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A Digital Trigonometry Module Based on Discovery Learning and Critical Thinking Skills

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Abstract. Trigonometry is one of the most challenging materials for most students because the abstraction of trigonometry material requires reasoning. The teaching methods used to teach trigonometry material often don't have two-way communication. Using textbooks for teaching material also causes students to have difficulty solving problems requiring critical thinking skills. This study aims to develop a digital trigonometry module based on the discovery learning model to improve critical thinking skills. This research is a research and development using the ADDIE model with five development steps. The instruments used are validation questionnaires, response questionnaires, also pretest and post-test questions. Based on the product validation test, the digital trigonometry module based on the discovery learning model is a very good category in terms of material with an average score of 94 and very good in terms of media with an average score of 99. The digital trigonometry module based on the discovery learning model is a good category from practical categories. The digital trigonometry module is also effectively used to improve critical thinking skills based on the comparative analysis of the pretest and post-test averages.

INTRODUCTION

The spread of Covid-19 increasingly under control has brought Indonesia to a transitional period to welcome this good development towards an endemic phase. Various appeals from the Ministry of Education, Culture, Research, and Technology urge policymakers to open face-to-face learning in schools and develop structured, systematic, and massive strategies that involve various parties. As for the aspects that need to be considered to encourage the restoration of education services, one of which is the safe participation of 100 per cent face-to-face learning and the use of information and communication technology.

The demand for the use of this technology has existed for a long time, but there are some gaps in its application. The existence of geographical disparities, the spread of infrastructure, digital literacy of teaching staff, and different teaching methods are the diversity of spans of control in the digital education ecosystem in Indonesia. So it takes more than one scenario or specific strategy to be applied in learning during the post Covid-19 digital education transformation. On the other hand, we still often encounter student complaints and difficulties while understanding learning materials and solving contextual problems. It is not uncommon for us to find learning that occurs only in one direction. Even two-way learning occurs quickly because education focuses on the teacher as a learning resource. This problem also happens in learning mathematics, including trigonometry material with abstract objects, requiring more reasoning. This abstraction of objects in mathematics has the potential to become an obstacle or difficulty for students

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who study it with a low level of readiness [1]. Moreover, the materials in mathematics also are hierarchical studies, so in acquiring knowledge, students need sufficient learning experience during the learning process [2].

Trigonometry is a branch of mathematics that studies the relationship between sides and angles in triangles ([3]–[5]). According to Weber [6], trigonometry is the earliest topic that connects algebraic reasoning, geometry and graphs, which are prerequisites for understanding topics in Newtonian physics, architecture, surveying and many other engineering disciplines. The role of trigonometry in connecting the reasoning of several branches of mathematics doesn't make learning achievement the primary orientation of teachers. The trigonometry material still poses difficulties for most students (Blackett & Tall in [6]). In learning trigonometry, it was found that there are still many students whose ability to analyze, evaluate, and design the proper steps to solve trigonometry problems still reaches 26.7% - 30% [7]. In other words, students' higher order thinking skills in learning trigonometry are still relatively low.

This low ability also occurs in one of the state senior high schools in the Sukoharjo district, which, based on initial observations, has difficulty determining important information relevant to trigonometric problem-solving. Students also still have difficulty using this vital information in problem-solving steps. Even students cannot give logical reasons for each problem-solving stage, so the conclusion is still incorrect. The condition of these students illustrates the lack of high-level thinking skills of students at these one of the state senior high schools in the Sukoharjo district, especially critical thinking skills such as the unreached indicators that appear in the results of the researchers' initial observations. This unreached critical thinking skill indicator in line with the results of the pretest of critical thinking skills held on Tuesday, April 12, 2022, for 36 students of class X MIPA 2.

