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Interactive e-module based on PQ4R on e-learning platform to improve conceptual understanding of 12th grade students

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Abstract. Based on an analysis conducted at the senior high school level, it was found that several students were still unable to grasp mathematical concepts effectively. One contributing factor to this issue was the lack of engaging and interactive instructional media. This study aimed to develop e-learning as a medium for mathematics instruction to improve concept comprehension among twelfth-grade students. This research followed a design-based approach using the Plomp model, which consisted of three stages: the preliminary research stage, the development stage, and the assessment stage. The subjects of the study were 12th-grade students from SMA Negeri 1 Ubud. The instruments used in this study included product validation instruments, practicality instruments, teacher and student questionnaires, as well as effectiveness instruments in the form of pre-tests and post-tests. The characteristics of the developed product included interactivity, a systematically structured learning management system, and the ability to facilitate both teachers and students in accessing learning materials and outcomes within a well-integrated system. The results indicate that the developed e-learning media is valid, practical, and effective. Further research is recommended to add Artificial Intelligence (AI) integration so that the content is more extensive.

Introduction

As a result of the covid-19 pandemic, e-learning has become a solution in schools as a means to support the continuity of online learning. Teachers tend to have limited experience in using e-learning. However, on the other hand, the demand for e-learning has increased because it offers great flexibility in the learning process, allowing students to learn independently online from their homes. Müller et al. (2021) state that even though the covid-19 pandemic has ended, e-learning remains relevant as it encourages reflection on improving teaching in face-to-face classrooms. A blended learning approach is generally effective but requires additional support to successfully integrate both technology-based teaching and pedagogy.

Mayer & Clark (2016) define e-learning is an instructional tool that can be delivered through digital devices (such as desktop computers, laptops, tablets, or smartphones) to support learning. The forms of e-learning include: (1) storing and/or transmitting learning materials electronically via external drives, cloud storage, internal or external memory, or internet servers, (2) providing content relevant to learning objectives, (3) using media elements such as text and images to convey

content, (4) employing instructional methods such as examples, practice, and feedback to support the learning process, (5) being either instructor-led (synchronous e-learning) or designed for self-study (asynchronous e-learning), (6) facilitating both synchronous student collaboration, such as in Google Meet, and asynchronous collaboration, such as in discussion boards, and (7) helping learners develop new knowledge and skills related to individual learning objectives or improving organizational performance.

Galang & Hallar (2021) state that e-learning is seen as good used by educators and learners as an effective tool to improve instruction delivery and develop knowledge acquisition skills through learning transfer, and the use of e-learning is considered the best in distance learning. Ozaydin Ozkara & Ibili (2021) states that the use of e-learning is influenced by the age of the user and the type of education, but is not influenced by the gender of the user, and also the attitude of the e-learning user tends to vary in the way they learn. Ngabiyanto et al. (2021) also stated that educators' experience in managing e-learning also affects the use of e-learning. Im (2021) stating the reasons for not using e-learning due to the low effectiveness of learning in using e-learning and also the difficulty of finding suitable e-learning content, such as compact modules learning about specific knowledge and skills, as well as in using e-learning lack of user interaction in e-learning content. Balcı et al. (2021) stating that attitude and readiness in using e-learning are the main factors that affect the effectiveness of e-learning. Faris et al. (2021) states that Moodle is one of the recommended e-learning systems to be used in schools for distance education. From some of these findings, it can be concluded that the use of e-learning has good potential to be used in learning by paying attention to: (1) the age level of the user, (2) the way the user learns, (3) the user experience of managing the appropriate e-learning content, (4) the interaction between users, and (5) the attitude and readiness of the user to adapt to the technology in e-learning.

The use of e-learning can be further supported by the presence of interactive e-learning modules (Sukendra et al., 2023). Interactive e-modules are electronic-based learning materials designed to provide direct responses and are written with the aim of enabling students to learn independently, either with or without teacher guidance. A module serves as a structured learning program for students, requiring minimal assistance from teachers to plan clear learning objectives, provide relevant learning materials, select appropriate learning tools, and conduct assessments to measure learning success.

