningfully and systematically.

In recent years, learning media have undergone a significant shift toward digital formats. The rapid development of technology has influenced the educational landscape, including mathematics education. As mathematics is a subject that underpins many fields of science and technology, its learning process must also adapt to digital innovations. Electronic learning (e-learning) is one of the innovations that enables students to access learning resources flexibly anywhere and anytime while providing opportunities for teachers to enrich learning with multimedia components (Karlimah et al., 2021). Holmes and Gardner (2006) define e-learning as online access to learning resources, regardless of time and place, highlighting its potential to expand learning opportunities (Holmes & Gardner, 2006). Similarly, Aldrich (2004) conceptualizes e-learning as the integration of processes, materials, and infrastructure through computer networks to improve the quality of learning activities, including management and distribution of teaching resources (Aldrich, 2004). Among the various forms of e-learning, electronic modules (e-module) have become increasingly popular in educational practice. An e-module is a systematically arranged set of self-learning materials, presented in electronic format, and often enriched with multimedia features such as hyperlinks, animations, videos, and audio. These features make e-module interactive and engaging, encouraging students to actively explore mathematical concepts rather than passively receiving information (Kemdikbud, 2017). E-module also provide practical benefits: they are easy to use, accessible for repeated study, and can even be monitored by parents to support students' learning at home (Setiawati et al., 2023)

Research on e-module has shown promising results across various subject areas. For example, Asrial et al. (2019), Leidel et al. (2013), and Syahrial et al. (2020) reported that e-module designed with specific educational innovations such as ethnoconstructivism principles and 3D page flip technology can enhance interactivity, improve student motivation, and increase learning outcomes in both science and mathematics (Asrial et al., 2019; Leidel et al., 2013; Syahrial et al., 2020). The integration of multimedia components makes it easier for teachers to present abstract material and for students to engage with the content more effectively. In mathematics education specifically, e-module are typically structured to include key components such as a title page, introduction, learning objectives, instructional content, exercises, evaluations, and a glossary (Fitrio & Merliza, 2023; Rohmatulloh et al., 2022; Wahyudi, 2019). These components ensure that the learning resources are systematically organized and aligned with curriculum goals. Studies further indicate that mathematics e-module can strengthen students' problem-solving abilities, encourage independence in constructing understanding, and promote higher-order thinking skills such as critical, creative, and analytical reasoning. Despite these advantages, existing mathematics e-module still present important limitations. Many of them focus primarily on the delivery of instructional content and interactive features but often lack strong connections to students' real-life experiences. As a result, the abstract nature of mathematics can remain distant from students' daily contexts, potentially reducing engagement and limiting opportunities for meaningful understanding. This limitation highlights the need for a learning approach that bridges the gap between abstract mathematical concepts and their application in everyday life (Schoenherr, 2024; Syarif & Achmad, 2020).

Realistic Mathematics Education (RME) is one such approach. Developed in the Netherlands, RME emphasizes contextualization, modeling, interactivity, progressive formalization, and conceptual understanding (Do et al., 2021; Zanten & Heuvel-Panhuizen, 2021). By embedding mathematical problems in real-life contexts, RME enables students to see mathematics as meaningful and applicable. Studies show that RME helps students understand concepts more deeply, enhances motivation, and fosters critical and analytical thinking skills (Çakıroğlu et al., 2023). When combined with digital technology, the RME approach has the potential to make mathematics learning more interactive, engaging, and effective by allowing students to visualize problems and solutions in concrete, exploratory ways (Çakıroğlu et al., 2023; Do et al., 2021).