The results of the student's initial test showed that the average score obtained by students on each indicator of students' critical thinking skills was still far from the maximum score they should have achieved. The maximum score for the overview indicator of critical thinking is 2, while the other five critical thinking indicators are 4. The average value of students' critical thinking skills only gets a score of 38.89, which in this case is still less than the school's minimum completeness criteria (i.e. 60). Based on the results of follow-up interviews with students, it is also known that students' lack of critical thinking skills is caused by the teacher's learning model that has not optimized students' learning independence in constructing their knowledge. So far, students tend to memorize trigonometric formulas given by the teacher. Therefore, they find it difficult when they have to provide logical reasons and make appropriate conclusions in the context of concept discovery through the active participation of students. So, learning trigonometry there requires a learning model that can stimulate students' knowledge construction through independent concept discovery and involving student activities such as the discovery learning model. In selecting the suitable learning model, the teacher must pay attention to several aspects, including student limitations, interest in learning, and the interactive feature of the teaching materials used to support the chosen learning model [8].

According to Jana & Fatmawati [9], the discovery learning model can encourage students to find concepts and train students to discuss and cooperate reasonably so that teachers only facilitate meaningful learning for students with guidance. The discovery learning model can also direct students to understand concepts, meanings, and relationships, through a process that ultimately concludes [10]. Several studies that support the improvement of students' critical thinking skills through the application of the discovery learning model include research by Haeruman, et al. [11] and research by Wati, et al. [12] about improving students' critical thinking skills through the application of the discovery model whose achievement is higher than conventional learning models; research by Kurniati, et al. [13] and research by Pratiwi, et al. [14] regarding the application of the discovery learning model that can improve students' critical thinking skills.

In addition to learning models, teachers must also be able to overcome time constraints and the breadth of material covered as a learning strategy in the post-pandemic period. In this case, the discovery learning model also requires support in the form of teaching materials that students can learn independently with a more flexible presentation in terms of time and use, such as digital modules. According to Nugraha [15], digital modules can be used as learning tools that utilize computers/other electronic devices to display text, images, graphics, audio, animation, and video that can be accessed anytime and anywhere. Several research results also support the importance of teaching materials in the form of digital modules, such as research by Islahiyah et al. [16], which shows that teachers need interactive teaching materials such as digital modules and can improve students' mathematical abilities in solving problems; research by Daroini et al. [17] which shows students' need for digital modules with steps to solve math problems in online learning so that students can learn independently. Based on the problems above, the researcher intends to develop a digital module to improve students' critical thinking skills with the discovery learning model. Therefore, this research aims to develop a digital trigonometry module based on a discovery learning model to improve students' critical thinking skills.

METHOD

This research includes research and development (R&D) using the ADDIE model, which consists of 5 (five) stages, namely analysis, design, development, implementation, and evaluation. The population used in this study were all grade X students from one of the state senior high schools in the Sukoharjo district, while the samples were 36 students of grade X MIPA 2. The data collection instruments were pretest and posttest instruments, material validation questionnaires and media validation questionnaires, and student response questionnaires.

The research started by analyzing the material, learning situation and student characteristics. Then the researchers designed a digital module based on the analysis results in the previous stage. The researcher continued the research by developing a digital module based on the discovery learning model with characteristics adjusted to the design results in the second stage. Researchers validate the results of its development to validators, both material and media. After the digital module is declared valid, the researcher then implements the module in schools. Before applying the digital module based on the discovery learning model, researchers conducted a pretest to determine students' critical thinking skills in solving trigonometry problems. Then learning is carried out in six meetings. After all the material was given, the researchers held a posttest at the sixth meeting to reassess students' critical thinking skills.

Data from the written test results were processed using descriptive and inferential statistics. Descriptive statistics describe the test results of critical thinking skills descriptively. In contrast, inferential statistics describe a significant increase in results before and after being given treatment. Shapiro Wilk test was used to test the normality of the data. Data can be normal if it has a significant value > 0.05. While the hypothesis test used to see the effectiveness of the digital module based on the discovery learning model is the paired sample t-test. The basis for decision-making in the test is H0 and H1. H0 is rejected, and H1 is accepted if t-count > t-table or significance probability <0.05. The research hypothesis is as follows.

1. Null hypothesis (H0): students' average critical thinking ability before and after being given a digital trigonometry module based on the discovery learning model is the same.
2. Alternative hypothesis (Ha): students' average critical thinking ability before and after being given a digital trigonometry module based on the discovery learning model is different

After that, the researcher carried out the N-Gain test to determine the improvement of students' critical thinking skills in terms of students' pretest and posttest results. Finally, the N-Gain value which used to select the category of change/increase that occurred with the N-Gain value [18].