One common issue encountered is students' lack of conceptual understanding when learning a topic. Komarudin et al. (2021) state that conceptual understanding, especially in mathematics, is a form of mathematical proficiency or ability that meets the expected standards, such as demonstrating learned mathematical concepts, explaining the relationships between concepts, and accurately, efficiently, and precisely applying mathematical concepts or algorithms to problem-solving. Naufal et al. (2021) note that low academic achievement in understanding geometry concepts is a common issue faced by high school students worldwide, including in Indonesia. Chen et al. (2021) found that (1) students' performance in geometry-related topics is worse than in other areas of mathematics and (2) the average scores of students in geometry topics are lower than in other mathematical subjects. The ideal condition in the use of e-modules to improve students understanding of concepts is to use e-modules with systematic and well-managed procedures. According to Sanacore (1982) the PQ4R (Preview, Question, Read, Reflect, Recite, and Review) procedure has a more effective impact on improving overall conceptual understanding.

The findings in schools are based on the results of direct observation and interviews with several mathematics teachers, namely that the use of e-learning in schools has started during the covid-19 outbreak and its management has not been well organized, the provision of information about learning modules is given in pdf form and the evaluation process is carried out with google form,

as well as the interaction process is carried out using the help of WhatsApp. The current state of students is actively using e-learning and the results are still not able to understand the material well even though the learning process has returned to normal as usual offline.

Some of the research results that have been carried out related to the development of modules on geometry materials are such as Susanti et al. (2021) which states that the flip pdf corporate based e-module on wide material and ball volume has valid, practical and effective quality to be used for grade VI elementary school students. Riski & Hastri Rosiyanti (2021) stated that the design of the transformation geometry material module with the help of Canva, Adobe Photoshop, and Microsoft Word applications can improve the mathematical understanding of high school students in grade XI. Tobing et al. (2021) stated that the e-module designed using sigil distance material is valid and practical for high school students in grade XII. Natalia Rosalina Rawa et al. (2021) stated that flat geometry modules (lines, angles, triangles, and squares) based on the 7E learning cycle model for junior high school students are categorized as valid and practical. From some of the results obtained in general, the geometry module developed: (1) it has not been able to provide information that students are actually learning the module, (2) the material is not structured systematically and sequentially for students to easily understand, and (3) it is not enough to provide feedback to students to be able to motivate students to learn (Widana & Laksitasari, 2023).

Seeing the lives of students at school who are already used to using the internet, they can easily provide material with interactive e-modules based on PQ4R on the e-learning platform. The advantages of PQ4R-based interactive e-modules on the e-learning platform are: (1) the material can be accessed anywhere and anytime, (2) student learning activities are systematically designed from observing, asking, answering, discussing, and remembering, and (3) can guarantee student interaction in each individual to answer exactly what the student achieves in learning. With the convenience and benefits provided, it is hoped that the development of an interactive e-module based on PQ4R on this e-learning platform can help students in learning related to geometry materials, and help teachers to evaluate the student learning process.

Based on these considerations, improving understanding of concepts requires the development of learning media that can provide information to students systematically and be well managed, and can provide feedback to students in the learning process. The use of e-learning has started during the covid-19 condition, but in the process of using it is still not optimal and tends to only provide material in pdf form and has not been systematically structured and not managed properly. After the covid-19 outbreak ended, learning took place as before, but currently the use of e-learning is still needed to maximize learning outcomes in the classroom. Therefore, this study focuses on how to use e-modules in current e-learning flatform? The purpose of this study is to produce an interactive e-module based on PQ4R on an e-learning platform to be able to improve students' understanding of mathematical concepts.

Method

Based on the identified problems and to achieve the expected objectives, the type of research used is design research, which refers to the development research theory by Plomp. Design research aims to design and develop a product such as programs, strategies, learning materials, products, and systems as solutions to common educational issues. It also seeks to expand knowledge about the characteristics of these products, the design process, and their development. This research employs a mixed-methods approach.

This research uses the stages of design research theory. Tjeerd Plomp et al. (2013) stated that there are three stages in design research which include Preliminary Research, Development or

Prototyping Phase, and Assessment Phase. The first stage conducts a needs and context analysis, collects literature, and establishes a conceptual or theoretical framework for the research. Then the second stage is to develop each cycle and evaluate the cycle micro as the most important research activity that aims to improve and improve the product. And the last stage is to conduct a summative evaluation to be able to conclude whether the solution or product meets the predetermined specifications. At this stage, it also tends to produce recommendations for product improvement, the term can be said to be semi-summative. The flow of the research is presented in the following image.