Although RME has been widely discussed in the literature, its concrete integration into digital formats, particularly e-module, is still limited. Several studies related to RME e-module have been conducted by 'Adna et al. (2024), Napfiah & K, (2024), Palinussa et al. (2025). Previous studies have highlighted the theoretical advantages of Realistic Mathematics Education (RME) and its application in e-modules; however, few have systematically examined the design and development of interactive RME-based e-modules that explicitly promote student independence in learning. In addition, many existing mathematics e-modules remain limited in interactivity and design quality and rarely integrate realistic contexts, particularly in geometry topics. This indicates a clear research gap regarding the development of RME-based e-modules that combine contextual learning, meaningful interactivity, and learner autonomy. Responding to this gap, the present study focuses on designing and developing an RME-based e-module for triangle concepts at the junior high school level, a topic often perceived as abstract and difficult for students. The novelty of this study lies in its structured integration of RME principles into an interactive digital e-module that supports self-instruction and contextual understanding, validated systematically through expert review and student responses. This contribution not only strengthens the pedagogical integration of RME and digital learning but also provides practical implications for improving geometry instruction in junior high school mathematics.

Methods

This study employed the Design and Development (D&D) model proposed by Richey and Klein (2007), which was selected because it offers a systematic framework for developing educational products with iterative refinement. The model consists of three main stages: design, production, and evaluation, providing a structured process to ensure that the RME-based e-module on triangle material is pedagogically sound and practically usable for junior high school students (Richey & Klein, 2007). The following is a flowchart of the research process.

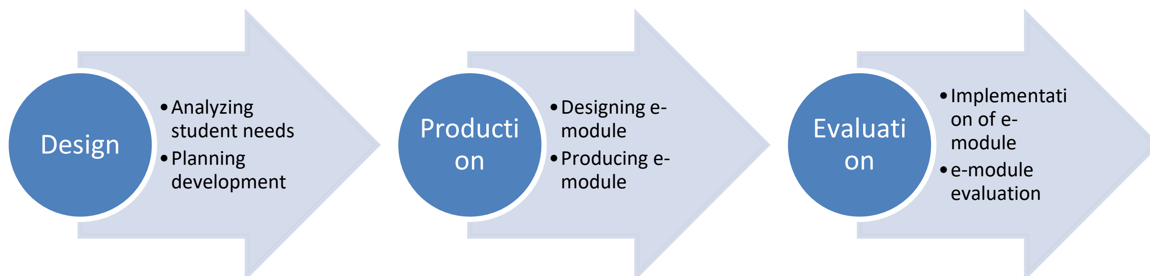

Figure 1. *The research flowchart*

In the design stage, observations and interviews with teachers and students were used to identify learning obstacles and instructional needs related to triangle material. In the production stage, an RME-based e-module was produced and evaluated using expert validation questionnaires to assess its validity. In the evaluation stage, student questionnaires were administered to examine the practicality of the e-module. Data from expert validation and student responses were analyzed using descriptive quantitative analysis to determine the validity and practicality of the developed e-module.

The study was conducted at a junior high school in Bandung City, Indonesia. The participants consisted of three experts and ten Grade VII students. The experts were selected based on their qualifications as mathematics education lecturers holding doctoral degrees and having expertise in mathematics content, instructional media, and educational assessment. The student participants were selected through purposive sampling and involved in a limited trial to evaluate the usability and practicality of the e-module.

The research instruments included expert validation questionnaires and student response questionnaires. The expert validation instrument was designed to assess the quality of the e-module in terms of content accuracy, instructional design, and media presentation. Prior to implementation, the instruments were reviewed and validated by experts to ensure content validity, clarity of items, and relevance to the research objectives. The expert validation instrument comprised statements addressing self-instruction, self-contained, user-friendly, and adaptive aspects of the e-module. The student response instrument consisted of items measuring learning aspects, usefulness, and visual appearance after using the e-module.

The measurement instrument employed a five-point Likert scale to assess participants' perceptions (Chen & Liu, 2023). The scale categories consisted of very poor (1), poor (2), fair (3), good (4), and very good (5). Participant scores were calculated using the following formula:

$$Score = \frac{Total\ Score\ Participant}{Total\ Score\ Maximum} \times 100\%$$

The following is a table of criteria for measurement results using a Likert scale:

Table 1. *Likert Scale Criteria*

Score Range	Criteria
0%-20%	Very Inappropriate
21%-40%	Inappropriate
41%-60%	Fairly appropriate
61%-80%	Appropriate
81%-100%	Very appropriate

Results

The results obtained from the implementation of the RME e-module with this triangle material are in the form of designing, producing and evaluating e-module.