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RESULT AND DISCUSSION

The first stage in this research begins with the analysis stage, namely the information search stage, before designing the digital module. At this stage, student needs are analyzed, including material, learning situations and student characteristics. In the analysis stage, the researcher observed and interviewed students and mathematics teachers at one of the state senior high schools in the Sukoharjo district. Then, the researcher tested students' critical thinking skills on trigonometry material. This activity is intended to find out the problems of students' critical thinking skills during trigonometry lessons based on the point of view of teachers and students. Based on the results of the written test, it is known that the average score of students' critical thinking skills on trigonometry material has not reached the school appoint minimum completeness criteria. The average score of students' overall critical thinking skills was only 38.89, which in this case was still less than the school's Minimum Completeness Criteria (KKM) (i.e. 60).

Preliminary observations indicate that students have difficulty determining important information relevant to solving trigonometric problems. They also still have difficulty using this vital information in problem-solving steps. Moreover, the students are less able to give logical reasons for each stage of solving the problem, so the conclusion is still incorrect. Furthermore, the researchers conducted follow-up interviews with students. These activities found that the lack of students' critical thinking skills was one of the causes of the teacher's learning model that had not yet optimized students' learning independence in constructing their knowledge. So far, students tend to memorize trigonometric formulas given by the teacher. Therefore, they have difficulty delivering logical reasons and making appropriate conclusions when learning is oriented to concept discovery through active student participation. From this, we can conclude the need for a trigonometric learning model suitable for

students' conditions at these school. One of the models that can stimulate students' knowledge construction through independent concept discovery and involving student activity is the Discovery Learning model.

The material analysis results also showed obstacles and difficulties for students during trigonometry learning because more than 52% of teachers gave direct assignments to students at the school without explaining the material in detail. Meanwhile, another 48% of teachers provide brief explanations through learning videos uploaded by teachers on Youtube. Almost 80% of the trigonometric material presented also contains trigonometric formulas using textual books that require a lot of teacher guidance. Hence, students can only apply formulas. The limited time and breadth of the scope of trigonometry material require teachers to have the right learning strategies, both in terms of learning models and teaching materials that support learning models that students can learn independently with more flexible presentations, such as digital modules. With digital modules, students are expected to get clearer visualizations in understanding the material presented by the teacher, especially material that has a high level of abstraction such as in mathematics. So that the presentation of the right visualization becomes an important key in obtaining a rapid cognitive response from students.

By referring to the needs analysis in the first stage, the researcher designed teaching materials that did not require much teacher guidance and could be used independently by students. In this case, the researcher developed a digital trigonometry module based on a discovery learning model that activates the construction of students' knowledge through discovery and not only given knowledge. The development of the digital module is also oriented towards improving students' critical thinking skills so that the digital module contains the discovery model syntax, which is correlated with indicators of students' critical thinking skills. At the beginning of the learning activity, the module presents problems as a form of stimulus for certain problems for students to observe through videos. This activity shows the syntax of discovery learning model stimulation oriented towards achieving the aspects of focus and situation of critical thinking skills. Furthermore, the activities in the module are continued with activities based on other discovery learning syntaxes, namely problem statements, data collection, data processing, verification, and generalizations oriented towards achieving the aspects of reasoning, clarity and an overview of critical thinking skills.

In the next stage, researchers developed a trigonometric digital module according to the initial design in PDF and video formats with the help of the VideoScibe application. Then the module in PDF format and the video in mp4 format are imported into the Flipbook PDF Corporate Edition application and the project file is published in HTML format. As an adjustment to the characteristics and functions of the digital module, the researchers added additional supporting features by using the FAPA book extender application to expand the Flip PDF Corporate Edition functionality on Android devices. Therefore, the researchers made the book configs according to the needs of certain features in the digital trigonometry module, so that the digital module was in the form of an application that could be accessed online or offline. After finishing the development, researchers validated the product to 3 (three) validators in terms of material and media with details of 2 (two) lecturers and one teacher. Based on the material validation of assessment questionnaire results, it was found that the digital module developed was valid with an average score of 94 and categorized as very good. At the same time, the results of the media validation questionnaire showed the validity of the digital module with an average score of 99 and categorized as very good.