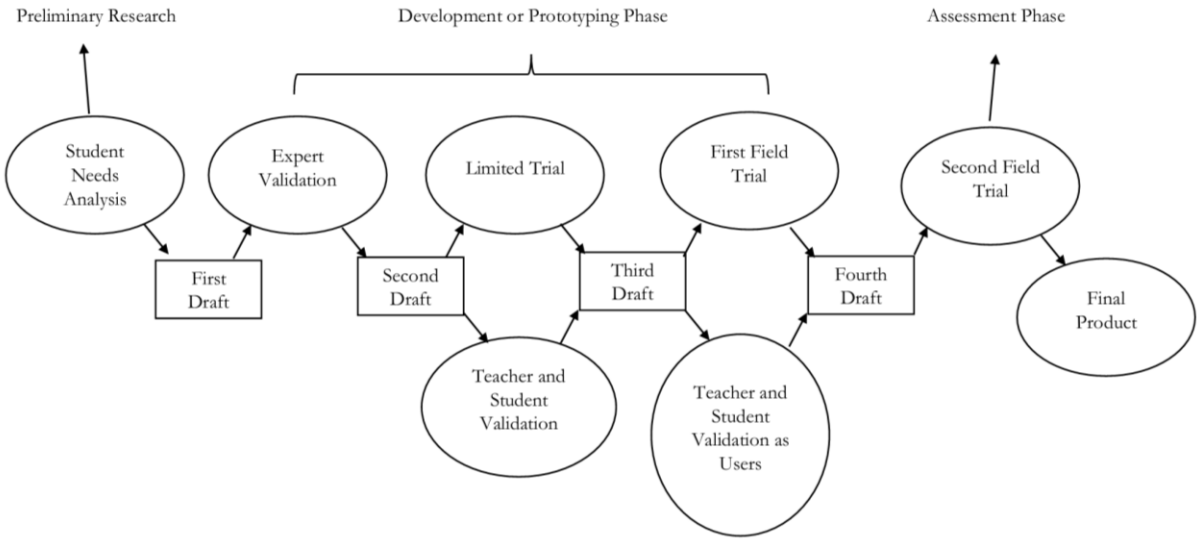

Image 1. Research Flow Design

The preliminary research stage to analyse the needs and context is to conduct a study related to the needs that are needed as a result of the gap between the circumstances that should exist and the circumstances that occur in real life in the school. This analysis is related to content standards, math books, learning materials, learning tools, and several theories in learning that are used to be able to explain and support the meaning of situations that occur in schools. Collecting literature is browsing relevant literature that has been published as a reference or reference that can support product development to provide the necessary needs to be able to establish an appropriate conceptual or theoretical framework for research.

Development or prototyping phase, namely designing an e-module that suits the needs of teachers and students in the learning process into draft I. Furthermore, conducting an expert test (validation) of draft I which includes the suitability of content standards, competency standards, basic competencies, concepts, principles and characteristics of e-modules. Validation involves two experts appointed based on considerations of the field of knowledge and the relevance of their experience. Then revise draft I so that the next draft with valid quality becomes draft II. After obtaining draft II, it then conducted a limited trial for several relevant students as an illustration of the implementation of the use of e-modules with formative evaluation using observations, tests, and questionnaires that are appropriate to draft III. Then conduct the first field trial for several students as an overview of the quality of the e-module that is valid, practical and effective with formative evaluation using observation, interviews, tests, and questionnaires that are appropriate to draft IV.

The final stage is the assessment phase to carry out a second field trial for several classes of students as an overview of the quality of the e-module with semi-summative evaluation using observation,

interview, or test techniques. The results are characteristics of a valid, practical, and effective (final) e-module.

This research was conducted at SMA Negeri 1 Ubud during the odd semester of the academic year 2024/2025. The subjects of this study included experts, students, and teachers involved in the process of obtaining a valid, practical, and effective product. The experts were university lecturers competent in the field of mathematics, responsible for providing information on product validity through the completion of validation sheets. The students were active 12th grade learners at SMA Negeri 1 Ubud, responsible for providing information on the practicality and effectiveness of the product through questionnaires, concept comprehension tests, and interviews. The teachers were active mathematics instructors at SMA Negeri 1 Ubud, responsible for providing information on the practicality of the product through questionnaires and interviews.

