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Development of Geometric Transformation E-Module Assisted by GeoGebra Software to Enhance Students' Mathematical Abilities during the COVID-19 Pandemic

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Abstract

During COVID-19 pandemic, teaching and learning was changed from face-to-face learning to online learning. There were many obstacles in learning mathematics by online-based learning. Such as geometric transformation, some material needs to be represented by a graphic or image, so that students will be easier to learn. This research was aimed to develop geometric transformation e-module assisted by GeoGebra software. The method of this research was used 4D-model developed by Thiagarajan, Semmel, and Semmel. The final draft of the e-module was validated by media and material experts. The results of this research showed that E-module was valid and feasible to be used in geometric transformation learning process. The feasibility of the module was proven by the average score of the validity test was 88% and 86.67%, that can be converted to very good criteria. A small group trial in using e-module obtained student responses is 82.30% which means that the e-module is good and easy to use. This study has implications in education, that can be used to enrich students' knowledge in the learning process of geometric transformation material, increasing student's activity, motivation, and learning outcomes.

Keywords: *E-module,* GeoGebra, *COVID-19 Pandemic*

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Abstrak

Selama pandemi COVID-19, proses belajar mengajar diubah dari pembelajaran tatap muka menjadi pembelajaran daring. Banyak kendala dalam pembelajaran matematika dengan pembelajaran berbasis online. Seperti transformasi geometri, beberapa materi perlu direpresentasikan dengan grafik atau gambar, agar siswa lebih mudah mempelajarinya. Penelitian ini bertujuan untuk mengembangkan e-modul transformasi geometri berbantuan perangkat lunak GeoGebra*. Metode penelitian ini menggunakan model 4D yang dikembangkan oleh Thiagarajan,* Semmel*,* and Semmel*. Draf akhir e-modul divalidasi oleh ahli media dan materi. Hasil akhir dari penelitian ini menunjukkan bahwa E-modul sudah valid dan layak digunakan dalam proses pembelajaran transformasi geometri. Kelayakan modul dibuktikan dengan skor rata-rata uji validitas 88% dan 86,67% yang dapat dikonversi menjadi kriteria sangat baik. Uji coba kelompok kecil dalam penggunaan e-modul diperoleh respon siswa sebesar 82,30% yang berarti e-modul sudah baik dan mudah digunakan. Penelitian ini berimplikasi pada pendidikan, yaitu dapat digunakan untuk memperkaya pengetahuan siswa dalam proses pembelajaran materi transformasi geometri, meningkatkan aktivitas, motivasi, dan hasil belajar siswa.*

INTRODUCTION

During the COVID-19 pandemic, the implementation of the learning process at school has changed (Anggraini & Mahmudi, 2021; Mairing et al., 2021). It is carried out a great impact on the educational aspect. The most noticeable change was the implementation of learning that is held face-to-face in the classroom turns into virtual learning (Gillett-Swan, 2017). However, the virtual learning process has some problems practically (Curtis & Lawson, 2001; Handayani & Irawan, 2020). It also affects Students' mathematical abilities which are decreasing.

A student's mathematical ability refers to their proficiency and skills in various mathematical concepts and problem-solving within the field of mathematics (Al-Mutawah et al., 2019). Mathematical ability can be seen as the capacity to solve mathematical problems effectively. It involves the ability to perform mathematical tasks, solve quantitative problems, and understand mathematical concepts (Lerman, 2020). Student's Mathematical ability can be influenced by various factors such as self-efficacy, conceptual understanding, procedural knowledge, and problem-solving skills (Cano & Lomibao, 2023; Hoffman & Spatariu, 2008). Students' mathematical ability is really needed during the mathematics learning process (Setiawan et al., 2022). In Highly able mathematics students should independently demonstrate the ability to display mathematical thinking and have a keen awareness of mathematical structure, patterns, and relationships. They should also be able to reason logically, communicate mathematically, and make connections between mathematical concepts and other disciplines (Looi & Kadosh, 2016). However, mathematical ability of Indonesian students remains below standards as compared to those in other nations (Argina et al., 2017). Indonesian students' mathematical ability is only placed 72 out of 79 nations in the 2018 Program for International Student Assessment (PISA) survey, with an average score of 379, which is lower than that of Indonesia in 2015, which was ranked 63. The most recent educational innovations must be available to give students and instructors the chance to adequately complete off-class learning to overcome the generally poor mathematical ability of Indonesian students. To make learning more advanced and interesting, it becomes necessary to design a concept and process for information technology-based education. So, Indonesian student's mathematical abilities must be improved by implementing appropriate learning methods and developing learning media or module (Sutisna et al., 2018; Ulandari et al., 2019). During COVID-19 Pandemic, students cannot manage their learning well due to