1. Design

The design stage involves observing the needs of students and the schools that will be used as trial locations. The observation results obtained are:

1) Students often feel bored with conventional geometry lessons
2) Students are less interested in printed modules because they are not interactive
3) Students feel that they are not free because they learn geometry using the lecture method and explanations carried out by the teacher
4) Students lack experience using technology for learning
5) Teachers use less technology in learning
6) Teachers use conventional methods and printed modules in learning

Based on the observation results, several learning conditions were identified, including low student engagement in learning triangle concepts, limited use of contextual problems, and minimal utilization of digital learning media in mathematics instruction. These findings were used as the basis for designing an RME-based e-module on triangle material. The e-module was planned to include realistic problem situations, interactive digital features, and self-instructional components aimed at supporting student engagement and independent learning. At the design stage, the e-module was developed by translating the observation findings into specific design features. These features included the use of real-life contexts related to triangles, interactive activities to increase student interest, and flexible learning paths that allow students to study independently using digital media. In addition, the e-module was designed to support teachers by providing a technology-based learning resource that can be integrated into classroom instruction.

2. Production

At the production stage, the author tried to create an e-module by consulting an expert, namely one of the Professors of Mathematics Education at the Indonesian University of Education with the help of the Articulate Storyline 3 (AS 3) application. The resulting e-module application is programmed to be used using Android by students. Convert the AS 3 project into an Android application with the help of Website 2 APK Builder Pro.

The appearance of the e-module and explanation of the general parts of the successfully created e-module are as follows:

1) E-module Cover Page

This section includes an introduction to the e-module title, an illustration of the e-module cover and filling in the student's name to start the e-module

Figure 2. *E-Module Cover Page*

2) List of contents

This section contains outline information for the Triangle RME e-module. In this section, students can go directly to the intended page by clicking on one of the outline lists on that page.

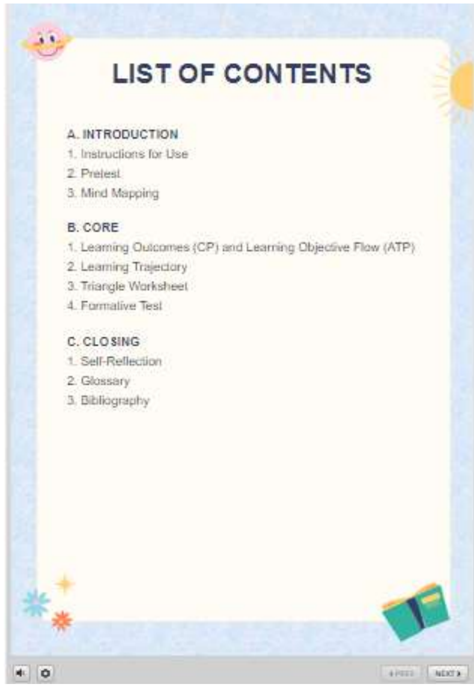

Figure 3. *Display of the E-Module Table of Contents*

3) Material

This section contains material that will be presented in the e-module. Presentation of material can be in the form of images, writing or video.

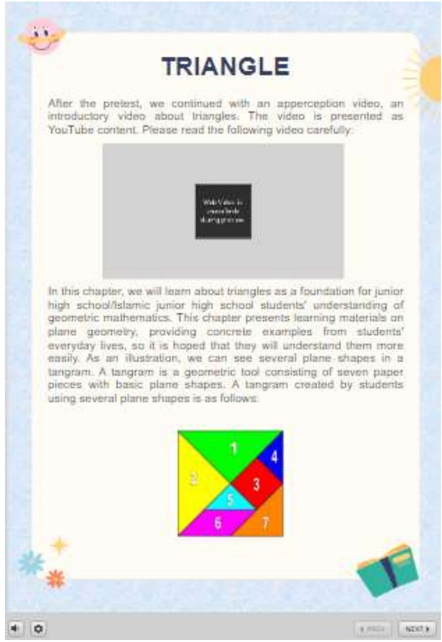

Figure 4. *Display of E-Module Material*

4) Student Worksheet

In this section, practice questions and problems related to the material are presented which students can solve by following the instructions given. Students can also check whether the results of their work are correct or not.