Information regarding core competencies and basic competencies was collected through a literature review. Information on the characteristics of the teaching materials used was gathered through student interviews, direct classroom observations, and teacher interviews. Information on product validity was obtained through expert assessments using validation sheets. Information on product practicality was collected based on the implementation of the product and the responses from teachers and students via questionnaires. Information on product effectiveness was gathered based on students' conceptual understanding through tests. Information on product implementation was collected based on test results and interviews with selected students and teachers as users.

The instrument used to obtain information on the characteristics of the teaching materials consisted of structured interview notes. The instrument for assessing product validity was an expert validation sheet. In this study, product quality assessment by experts referred to the Learning Object Review Instrument (LORI). The instrument used to evaluate product practicality was a questionnaire that gathered responses from students and teachers on product usage. The instrument used to assess product effectiveness was a mathematical concept comprehension test for students.

The validity of the questionnaire instrument, expert assessment sheets, and student tests was based on expert validation results. Expert assessments used the Learning Object Review Instrument (LORI). Teacher and student evaluations used an assessment table with a Likert scale. The improvement in students' conceptual understanding was measured using pretests and posttests. The results were further supported by interviews, comments, and suggestions that provided insights into the implementation of the product. Interview subjects included teachers as instructors and students with the highest and lowest conceptual understanding test scores. General comments and suggestions were gathered from expert assessments and user feedback. Qualitative data served to strengthen the overall research findings and the implementation of the designed product.

Product Validity

Expert assessment uses the Learning Object Review Instrument (LORI), so the scoring rules in the assessment sheet are as follows.

$$Average\ score = \frac{score}{maximum\ score} \quad \text{..... (1)}$$

Table 1. Questionnaire Category Scores

Category	Score
Excellent	5

Category	Score
Good	4
Keep	3
Less	2
Very Less	1

Source: (John Nesbit et al., 2009)

Product Practicality

The assessment of teachers and students uses a Likert scale, so the rules for scoring in the questionnaire are as follows.

$$Average\ score = \frac{score}{maximum\ score} \quad \text{..... (2)}$$

Table 2. Teacher and Student Questionnaire Rubric

Category	Score
Excellent	5
Good	4
Keep	3
Less	2
Very Less	1

Source: (Sugiyono, 2019)

Table 3. Product Practicality Criteria

Percentage Score	Category
$PS \geq 80$	Very Practical
$60 \leq PS < 80$	Practical
$40 \leq PS < 60$	Quite Practical
$20 \leq PS < 40$	Less Practical
$PS < 20$	Very Impractical

Source: (Lisyanti, 2019)

Product Effectiveness

Increasing students' understanding of concepts is seen from pretest and posttest scores.

$$Increased = \frac{pos\text{-}test - pre\text{-}test}{maximum\ score - pre\text{-}test} \quad \text{..... (3)}$$

Table 4. Product Effectiveness Criteria

Increased	Criterion
$0.70 \leq p$	Effective
$0.30 \leq p < 0.70$	Quite Effective
$p < 0.30$	Less Effective

Source: (Lisyanti, 2019)

Results and Discussion

The results obtained from the beginning to the end are results that go through several stages according to the procedures of the design research. The first stage is the initial study phase, which serves as the foundation for developing a necessary product. The findings obtained include various pieces of information related to the state of mathematics learning in the classroom. Generally,

learning is conducted conventionally using textbooks provided by schools. The use of technology, such as digital learning media, was fully implemented during the covid-19 pandemic. However, once conditions returned to normal, learning was carried out as usual in the classroom. Online materials, such as PDFs and assignments via Google Forms and similar platforms, were only provided in specific situations, such as when teachers were unable to attend, for chapter assessments, or under certain conditions that necessitated online learning.

In the context of online learning, commonly referred to as e-learning, teachers have generally not yet fully utilised technology-based media effectively. This is primarily due to their lack of familiarity with e-learning and managing it as part of classroom instruction. As a result, teachers predominantly use WhatsApp groups as a learning medium, despite several challenges, such as suboptimal management of learning activities within the group and limited interaction, which in some cases cannot be tailored to individual students. So, it is relevant to manage e-learning properly through interactive module content.