The digital trigonometry module that has been declared valid is then implemented in 36 students of grade X MIPA 2 from one of the state senior high schools in the Sukoharjo district. The first time students are asked to download the digital module application at the following address: https://drive.google.com/file/d/1s6Kk6DRzgJzahQ3Z6L93DOzzCrXc1Q5f/view?usp=sharing. Students look enthusiastic when using digital modules that can be opened offline and have an attractive appearance. They look serious about studying trigonometry material through their respective smartphones. The activity in the module begins with careful observation of the video containing contextual problems related to trigonometry, as shown in Figure 1 (a)- (b) below.

(a) Students simultaneously use their digital module (b) The student observes problems in the video

FIGURE 1. Student activities at the beginning of learning with the module

In this activity, the teacher is doing the first syntax of the Discovery learning model (Stimulation) by providing a stimulus to students in the form of contextual problems to be observed and listened to through digital video modules. Next, the teacher performs a second syntax (problem statement) by inviting students to find all information related to the problem and formulate the problem appropriately. In the third syntax (data collection), the teacher asks students to collect data to find problem-solving solutions or alternative solutions that might be used as problem-solving. In the fourth syntax, the teacher facilitates students to try and explore their conceptual knowledge in applying problem solutions. The next activity for students is to check the data processing results through various activities or search for relevant sources and associate them in compiling conclusions according to the fifth syntax (verification) of the discovery learning model. Finally, the teacher directs students to generalize their conclusions (syntax of generalization).

The researcher gave a questionnaire to determine the student response after using the digital module, then continued with the posttest to measure students' critical thinking skills. Based on the student response questionnaire results, it is known that the results of student assessment of the use of digital modules are categorized as good, with an average score of 98.92. Thus the developed digital module is declared to meet the practicality of a development product.

The last stage is evaluation. In addition to testing the product's practicality, the researcher also tested the effectiveness of the product through a statistical paired sample t-test. Before performing the paired sample t-test, the researcher tested the normality of the data using the Shapiro-Wilk test. If the results of testing the normality it has a significant value > 0.05, the data can be said to be normal. Based on the results of the normality test using the Shapiro-Wilk test, obtained a score of 0.206 or greater than 0.05. So it can be concluded that the student's critical thinking skills data is normally distributed. Furthermore, statistical testing was carried out using a paired sample t-test with the help of SPSS software. Based on the data processing results, the value of Sig. is $0.000 < 0.05$. This means that the null hypothesis, which states students' average critical thinking skills before and after being given a digital trigonometry module based on the discovery learning model is equally, will be rejected. Or in other words, there is a difference in students' average critical thinking skills before and after being given a digital trigonometry module based on a discovery learning model.

The researchers used the N-Gain test to determine how much improvement in students' critical thinking skills was due to the provision of digital modules. The N-Gain test results obtained a value of 0.48. If seen from these results, it can be said that the increase in students' critical thinking skills is included in the medium category. Therefore, based on data analysis, it can be concluded that the digital trigonometry module based on the developed discovery learning model is effectively used to improve students' critical thinking skills. This improvement of critical thinking skills due to the effectiveness of learning by using the discovery learning model is in line with the results of research by Ramdhani, Usodo, and Subanti [19].

This is in line with the results of research conducted by Rangkuti [20] that learning using electronic modules based on the discovery learning model can improve students' critical thinking skills. The difference with previous research is that in Rangkuti's [20], there was an increase in the average score but not significant, but in this study,

there was an increase in the average score of students. The effectiveness of the digital trigonometry module based on discovery learning on the achievement of critical thinking skills in this study is presented in Figure 2 below.