the limitations of the learning process. They tend to reduce their understanding of mathematical material. To prevent science and mathematics concepts from becoming dull, it is imperative that aspiring teachers learn to work with CTL as an antidote to knowledge transfer (Lestari et al., 2020; Mukwambo, 2016). So, teachers are forced to create various innovations to achieve effective learning. Teachers can use audio-visual media to engage students' interests, avoid giving too many tasks, and provide contextual assignments that are in accordance with the daily life of students.

In mathematics, audio-visual media is needed to visualize abstract material. The application of technology is a new alternative as a learning media in online learning (Muqorobin & Rozaq Rais, 2020). The use of technology provides great benefits in learning mathematics during online learning. One of the computer software that provides many benefits in learning mathematics is GeoGebra. GeoGebra is an online software that is available for free. It can be used as a mathematics learning media that can help teachers to design effective learning (Arbain & Shukor, 2015; Negara et al., 2022; Suryani et al., 2020) and assist lecturers in higher education (Sulistyawati & Rofiki, 2022). Based on Abramovich (2013), it can be used to learn geometry, algebra, and calculus at grade level and different ways of teaching.

Geometry is the oldest branch of mathematics. One of the topics in geometry is geometric transformation. The concept of geometry transformation is built by the concept of geometry and the concept of related interrelated functions (Malatjie & Machaba, 2019). Geometric transformations are very useful for developing spatial skills, reasoning skills in geometry, and strengthening proofs in the field of mathematics (Hanafi et al., 2017). Additionally, learning geometric transformations will provide many opportunities for developing visualization skills (Paradesa, 2016). Visualization aids play an important role in learning geometric transformations. By using display data visualization, it will be easier to see data that is hard to be viewed while thinking (Healy, 2018). For this reason, innovation in learning mathematics is needed using GeoGebra software. By GeoGebra, the teacher will be easier to demonstrate or visualize geometric transformation concepts, and it can also be used in the construction of mathematical concepts.

Based on the results of interviews with teachers at five schools in Sidoarjo and Surabaya city, during online learning, mathematics teachers in schools convey learning by providing explanations but giving little illustrations. They tend to use Microsoft PowerPoint as a learning media. In geometric transformation, students find it difficult to illustrate how the results of the transformation of geometric shapes. In addition, the mathematics learning process held at the SMK Manba'ul Ihsan Gresik during the pandemic was also limited to online learning using PowerPoint media and conventional textbooks. This affected students' mathematical abilities, especially in geometry transformation material, which was very low. In line with research conducted by Liono et al. (2021) and Medina Herrera et al. (2019), information was obtained that during online learning, students experienced difficulties in visualizing the transformed objects. Based on the information that many students have difficulty learning geometric transformation, teachers need to provide various alternatives to teaching geometric transformation, especially during online learning in the pandemic era. One of the alternatives is involving technology or the mathematics application in the learning

process, so that, students can practice math in a fun and engaging way.