The second stage involves product development based on the findings from the initial study. The outcomes of this stage include the design of an interactive e-module based on the PQ4R approach on an e-learning platform, along with validation, effectiveness, and practicality instruments for the e-module. The designed product and instruments then undergo a validation process by two expert lecturers specializing in mathematics education to ensure that the product and instruments are ready for field testing. The validation process also results in corrections, suggestions, and feedback, which serve as the basis for refining and improving the instruments so that they can be effectively used in practice. The evaluation results obtained are as follows.

Table 5. The Result of Expert's Validation

Validator	Score Average	Total Score Average	Category
Validator 1	4.62	4.68	Excellent
Validator 2	4.75		

The e-module, which is designed based on preliminary research, obtains several improvement processes and inputs related to the content contained in the module. Improvements were made in terms of the content of the material which was adjusted to the theoretical and practical provisions in the school. Then in the use of modules in e-learning, there are also some improvements in the display, instructions, and some technical things to be used by teachers and students well in the classroom during the teaching and learning process so that there are no significant obstacles.

The next stage is a limited trial conducted after obtaining the second prototype, which has been refined based on expert validation from faculty members. This limited trial process includes the use of the e-module, observation, evaluation, and reflection on the e-module implementation. The collected data consists of scores from users and observers, which are then analysed to determine the average score from each evaluator. The results are presented in the following table.

Table 6. The Result of Limited Trials

Instrument	Average	Score	Category
Pre-test	59.00	0.292	Less Effective
Post-test	71.00		
Questionnaire for Teachers	3.43	85.937	Very Practical
Questionnaire for Students	3.47	86.875	Very Practical

The results of the limited trial process carried out with five students and two mathematics teachers, obtained quantitative input that there was an increase in learning outcomes shown from student

scores, which means that its use is included in the effective category. Then the results of the questionnaire of teachers and students as users are quantitatively practical. In terms of product quality, it shows the use of technology in learning well, but technically there are still some small technical obstacles such as setting up each student's account, instructions for using modules, and there are student activities whose process is not yet known. So that for some of these thing improvements can be made to be used in field trials.

Field trials were conducted as a follow-up stage after the limited trials, which took place following the third prototype's development. This prototype was refined based on necessary improvements aligned with real-world conditions. The field trial process included the use of the e-module, observations, evaluations, and reflections on its implementation. Data collected consisted of scores from users and observers, which were then analyzed to determine the average score for each evaluator. The results obtained are presented in the following table.

Table 7. The Result of First Field Trial

Instrument	Average	Score	Category
Pre Test	70.64	0.253	Less Effective
Post Test	77.25		
Questionnaire for Teachers	3.56	89.062	Very Practical
Questionnaire for Students	3.50	87.500	Very Practical

The second field trial was conducted as a refinement stage after the fourth prototype was obtained from the results of the first field trial. This field trial process involved the use of the e-module, observation, evaluation, and reflection on the e-module's implementation. The results obtained are presented in the following table.

Table 8. The Result of Second Field Trial

Instrument	Average	Score	Category
Pre Test	77.74	0.771	Effective
Post Test	92.41		
Questionnaire for Teachers	3.87	96.875	Very Practical
Questionnaire for Students	3.70	92.641	Very Practical

Each stage of the field trial also includes assessments using pre-tests and post-tests. This stage is conducted in the 12th grade, with the results focused on the final product that meets the criteria of being valid, practical, and effective. The obtained results are presented in the following table.

Table 9. Results of the recapitulation

Assessment	Score	Category
Experts	4.68	Excellent
Questionnaire for Teachers	96.87	Very Practical
Questionnaire for Students	92.64	Very Practical
Post-Pre Test Results	0.77	Effective

The e-learning display is designed in a minimalist manner and does not have a combination of colors that are too bright and striking, so that it gives an attractive and concise impression for students to access. The background section used looks simple with some interesting combinations by displaying some form elements related to relaxing math learning. After logging in, students will head to the main page to start learning. After students successfully log in using their respective accounts, there is a choice of grade XII mathematics modules to start learning. Students can see

several features available in addition to the home page, namely dashboards, calendars, and assignment files.