Figure 5. *Display of the E-Module Student Worksheet*

5) Triangle Subchapter Final Test

This section contains an evaluation test on learning outcomes regarding triangles. In this section, students fill in the answers and send the answers by clicking submit.

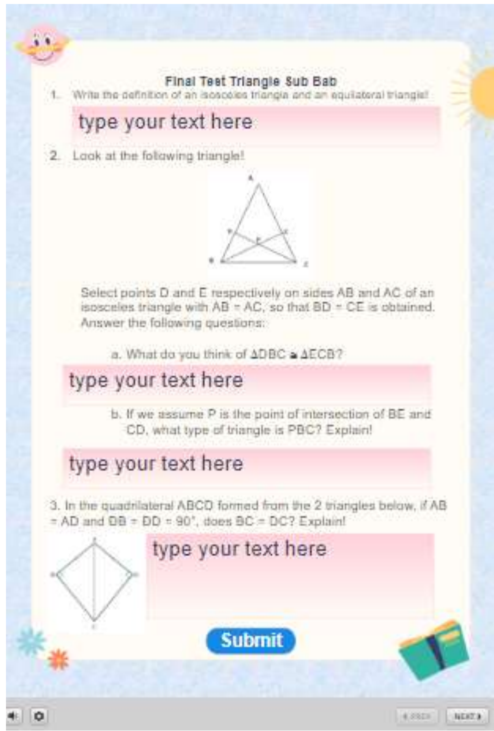

Figure 6. *Display of the E-Module Final Test*

The developed e-module consists of several structural components, including a cover page, interactive table of contents, material presentation, student worksheets, and a final test. The cover page was designed with student identity elements to personalize the learning resource. The interactive table of contents allows users to navigate flexibly between sections. The material presentation combines text, images, and videos to explain triangle concepts, while student worksheets are embedded to support learning activities. A final test is provided at the end of the e-module to assess students' understanding of the material.

At the production stage, the e-module was developed by considering expert suggestions and utilizing supporting software applications. The content and structure were adjusted to accommodate the characteristics of triangle material and to comply with standard e-module components applied in Indonesia. The production process involved organizing learning content, integrating worksheets and assessments, and converting the e-module into a digital format that can be accessed through Android devices. Expert input was used to refine content accuracy, media presentation, and usability before the e-module proceeded to the evaluation stage.

3. Evaluation

At the evaluation stage, the results obtained are in the form of e-module evaluations from experts and students. Based on the questionnaire that was filled out by experts, the evaluation results obtained were an overall criteria score of 90.3%, which means that according to the Likert scale criteria, the RME e-module with triangle material is very suitable for use by students. The details on each aspect can be seen in the following table:

Table 2. *Expert Validation Result Scores*

Aspect	Score	Category
Self-Instruction	88.8%	Very suitable
Self-Contained	90%	Very suitable
User-Friendly	82.5%	Very suitable
RME Aspects	100%	Very suitable
Overall Aspects	90.3%	Very suitable

Based on Table 2, each percentage score is obtained for all aspects of material and media expert validation. The self-instruction aspect is 88.8%, the self-contained aspect is 90%, the user-friendly aspect is 82.5%, and the RME aspect is 100%, which means that all aspects of material and media expert validation are in very suitable criteria. Meanwhile, based on responses from students, the evaluation results obtained were a criteria score of 86,9%, which means that according to the Likert scale criteria, the RME e-module with triangle material is very suitable for use by students. The details on each aspect can be seen in the following table:

Table 3. *Scores of Student Response Results*

Aspect	Score	Category
Learning	85.6%	Very suitable
Usefulness	85.1%	Very suitable
Appearance	89.9%	Very suitable
Overall Aspects	86.9%	Very suitable

Based on Table 3, each percentage score is obtained for all aspects of student responses as users. The learning aspect is 85.6%, the usefulness aspect is 85.1%, and the display aspect is 89.9%, which means that all aspects of material and media expert validation are in very suitable criteria. Apart from that, the evaluation results can also be seen from several suggestions and comments from experts and students.