Many researchers have used GeoGebra to study geometry. Faizah and Astutik (2017)have developed student worksheets with the help of GeoGebra and linear programming material and are stated to provide effective results to improve students' understanding. Setiawati et al. (2021) produced student worksheets based on GeoGebra-assisted guided discovery on the material of plane that is valid, practical, and effective. In the research conducted by Andarwati and Hernawati (2013), the students' worksheet that has been developed was valid and effective to use in trigonometry. Suryani et al. (2020) developed a learning module on triangle material using GeoGebra so that it obtained a good practical result. Paradesa (2016) and Owusu et al. (2023) have developed teaching materials assisted by GeoGebra software in the transformation geometry course class. Most of the existing research developed worksheets for students in school and a module assisted by GeoGebra Software for university students in college. However, there are limited studies that integrate GeoGebra in the module that is specifically used by teachers as teaching material for transformation geometry in class. Even though, by integrating GeoGebra in the module it really helps students in understanding transformation geometry material.

Based on the explanation, GeoGebra has been widely used to help study various learning subjects. However, A few teachers in Gresik-East Java used GeoGebra to help improve students' understanding, especially on geometric transformation material. Moreover, the availability of innovative modules during online learning is very limited. Hence, this research aims to develop an e-module assisted by GeoGebra Software to improve students' understanding of geometric transformation which is expected to help visualize objects.

METHOD

This research is development research using the Four-D or Thiagarajan model, which consists of four steps, define, design, develop, and disseminate (Thiagarajan et al., 1974). The product of this research was an E-module of geometric transformation assisted by GeoGebra Software. The need analysis was carried out on the defining step by conducting the analysis of the student's characteristics, the curriculum applied, and formulating learning objectives. Then, the researchers compile the E-module design. In the designing step, Thiagarajan formulates 4 steps, i.e., criterion test construction, media selection, format selection, and initial design. Then, the product is tested for validity and effectiveness in the developing step. The product of this research was validated by two experts, a lecturer of the Educational Technology Department of the University of PGRI Adi Buana Surabaya and the teacher as the experts on the mathematics material. After the product was claimed as valid by the experts, then it limited trial was conducted on the eleven-grade students to test the effectiveness of the product.

The research instruments used are 1) an expert validation questionnaire. There are two types of expert validation questionnaires, content, and design validation; 2) students' response questionnaire; and 3) evaluation test sheet. It is the instrument used to measure student learning outcomes after carrying out learning using the e-module developed in this research.

This module will be tested on 15 students of class XI in SMK Manba'ul Ihsan Gresik. Most students at SMK Manba'ul

Ihsan Gresik live in Islamic boarding schools where access to technology is still minimal. Students can use information technology while at school. Whereas during a pandemic, they are required to study from home. They are not used to interacting with information technology, so that, it is very necessary to provide a module that contains steps for using the GeoGebra software so the geometry transformation material can be more easily understood.

The last step is analyzing the data obtained from the research. The researcher used quantitative and qualitative analysis. The data obtained is in the form of numbers, it will be analyzed using quantitative method, then converted into qualitative data that will be used to assess the product's validity. The evaluation criteria of the module are 1) valid based on the experts if the average of the average score is greater than 75%, 2) the average student response obtained is in the "Good" category, and 3) more than 80% of students in the class scored greater than 80.

RESULTS AND DISCUSSION

Results

The product of this development research is an e-module that meets the valid criteria. The development of the module in this research is assisted by GeoGebra software which aims to help provide clearer visuals to students in understanding the concept of geometric transformation. The results of this research can be described at each stage of the Four-D models (Thiagarajan et al., 1974) of research and development as follows.

Define

In the defining step, the need analysis was carried out by conducting the analysis of the student's characteristics, the curriculum applied, and formulating learning objectives. Based on the field survey, the students were less interested in learning mathematics during the online learning process. They found some difficulties to understand the concept of geometric transformation using pictures in the textbook. Some teachers experienced problems in providing clearer visuals to students during the online learning process. From that problem, the researcher took the initiative to provide an e-module assisted by GeoGebra software. The e-module developed in this study has been adapted to the applicable curriculum in the school, 2013 curriculum. Then, researchers formulate learning objectives that are in accordance with the curriculum.