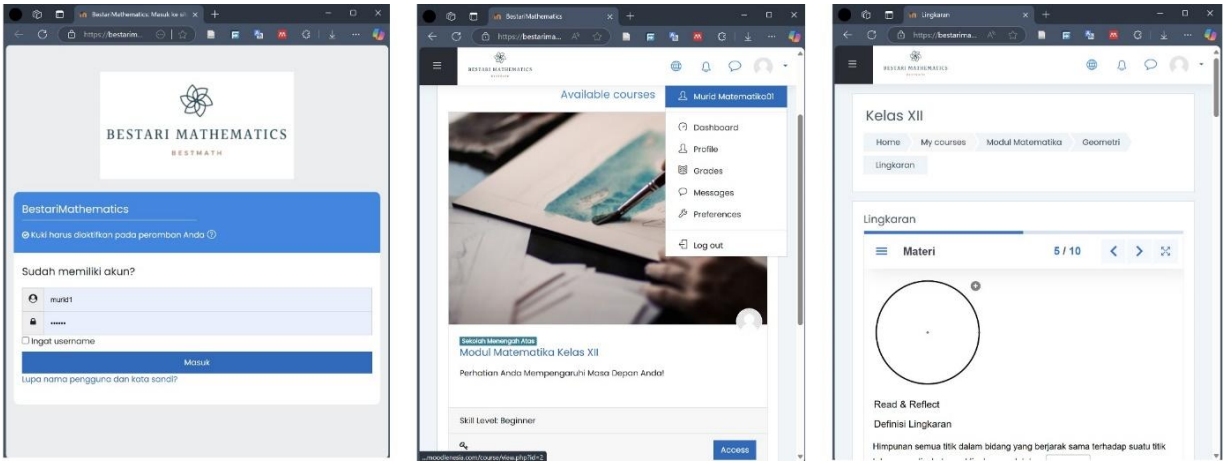

Image 2. E-module Layout

The product developed image 2 is an interactive e-module based on PQ4R on an e-learning platform to improve students' understanding of the concept of geometry material for grade XII students. The e-learning used is Moodle that contains several features to manage the process of providing material and the evaluation process of mathematics learning, especially for geometry materials. The modules developed based on PQ4R are previews, namely reviewing or skimming questions, questions or questions based on what has been read, reading or reading the material in depth, reflecting or reflecting on the material that has been studied, reciting or mentioning the information that has been obtained, and reviewing or reviewing to remember more deeply the material information that has been received. The initial view of e-learning contains the starting page to log in with the username and password that each admin, teacher and student has as shown in the image below.

The menu contained in this e-learning contains instructions for the use of e-learning that emphasizes student activities in order to get maximum results. Students can also visually see the progress of activities that have been in e-learning. Then there is a notification and message feature if there is important information addressed to the student concerned through a special delivery to each student account. In general, the activities of each student will be carried out independently so that they cannot be disturbed by outside parties or other students. This is because the process of accessing student activities directly on each student's device individually as progress is recorded in each account they have.

In the e-module section, there is an initial display that shows the identity of the compiler and several features that can be used to facilitate access to information in the module. Then for the display of the third part of the module is the learning objectives which provide an explanation of the targets that will be achieved by students in the learning process through e-learning.

In the material section, there are several student activities that can be recorded directly after students check the results of the activities carried out. Directly there will appear a section of student activities that have correctly fulfilled the answer key and or will also appear directly a section of student activities that have not correctly fulfilled the answer key provided. So that this activity can indirectly provide better information to students, especially to students who have critical thinking can raise several questions as a result of the process of the activities they carry out.

In the summary section, it provides instructions to students to answer questions as a result of the overall activity they have done. Furthermore, the last part will contain about the total score and some progress and interactions that have been made by students in the use of modules through e-learning. So that each student has results that tend to be not the same and has progress in accordance with the activities that he has really done directly independently.