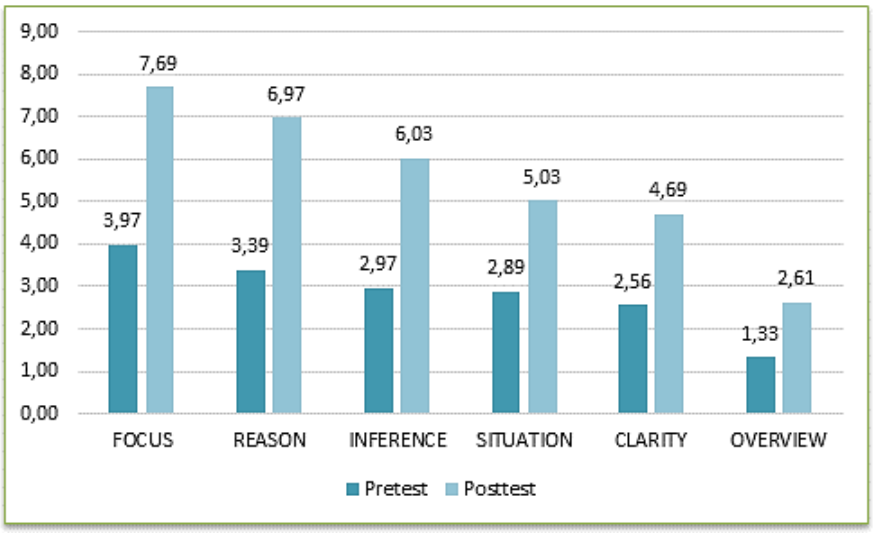


FIGURE 2. Results of Pretest and Posttest Critical Thinking Skills

From Figure 2 above, it is known that the achievement of the critical thinking ability indicator on the pretest on average is still 50% lower than the post-test score, both on the indicators of focus, reason, inference, situation, clarity and overview. The comparison of achievement of the indicators of students' critical thinking skills above shows that using digital trigonometry modules based on discovery learning significantly increases students' critical thinking skills.

Judging from the increase in students' critical thinking skills due to the use of module teaching materials and discovery learning models, several interactive features in this digital trigonometry module also support students' enthusiastic attitudes. An example of a superior feature of this digital module is the availability of a camera feature that can take pictures or screenshots of students writing with a camera icon, as shown in Figure 3 below.