Here are some suggestions and comments from experts:

Table 4. *Expert Suggestions and Comments*

Number	Suggestions and Comments
1	It is necessary to use more problems that are relevant to everyday life to attract students' interest
2	It is necessary to add captions to the images presented
3	It is necessary to add clearer instructions for the flow of problem solving
4	Use a more interesting theme

5	E-module are good enough to help teachers convey material to students and make it easier for students to understand the material
6	The RME-based Triangle e-Module is good and the data bridges students in understanding the Triangle concept

Some suggestions and comments from students as users are presented in the following table:

Table 5. *Suggestions and Comments from Students*

Number	Suggestions and Comments
1	A few obstacles and difficulties
2	There were several questions that I felt were right but wrong, it was difficult to justify the answers
3	Fun, very helpful in the learning process
4	This module can increase the willingness to learn and enthusiasm for learning
5	It just lags sometimes, fix existing bugs
6	Corrected several sentences in the question
7	Pretty cool, can be multiplayer, I hope there's a game
8	Add videos that tell you how to solve the questions in the module
9	Cannot be installed on iOS

At the evaluation stage, data were obtained from expert validation and student response questionnaires using Likert scale criteria. The results of material and media expert validation show that the self-instruction aspect achieved a score of 88.8%, the self-contained aspect 90%, the user-friendly aspect 82.5%, and the adaptive aspect 100%. All aspects were categorized as very suitable. These results indicate that the developed RME-based triangle e-module meets the required criteria in terms of content presentation, instructional structure, usability, and adaptability.

Based on student responses as users, the learning aspect obtained a score of 85.6%, the usefulness aspect 85.1%, and the display aspect 89.9%, all of which fall into the very suitable category. In addition to quantitative scores, experts and students provided qualitative suggestions, including the need to expand the range of learning materials and to improve the technological features to reduce technical errors during use. These evaluation results were used as the basis for identifying aspects of the e-module that can be refined in subsequent development stages.

Discussion

This discussion section critically examines the findings of the design, production, and evaluation stages of the RME-based triangle e-module development.

1. Design

From the results of these observations, the author designed the creation of an RME-based triangle e-module that accommodates the results of the observations with the aim that students do not feel bored, but instead become interested and gain meaningful experiences in learning mathematics using technology through e-module. This finding aligns with the essence of Realistic Mathematics Education (RME), which emphasizes meaningful learning situations, the use of real-life contexts, and the active involvement of learners in constructing mathematical knowledge (Palinussa et al., 2025; Syarif & Achmad, 2020). By situating the learning of triangles within realistic and technology-supported contexts, students are more likely to connect abstract mathematical ideas with concrete experiences, thus enhancing both engagement and understanding. Moreover, the design of an RME-based triangle e-module supports current educational demands for the integration of technology into teaching practice. One of the studies underscores that technology-enhanced mathematics learning environments improve student attitudes and learning outcomes when compared to traditional instruction (Omer et al., 2025). The present design also acknowledges the role of teachers, providing them with an innovative medium to support instruction in ways that are both pedagogically meaningful and technologically relevant. By equipping teachers with digital tools grounded in RME, this effort not only enriches classroom practice but also aligns with global calls for 21st-century skills development, particularly in terms of digital literacy and active learning (Bayley, 2022; Syarif & Achmad, 2020).