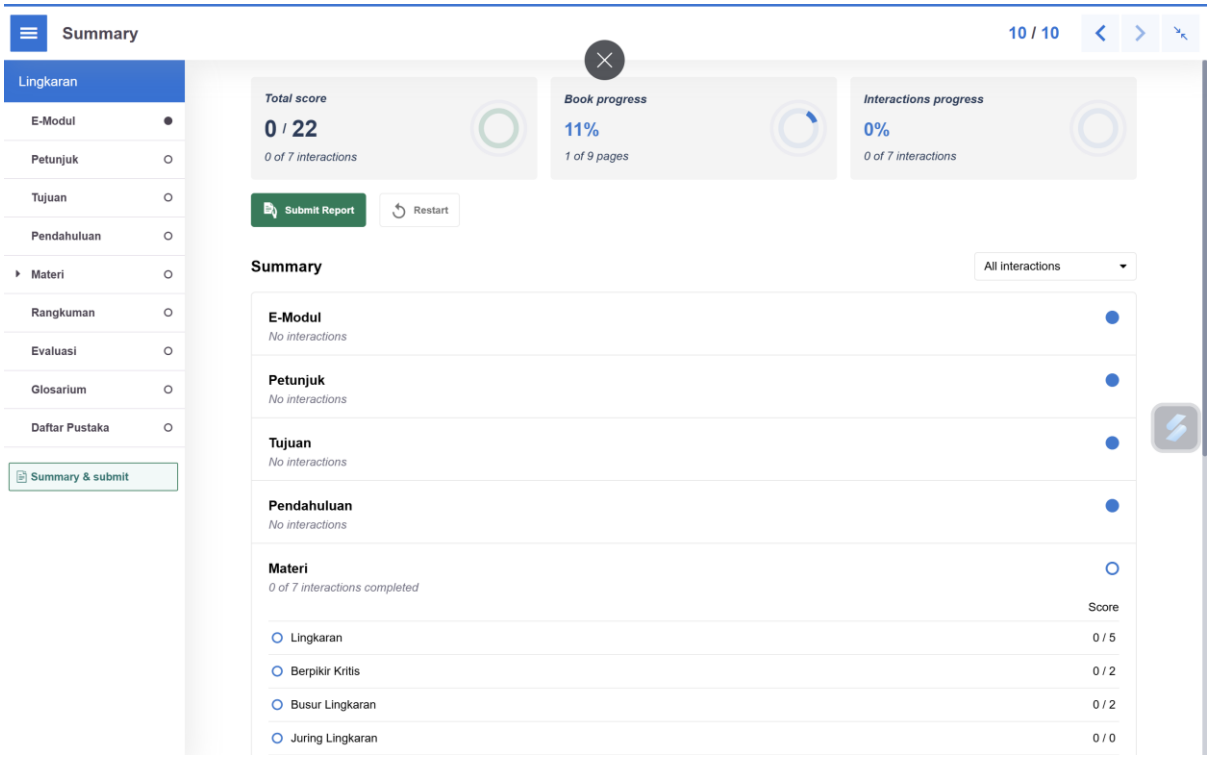

Image 3. Student Work Results View

Image 3 shows the final results of the students which can be displayed in the last part of the module activity. Based on the activities, students will produce performance processes that have been achieved and have not been achieved. Each part has its own assessment, so that the progress of student interaction will be clearly visible in each section. The most important part is how students can complete activities well and obtain good performance progress.

Teachers in assessing student performance can take advantage of this feature well and practically. The total score display will make it easier for teachers to see the overall value of each individual's student performance. The progress of student activities will provide information on how far students have learned and will be reported as the achievements of student activities displayed in the form of percentages. Then for activities that contain interaction activities, students will provide several questions that have been successfully answered by students with feedback that has been provided for each interaction carried out by students.

Product advantages with interactive features, students are not only passive recipients of information, but also actively involved in the learning process. In addition, a systematic learning structure makes it easier for teachers to design learning flows and monitor student progress periodically through the available evaluation and reporting features. Good system integration allows for immediate feedback, two-way communication, and flexibility in accessing materials anytime and anywhere. This certainly supports independent learning and strengthens the understanding of mathematical concepts as a whole. The features included in this interactive e-

module range from filling in the blanks, matching words, adjusting table components, reading texts, observing 2D or 3D illustrations, connecting images, multiple-choice questions, multiple-choice questions with more than one correct answer, and video presentations.