The e-module was developed using an easy language, providing some images and links to the online GeoGebra to make it easier to the students to make clearer visuals about the geometric transformation. In this module, researchers provide some problems equipped with the steps to solve the problem using GeoGebra Software. It was developed using an interesting layout so that the students do not feel bored to learn mathematics.

Design

The second step of the research is designing the product. In the designing step, Thiagarajan formulates 4 steps, i.e., criterion test construction, media selection, format selection, and initial design. The researchers constructed a criterion test, as the first action to find out students' initial abilities, and as an evaluation tool after implementation of the product. In the media selection, the researchers selected and determined the right media for the presentation of subject matter that is adapted to

curriculum analysis, analysis of student characteristics, and school facilities. The media selected in this research was the e-module developed using flipbook maker and it will be presented trough Zoom Meeting and Google Meet during online learning process. Then the format selection was adjusted to the characteristics of the students and the approach learning used student's centered learning. It will be developed by emphasizing on the interesting aspect and is easy to understand in accordance with the curriculum used in the school. The fourth step in this design stage is an initial design. In this step, the researcher made an initial design of the e-module and research instrument that will be used on the limited trial of the product. The research instrument developed in this step consists of 3 instruments, a validation questionnaire, a student response questionnaire, and an evaluation test. The following is a brief description of the design of the module.

The e-module developed consists of a cover, table of contents, instructions for using the module, mind map, geometric transformation materials, materials on GeoGebra software, evaluation tests, summaries, and a bibliography.

The cover of the module contains the title, author's name, and publisher. It was designed to reflect the contents of the module. It can be seen in Figure 1.

Figure 1. Module Cover

The table of contents in the module or teaching material serves as a listing of the order of the content of the material. The material is arranged based on the sub-chapters contained in the competency indicators along with the correct page order.

Instructions for use contain instructions for using the module. It is intended that students can use this module properly and correctly. In addition, a mind map is added which aims to show students what material will be studied. It is displayed in Figure 2 and Figure 3.

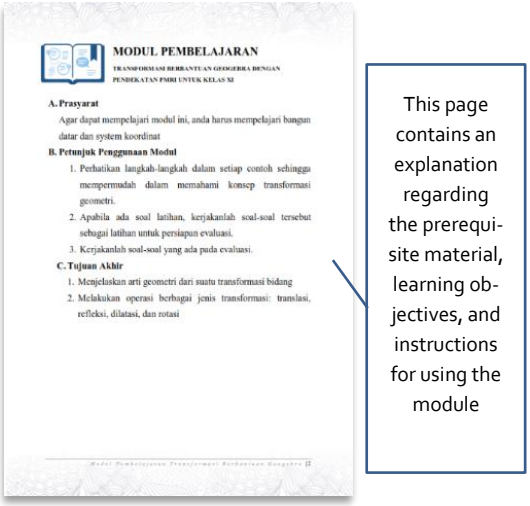

Figure 2. Instruction for Using e-Modul

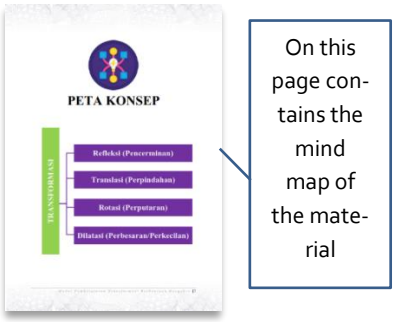

Figure 3. Mind Map of Geometric Transformation

The transformation material in the module contains reflection, translation, rotation, and dilatation sub-materials. In addition to presenting learning materials, this module also provides examples of the problem and the problem-solving of the geometric transformation material. It served the GeoGebra Software used in the

material. It can be shown in Figure 4.