At the design stage, the author designed the production of an RME-based triangle e-module to accommodate the observation points with the aim of ensuring that students do not feel bored, are interested, have more freedom, and have experience in learning mathematics using technology using e-module. Apart from that, it also aims for teachers to use technology as a support for learning today. This is in accordance with several studies which state that with digital media students do not feel bored, are interested, have more freedom, and have experience in learning mathematics ((Fatonah & Pranata, 2022; Rukayah et al., 2022; Yamasari, 2010).

In addition, the freedom and autonomy given to students through the use of e-module mirrors the findings of prior research in self-directed learning. According to one of studies, students who learn with digital materials that allow exploration and interaction show higher problem-solving ability (Novita & Herman, 2021). Therefore, the triangle e-module is not merely a supplementary tool but a pedagogical bridge that combines the principles of RME with the affordances of educational technology. Taken together, these results and prior research suggest that the development of an RME-based triangle e-module is a timely and relevant response to the dual challenges of fostering student curiosity and enhancing teachers' capacity to integrate technology. It positions mathematics learning not as a rigid transfer of formulas, but as an engaging, contextualized, and technology-supported activity that cultivates interest, independence, and deeper conceptual understanding.

2. Production

The structural components of the developed e-module including the cover page, interactive table of contents, material presentation, student worksheets, and final test demonstrate a systematic approach to digital instructional design. The personalized cover page gives students a sense of ownership, which can strengthen motivation and engagement in digital learning environments (Chao et al., 2016). The interactive table of contents reflects principles of user-centered design, allowing flexible navigation that supports learner autonomy (Zhang et al., 2022). Meanwhile, the presentation of material through multimedia formats such as text, images, and video which emphasizes that learning is more effective when visual and verbal channels are combined (Salam, 2018). This approach is consistent with the RME perspective, which promotes the use of contextual and visual representations to bridge abstract mathematical concepts with students' real-world experiences (Çakıroğlu et al., 2023).

At the production stage, the author produces e-module by paying attention to expert advice and using supporting applications. The manufacturing process takes into account the needs that accommodate triangle materials. The parts in the e-module also take into account the module parts according to the module standards applicable in Indonesia. This is in line with the Ministry of Education in Indonesia which states that standard e-module sections will be able to optimize the material to be developed and accommodate material coverage (Kemdikbud, 2017).

In addition, the integration of student worksheets and a final subchapter test illustrates how the e-module embeds both formative and summative assessment practices. The worksheet activities not only foster active problem-solving but also allow students to check their answers instantly, aligning with formative assessment principles that encourage feedback-driven learning regulation (Palmberg et al., 2024). The summative assessment in the form of a final test validates student learning outcomes, echoing research on the importance of integrated evaluation in digital learning environments (Ali, 2024). Overall, the production process reflects a deliberate synthesis of pedagogical theory, technological tools, and RME principles. Expert consultation ensured content validity, while the use of Articulate Storyline 3 and its conversion into an Android application enhanced accessibility and practicality. These features situate the triangle RME-based e-module as an innovative and evidence-based response to the current demands of mathematics education, supporting both student-centered learning and the integration of technology in classroom practice.

3. Evaluation

At the evaluation stage, the author carried out an evaluation by paying attention to the results of the Likert scale criteria scores and suggestions from experts and students. From the evaluation stage, each percentage score was obtained for all aspects of material and media expert validation. The self-instruction aspect is 88.8%, the self-contained aspect is 90%, the user-friendly aspect is 82.5%, and the adaptive aspect is 100%, which means that all aspects of material and media expert validation are in very suitable criteria. Meanwhile, based on student responses, each percentage score was obtained for all aspects of student responses as users. The learning aspect is 85.6%, the usefulness aspect is 85.1%, and the display aspect is 89.9%, which means that all aspects of material and media expert validation are in very suitable criteria. The score results obtained mean that the implementation of the RME e-module is appropriate and suitable for use by students at school. This is in accordance with several studies which state that the RME e-module will accommodate the material presented and is suitable for use if it meets the principles of e-module creation (Hikayat et al., 2020; Syarif & Achmad, 2020). Apart from that, media that supports RME will also improve students' mathematical abilities (Umbara & Nuraeni, 2019). Furthermore, suggestions from experts and students provide information that the e-module is good and very suitable but needs a wider range of material and a more up-to-date type of e-module making technology so as to reduce errors when using the e-module. This is the author's evaluation in developing and implementing the next e-module, because expert and user evaluation will make the resulting media better and the use of the media more optimal (Evans, 2008; Tosun & Altintas, 2024).