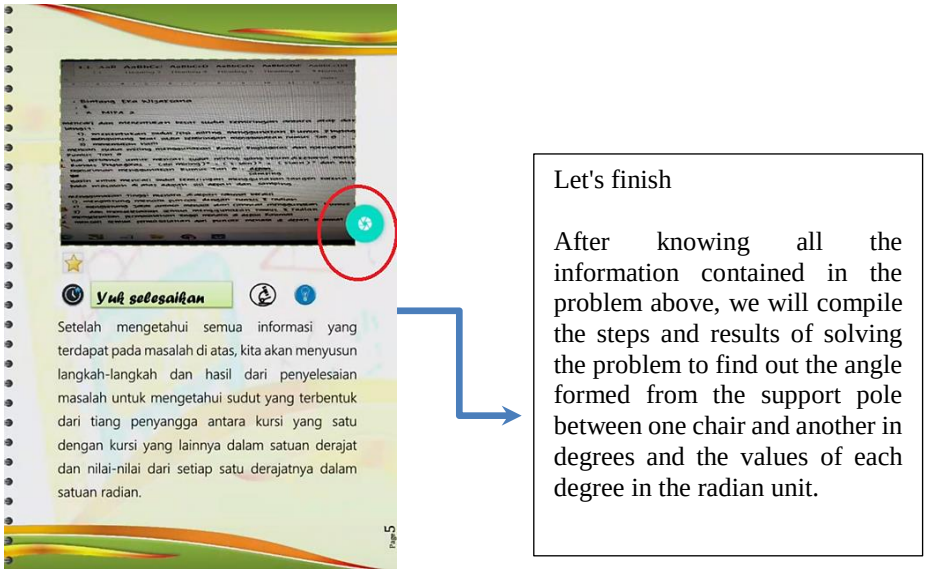
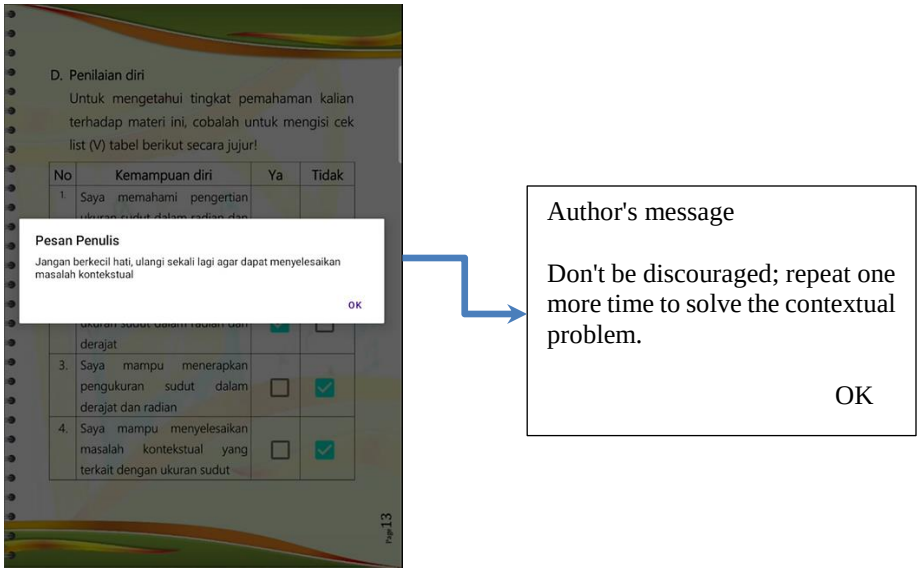
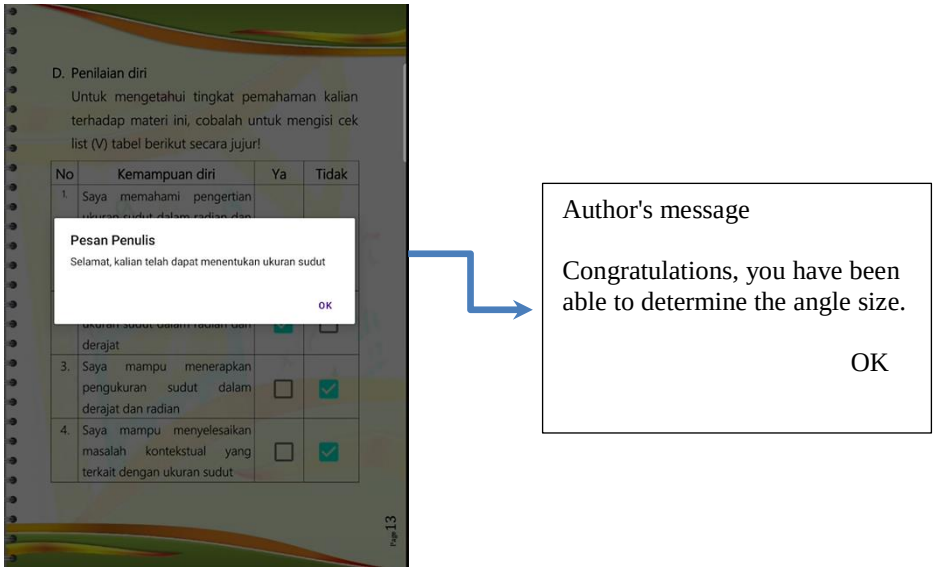


FIGURE 3. Camera feature for photographing students' written work

Another feature included in this digital module is a self-assessment feature that can help students evaluate their abilities if they choose specific options through feedback that contains positive motivation for students, as shown in Figure 4. (a)-(b) below.



(a) Features of self-assessment



(b) Features of self-assessment

FIGURE 4. (a)-(b). Features of self-assessment are positive feedback and motivation

In Figures 4. (a)-(b) above, we can be seen that the features of the digital trigonometry module developed in this study have fulfilled the self-instructional character of a module, where the module can enable users to be able to teach themselves or without depending on other parties. In the digital trigonometry module, an assessment is displayed that allows users to carry out self-assessment through measuring or evaluating the level of mastery of the material accompanied by feedback responses to the evaluation. So with this feature, module users can find out the level of their understanding of the material.

This digital module also has a video feature which still has a background and on the module's frame so that even though the video is displayed, the user can still see the module's complete display, as shown in Figure 5 below.