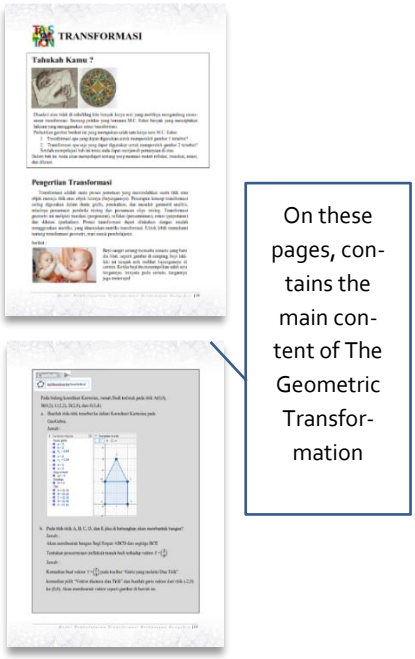

Figure 4. The Material of Geometric Transformation

The evaluation test provided in this module serves to assess student learning outcomes after using the module as teaching material in the learning process. Evaluation tests are prepared to refer to core competencies and basic competencies in the transformation material. Evaluation test problems are also equipped with an answer key so that students can study independently using this module. The evaluation test in this module contains 8 questions related to the transformation material.

The summary of a module is very important for students to remember the material that has been studied briefly, densely, and clearly. The initial design of this step is called draft 1 (see Figure 5).

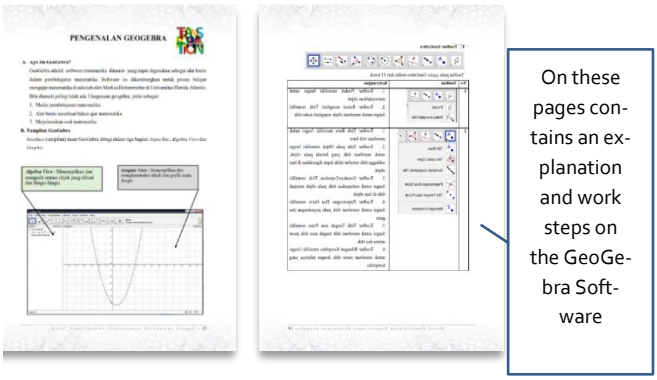

Figure 5. The Summary of the Material

Develop

In the development step, the e-module was compiled based on draft 1 which was designed on the previous step. The e-module produced at this step was limited to the initial product that still need to be validated and tested on students. The initial product in this stage is called draft 2.

The next step on this step was to validate draft 2 to the experts. Draft 2 of the E-module was validated by media and material experts. Module validation results were listed in Table 1.

Table 1. Recapitulation of Media Experts' Validation

Aspect	Indicator	Item
The e-module presentation	Design	4
	Text used in the e-module	5
	Image on the e-module	5
Media used on the e-module	Effectiveness of the media	4
	Instruction of use	4

Score: 22 | Average: 4.4 | Percentage: 88%

Based on Table 1, it can be known that the media validation got the percentage 88%. It can be categorized as "Very Good".

The results of material expert validation were listed in Table 2.

Table 2. Recapitulation of Material Experts' Validation

Aspect	Indicator	Item
Conformity of Material with SK and KD	Completeness of the material	5
	The breadth of the material	4
	The brief of the material	3
Material validity	Concept and definition accuracy	5
	Procedure and Algorithm accuracy	4
	accuracy of examples and questions	5

Score: 26 | Average: 4.33 | Percentage: 86,6%

Based on Table 2, it can be known that the material expert's validation got the percentage 86.67% which can be categorized as "Very Good".

From the experts, researchers got some advice to revise the e-module. The advice needs to be revised in the summary section and the example need to be arranged from simple to complex questions. Then it was revised based on the expert's advice, and draft 3 was obtained and ready to be tested in the trial class that consist of 15 students.

The next step is a limited trial to find out students' responses to using the e-module and the student's learning outcomes after the learning process using the e-module. The student's responses obtained from the trial class can be seen in Table 3.