According to Hudayanti (2022), interactive digital modules serve as learning aids that help students comprehend subjects by focusing on building a deep understanding of a specific topic. These modules also allow educators to observe student responses and encourage responsibility in completing assignments on time. Müller et al. (2021) state that e-learning remains beneficial for education even beyond the covid-19 pandemic, as it supports reflective learning and enhances face-to-face classroom instruction. Moreover, implementing the PQ4R strategy as a systematic learning method has been shown to improve students' conceptual understanding of mathematics. Hence, the development of an interactive e-module based on PQ4R within an e-learning platform presents a viable solution to address learning needs. Edwar et al. (2023) also highlight that the use of the PQ4R strategy in designing student worksheets is effective in schools, yielding results that are categorized as valid, practical, and effective.

The use of modules in e-learning that has been developed is very practical to use because it can be accessed only using cellphone devices, tablets, or laptops that are connected to the internet, all of which can use it. O'Neill (2024) which states that e-learning is a facility that can be used to provide instruction in the learning process by utilizing technology, which is designed in such a way that students can learn optimally to achieve certain learning goals without having to be in the same place. So that students can access and learn anywhere and anytime.

This is also strengthened by Wang (2024) & Sumandya et al. (2023) which states that the use of cloud e-learning can improve student learning performance in subjects in theory to be practicable. The use of the cloud to support the use of e-learning in the student learning process is very appropriate to be used as an efficiency in storage and useful to help manage the student learning process. The e-learning used in this study uses Moodle with a very diverse choice of capacity adjusted to the needs package used. The use of the selected capacity is usually adjusted to the circumstances of the school as well as the number of students who use it, the content to be displayed, and several other considerations that are adjusted by the school operator. The Moodle that the researcher chose is very helpful in the process of preparing the material, designing some questions to be given to students, and several activities that are very helpful for students in learning with enough storage capacity for approximately 3 classes in high school. The part to consider in terms of storage capacity is to have a backup of data to store automatically to avoid losing some important pieces of data due to updating or improving the e-learning system.

The results of the study showed that there was a significant improvement in the understanding of mathematical concepts of students who used the developed interactive e-module products. This is clearly seen in the results of the pre-test and post-test in the second field trial. This is in line with Monib (2024) said that the use of e-learning provides teachers and students with the opportunity to improve the maximum teaching and learning experience by utilizing several features in it. The use of e-learning is very useful in education, but it requires more advanced information and communication technology skills. Akuegwu et al. (2024) which states that to adopt the use of e-learning requires the readiness of school institutions such as the availability and accessibility of e-learning facilities, training in the use of e-learning both from the admin of the operator's staff, teachers and students as users, and the maintenance of facilities for e-learning can still be used optimally without any significant obstacles. This shows that the research objectives have been achieved well, but it is also necessary to pay attention to the availability of technology and also the readiness of all supporting elements in the school environment. The readiness includes the ability of individuals to operate digital devices, an understanding of e-learning platforms, and support

from schools in the form of training and the provision of adequate infrastructure. In addition, the maintenance of e-learning facilities and systems is also an important factor so that the learning process can run continuously without disruptive technical obstacles. Thus, the synergy between human resources and supporting facilities is the key in optimizing the use of e-learning in the world of education.

Conclusion

Researchers have developed an interactive module based on the PQ4R method on an e-learning platform that meets the criteria of being valid, practical, and effective in enhancing the mathematical concept comprehension of 12th grade students. The characteristics of the developed product include interactivity, systematically structured learning management, and ease of access for both teachers and students to obtain learning materials and results within a well-integrated system. The development of an interactive module based on the PQ4R method aims to assist students in understanding the material more deeply through an approach that emphasises the process of reading, questioning, connecting, reflecting, and repeating information. Product advantages with interactive features, students are not only passive recipients of information, but also actively involved in the learning process. In addition, a systematic learning structure makes it easier for teachers to design learning flows and monitor student progress periodically through the available evaluation and reporting features. Good system integration allows for immediate feedback, two-way communication, and flexibility in accessing materials anytime and anywhere. This certainly supports independent learning and strengthens the understanding of mathematical concepts as a whole. The features included in this interactive e-module range from filling in the blanks, matching words, adjusting table components, reading texts, observing 2D or 3D illustrations, connecting images, multiple-choice questions, multiple-choice questions with more than one correct answer, and video presentations. The limitations of the product require a stable internet connection, not all teachers and students can make the most of it, and it takes a long time to prepare for the initial administration. It is recommended to continue this research regarding the use of artificial intelligence (AI)-assisted e-learning in the mathematics learning process.

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