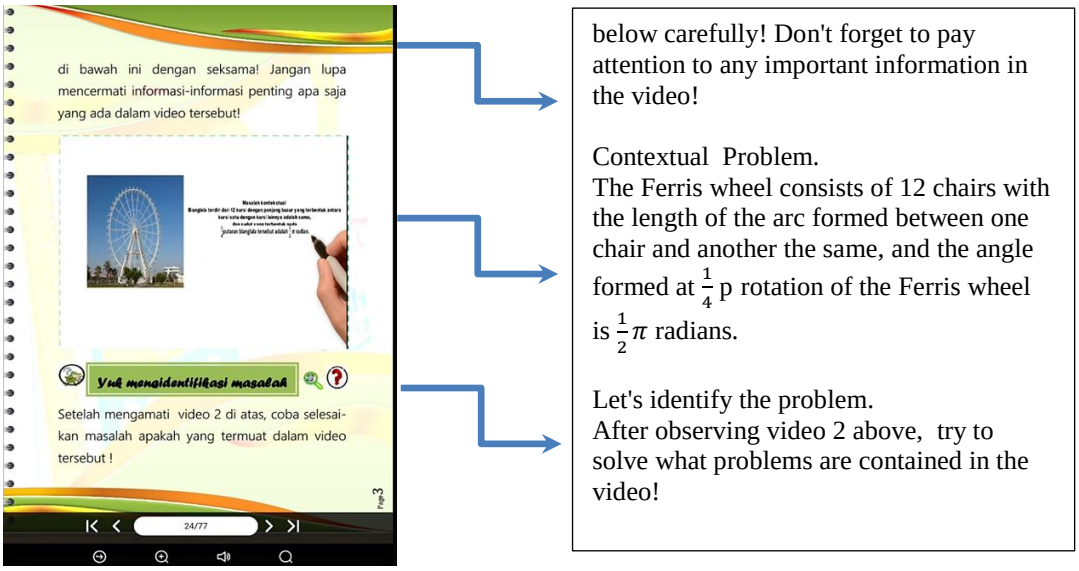


FIGURE 5. Video features presented in full in a digital module

This feature allows users to access the entire module material when it displays videos containing contextual issues offline. This feature shows the fulfilment of the adaptive characteristics of a module. This digital trigonometry module is packaged in such a way according to the development of science and technology so that users are more flexible in using the module even though the user does not have an internet quota. This easy and adaptive accessibility allows users of this digital module to learn the entire learning material from a particular unit of competency. Users are allowed to learn thoroughly by packaging the material into a unified whole supported by technology. Although there are advantages that can be used in digital trigonometric modules, in its implementation for the latest android version above version 11.0, it has not been developed, and the application still requires the creation of book configs.

Using trigonometric digital modules applied to this android platform shows that using smartphones during classroom learning can improve students' abilities and motivation, like Setyaningrum dan Waryanto's research result [21]. By using this digital module, both students and teachers are conditioned to use information and communication technology collaboratively without being limited by time and space, so that whenever and wherever they can communicate. This is in line with what was conveyed by Koc [22] that the integration of information and communication technology in learning can encourage more positive interaction and collaboration between students and teachers. Therefore, it is important for teachers to be able to design interactive learning according to the needs and characteristics of their students so that the quality of learning is gu aranteed and teaching effectiveness is achieved [23].

CONCLUSION

The digital trigonometry module based on the discovery learning model developed in the research is said to be successful if it meets the valid, practical, and effective criteria. Therefore, the data that has been collected is analyzed to determine the three eligibility criteria above. The validation analysis results show that the developed digital module has met the very good category in terms of material with an average score of 94 and the very good category in terms of media with an average score of 99. This trigonometric digital module, based on the discovery learning models and oriented toward critical thinking skills, also met the practicality of product development. It can regard the results of student responses in the good category, with an average score of 98.92. The results of the evaluation of the implementation of this digital module also show the module's effectiveness in improving students' critical thinking

skills during trigonometry learning, as indicated by the results of inferential and descriptive statistical tests. From the two statistical tests, it can be seen that there is a significant difference between the pretest and posttest scores.

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