Table 3. Recapitulation of Students' Response

Aspect	Score	Average	Percentage
Ease of use	66	4.40	88%
Presentation	62	4.13	82.6%
Quality of material	63	4.20	84%
Using contextual content	56	3.73	74.6%
Total Average			**82.30%**

Number of Students: 15

Based on Table 3, it can be known that the total average of the student's responses is 82.30% which means that the e-module is good and easy to use.

The students' learning outcomes after the learning process using the e-module can be seen in Figure 7.

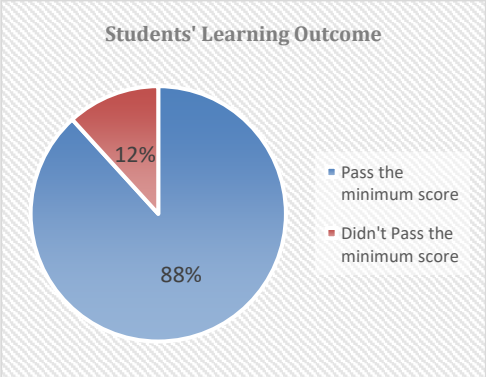

Figure 6. Students' Learning Outcomes

The information obtained from Figure 6 was that many students can be passed the minimum score for mathematics subjects set at school, namely 80. 13 students scored more than 80 and the rest (2 students) were still less than 80. They were tested after following the learning process using e-modules. It means that the e-module developed in this research is effective to use in the transformation geometry learning process.

Based on the limited trial of the e-module, researchers revised the e-module to be easier to use and understand by the students. Then, researchers got the final draft of the e-module. Hence, the e-module of geometric transformation developed in this research can be categorized as effective and ready to use in the class.

Disseminate

The e-module of geometric transformation that has been produced is not disseminated. It was handed over to the mathematics teachers at school to be implemented in the teaching and learning process.

Discussion

This research produced an e-module of

geometric transformation assisted by GeoGebra which is expected to help visualize objects in transformation geometry, so it can be increased the students' mathematical ability (Sutisna et al., 2018). In the developing step, the expert validation for the e-module was very good and worthy to be used. It also got good and easy-to-use categories, rated by the students in the limited trial class. The use of e-module assisted by GeoGebra software was acceptable in learning on online learning to help students understand and increase the student's mathematical ability in the subject of geometric transformation. By using GeoGebra Software, the e-module expect to have a positive influence on improving the students' mathematical ability and understanding of mathematical concepts in the learning process (Paradesa, 2016; Pratiwi, 2016; Setiawati et al., 2021).

GeoGebra Software used in the e-module, have some advantages on the learning process based on the results of the various studies, improved quality of learning, enhanced understanding, increased enjoyment during the learning process, improved knowledge retention, improved students' achievement, and support for mathematical proofs (Atteh & Asare, 2022; Birgin & Uzun Yazıcı, 2021; Celen, 2020; Shadaan & Leong, 2013; Tamam & Dasari, 2021). So, the use of GeoGebra software in this e-module is expected to help improve students' mathematical abilities.

The development of e-modules assisted by GeoGebra-assisted transformation geometry learning provides various benefits to enhance Students' mathematical ability. Firstly, E-module was designed for knowledge development and mastery competencies (Serevina et al., 2018). Lim et al. (2005) stated that the research on e-module creation showed that the e-module complies with student needs in terms of content, instructional techniques, teaching process, and software use. It in line with the statements of Sutisna et al., (2018) that Indonesian students' mathematical ability will be more advanced and interesting if it designed a a concept and process for information technology-based education.

Secondly, e-module can enhance teaching by supporting pedagogical content because it engages students to be more active by understanding the geometric transformation material on GeoGebra software (Yulando et al., 2019). This is in line with Logan et al. (2021) who stated that the development of e-module allows students to be better engaged with the content and more actively involved in their own learning. So, by using the e-module, Student's Mathematical ability can be increased based on various factors such as conceptual understanding, procedural knowledge, and problem-solving skills (Cano & Lomibao, 2023; Hoffman & Spatariu, 2008).