The evaluation findings provide nuanced insight into both the strengths and areas for further development of the e-module. Expert validation scores confirm that the module adheres to RME principles and meets pedagogical and media standards, particularly in facilitating student autonomy and self-directed learning. Student feedback further emphasizes the module's capacity to engage learners and promote interest in mathematics, while also highlighting practical issues such as technological bugs, platform limitations, and the need for additional real-life problems and multimedia support. These findings resonate with prior studies indicating that while digital RME-based interventions can significantly enhance engagement and conceptual understanding, their effectiveness is contingent upon usability, content relevance, and alignment with students' cognitive and motivational needs (Hikayat et al., 2020; Umbara & Nuraeni, 2019).

The design and development of the RME-based triangle e-module demonstrate a systematic integration of design, production, and evaluation processes in line with established instructional design principles. At the design stage, the observation that students often feel bored with conventional geometry lessons and exhibit limited engagement with printed modules underscores the persistent challenge of fostering meaningful learning experiences in mathematics classrooms. By situating triangle learning within real-life contexts and integrating technology, the e-module addresses these motivational and cognitive gaps, aligning with the core principles of Realistic Mathematics Education (RME) that emphasize contextualization, active student involvement, and the bridging of abstract concepts with tangible experiences (Palinussa et al., 2025; Syarif & Achmad, 2020). The design choices such as enabling student autonomy and providing interactive digital tools reflect current pedagogical shifts toward learner-centered and technology-enhanced mathematics instruction, echoing findings from prior studies which show that digital media and contextualized tasks increase student engagement, problem-solving ability, and conceptual understanding (Fatonah & Pranata, 2022; Novita & Herman, 2021; Rukayah et al., 2022).

The production stage further illustrates the careful operationalization of these design principles into a functional e-module. Expert consultation during production not only validated content and media accuracy but also reinforced pedagogical alignment, ensuring that the e-module accommodated both cognitive and technological needs. The integration of multimedia materials, interactive worksheets, and instant feedback mechanisms reflects the dual goals of supporting formative assessment and fostering self-regulated learning, consistent with research emphasizing the importance of immediate feedback in enhancing problem-solving skills and learning motivation (Chao et al., 2016; Palmberg et al., 2024). Additionally, the technical adaptation of the e-module into an Android-compatible application demonstrates responsiveness to practical considerations, ensuring accessibility and usability in contemporary classroom environments, which aligns with the global emphasis on digital literacy and the integration of 21st-century skills in mathematics education (Bayley, 2022).

Conclusion

This study contributes to mathematics education research by demonstrating that an RME-based e-module for triangle topics can be systematically designed and validated as a feasible and pedagogically meaningful digital learning resource for junior high school students. The findings highlight that integrating realistic contexts, interactive features, and self-instructional elements within an e-module supports more engaging and contextualized geometry learning, while also providing teachers with a practical medium for technology-enhanced instruction. The novelty of this study lies in the structured integration of Realistic Mathematics Education principles into an interactive digital e-module that emphasizes learner autonomy and is specifically tailored to triangle concepts at the junior high school level. Despite these contributions, this study is limited by the small-scale trial involving a limited number of students and by its focus on feasibility rather than long-term learning outcomes. Therefore, future research is recommended to investigate the effectiveness of the developed e-module on students' conceptual understanding, problem-solving abilities, and mathematical curiosity over extended periods and across broader educational contexts, as well as to explore further refinement of adaptive and interactive features to enhance its instructional impact.

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