Thirdly, e-module development can help estimate course length, development time, and total course cost (Yaniawati et al., 2021). Fourthly, e-module development has been studied for its validity, practicality, and effectiveness (Nurhikmah et al., 2021). Based on the study done by (van der Merwe et al., 2020), shows that students are more prepared in the learning process and obtain better results by using the module. So that, students will be more engaged with the mathematics learning process, and it is expected that it can have a positive impact on students' mathematical abilities.

Besides the benefits of e-module developments, there are also some potential drawbacks to consider. One of the disadvantages is that e-module in e-learning requires the accessibility of technology. Additionally, some students may struggle with self-directed learning and

require more guidance from the teachers (Kurniati et al., 2021). The last disadvantage of e-module development is that it may not be suitable for all types of content (Trilestari & Almunawaroh, 2021).

Based on the results of the analysis regarding the advantages and disadvantages of e-module development, it can be concluded that the development of e-modules assisted by the GeoGebra software provides benefits to the learning of geometric transformation, but in its use, teachers need to assist students to achieve the set learning objectives.

Implication

The development of an e-module assisted by GeoGebra software that has been carried out in this study has implications for education. E-modules of geometric transformation assisted by GeoGebra software can be used as enrichment material in the learning process of geometric transformation material, because by using this e-module students can get a more concrete representation of the results of transforming geometric objects through the GeoGebra software. GeoGebra facilitates the teaching and understanding of abstract transformation principles or concepts (Birgin & Acar, 2022; Birgin & Topuz, 2021; Dahal et al., 2019, 2022).

Students can learn geometric transformation material independently assisted by modules and GeoGebra software without the teacher's help, so that students' activity can be increased. Based on the student's responses to this research, the e-module is good and easy to use, so this can increase student learning motivation and can change the mindset of students who have considered mathematics as a difficult subject to be easier. Then, based on the test results, 86.67% of students passed the minimum score of the mathematics subject set on the SMK Manba'ul Ihsan Gresik. It means that the e-module can help to increase the student's mathematical abilities.

Limitation

The limitation in this research is the development of the module, which is limited to limited trials, so it is necessary to carry out wider dissemination to determine the effectiveness of using the module. Besides, the subject in this study was only in one school, then it could then be implemented for students in other schools.

The material that can be assisted with GeoGebra software is not only limited to transformation geometry, but can also be used in other relevant materials, such as linear programming, linear equations, inequalities, or algebra so that it can be developed into a wider material. The use of GeoGebra in mathematics learning is extremely beneficial for teachers in explaining mathematical material in the form of appealing visualization to develop students' understanding (Adelabu et al., 2022; Khansila et al., 2022; Munyaruhengeri et al., 2023; Nursyahidah & Albab, 2021; Suryani et al., 2020). Thus, students can be more helpful in studying mathematics material. In addition, this research can be continued to disseminate the developed e-module to see the effectiveness of its widespread use.

In the development process, the limitation of this study, the book was only validated by two validators, namely the media validator and the material validator. Furthermore, validation can also be carried out by linguists and graphic experts to obtain more accurate data in the assessment of the developed modules to understand the material.

CONCLUSION

To conclude, a geometric transformation e-module assisted by GeoGebra software was rated as valid by the media experts,

the material experts, and the students. The geometric transformation e-module assisted by GeoGebra software can be declared effective to enhance the students' mathematical ability based on the results of limited trials in class. The e-module will be ready to implement for the students in senior high school. The development of an e-module assisted by the GeoGebra software provides benefits to the learning of transformational geometry, but in its use, teachers need to assist students to achieve the set learning objectives. Based on the result of the development of a geometric transformation e-module assisted by GeoGebra software can be continued research to disseminate the developed e-module to see the effectiveness of its widespread use in increasing the students' mathematical ability, especially in geometric transformation.

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