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E-guided discovery module for cartesian coordinates topic in junior high school

Dian Permatasari[1], Tatang Herman[2*]

[1]Pendidikan Matematika, Universitas Islam Negeri (UIN) Sunan Kalijaga Yogyakarta, Daerah Istimewa Yogyakarta 55281, Indonesia
[2*]Pendidikan Matematika, Universitas Pendidikan Indonesia, Jawa Barat 40154, Indonesia
[1]dian.permatasari@uin-suka.ac.id, [2*]tatangherman@upi.edu

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*Corresponding author

Abstract:
Guided Discovery learning is an approach that actively engages students by allowing them to discover and investigate concepts independently. However, the development of guided discovery integrated with technology, especially on Cartesian coordinates, is still limited and has not been widely explored. Therefore, this study explores the ıntegrating guided discovery approach in an e-module for cartesian coordinates topıc of junior high school, involving one teacher and 32 students in one of the junior high schools in Purworejo. Qualitative data analysis was conducted through documentation and interviews, which were then organized into data reduction, display, and verification steps. The results indicate that the E-Guided Discovery Module require technical and pedagogical improvements. Recommendations for further development include enhancing the user interface, adding interactive features, and developing additional guidance. The E-Guided Discovery Module is an effective tool for improving students' mathematics learning, with the teacher's role being crucial in providing necessary guidance and support. As a recommendation, future research could explore the impact of varying levels of teacher guidance within E-Guided Discovery Modules to determine the optimal balance between student independence and necessary instructional support for enhancing mathematics learning outcomes.

Keywords: Cartesian Coordinates; E-Module; Guided Discovery; Junior High School.

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Introduction

Guided Discovery learning is an approach that actively engages students by allowing them to discover and investigate concepts independently (Yolanda, 2020). It emphasizes hands-on practice or investigations that guide learners toward predetermined or predictable sets of data or responses (Hammerman, 2006). According to Bruner, Guided Discovery is an inquiry-based teaching method grounded in constructivist theory. It involves problem-solving situations where students use prior knowledge and experience to uncover facts, correlations, and truths (Ishartono et al., 2016). In this approach, students are actively involved in learning through understanding concepts and principles, while teachers provide support, facilitating experiences that help students independently discover these principles. This process helps students develop creativity and build relevant knowledge applicable to solving real-world problems.

Guided Discovery has several benefits (Saumell, 2012), including: (1) encouraging analytical learning, (2) utilizing learners' cognitive skills, (3) enhancing critical thinking skills, (4) engaging students in problem-solving tasks, (5) helping learners realize and articulate their mental processes, (6) making learners active participants in the learning process, and (7) enabling learners to understand better and remember what they have worked on themselves. Research indicates that Guided Discovery can enhance student motivation and conceptual understanding (Maulidar et al., 2016; Sapitri et al., 2023). A study by Luthfiani and Yerimadesi (2022) found that guided discovery-based e-modules significantly improved student learning outcomes. Students using these e-modules showed significantly higher learning outcomes improvement than those in control classes without e-modules.

Incorporating Guided Discovery activities into teaching materials is essential, particularly in the context of the Industrial Revolution 4.0, which demands teaching materials that align with current technological advancements. Technology-based teaching materials are the most effective approach for junior high school mathematics education because they are easily adaptable to students' learning environments (Nasrudin et al., 2018). Additionally, electronic-based technology can optimize student competencies more effectively than other types of technology (Higgins et al., 2016). Thus, electronic-based teaching materials are crucial for junior high school students to understand mathematics. Teaching materials play a critical role in the teaching process for teachers (Aisyah et al., 2020; Subekti & Prahmana, 2021).

One such teaching material is the electronic module (e-module), which can make students more enthusiastic about learning and understanding the material the teacher provides (Subekti & Prahmana, 2021). An e-module is a technology-based learning tool that contains material, methods, limitations, and evaluation techniques, designed systematically and attractively to achieve the expected competencies in digital form (Rochsun & Agustin, 2020). E-modules offer more advantages due to their interactivity compared to printed modules. One significant advantage is that students can review learning material independently as needed (King & Robinson, 2009; Sugianto et al., 2017; Thuneberg et al., 2018). E-modules can integrate images, audio, video, animation, and quizzes in one information technology-based device (AlAli et al., 2023; Dewi & Primayana, 2019; Rahmadila et al., 2022; Rochsun & Agustin, 2020). The interactivity of e-modules positively impacts the learning process and student outcomes (Suwatra et al., 2018). These modules facilitate flexible, high-mobility information technology-based learning (Solikin, 2018). They are most effective when used with blended learning systems for online and offline sessions (Istuningsih et al., 2018). Therefore, developing an e-guided discovery module is a viable alternative to technology-based teaching materials that can assist students in their learning process.

One mathematical topic that requires improved teaching materials is Cartesian Coordinates. Studies indicate that students often struggle with this material. Research by Subekti et al. (2021) shows that students frequently fail to analyze and solve problems related to Cartesian coordinates. Similarly, Lango & Lede (2022) found that many students make mistakes in determining the initial point, quadrant, coordinate lines, and drawing Cartesian coordinates. Students often draw the X and Y axes without considering the number line pattern and incorrectly place points and draw coordinate lines. These errors suggest that students have not mastered the basic concept of Cartesian coordinates. This topic is also a prerequisite for other mathematical subjects, such as linear programming (Tamarudin, 2020), where students must create coordinate points from systems of linear equations. Students often make mistakes when creating Cartesian coordinate systems and scales.

Additionally, when studying linear equations, students must understand Cartesian coordinates but usually struggle to determine points correctly (Putra, 2016). Mastering this material is crucial for students. One effective way to teach this material is using technology-based learning media (Hikmah & Maskar, 2020). Learning Cartesian coordinates requires students to read coordinate points accurately. Effective learning media for Cartesian coordinates must visualize objects on the coordinate system since visualizing abstract concepts concretely can enhance understanding. Therefore, developing technology-based teaching material such as an e-module with a guided discovery approach is essential to improving students' knowledge of Cartesian coordinates.

Some studies have developed guided discovery-based modules on various topics, such as quadrilaterals (Fisher, 2022), function (Iltavia, 2019), and geometry (Siregar et al., 2020). These modules have shown that learning becomes more enjoyable and improves students' problem-solving abilities in mathematics. Student's ability to learn independently and actively during the learning process can also develop through the presentation of problems. On the other hand, there are many studies (Istuningsih et al., 2018; Rahmadila et al., 2022; Rochsun & Agustin, 2020; Saumi et al., 2022; Zakiyah et al., 2019) developed e-modules using some approach like contextual approach, augmented reality, problem-based learning, scientific approach, etc. These studies show that e-modules can improve learning outcomes and problem-solving. However, some studies show that e-modules using discovery learning can improve concept understanding, learning outcomes, and problem-solving (Ilmi et al., 2023; Luthfiani & Yerimadesi, 2022; Ramli, 2022).

However, there is still limited research on developing guided discovery-based e-modules, especially on the topic of cartesian coordinates. While many studies have developed guided discovery-based modules and e-modules on various mathematical topics, such as quadrilaterals, functions, and geometry, as well as employed different approaches like augmented reality and problem-based learning, research on the integration of guided discovery in e-modules, particularly for Cartesian coordinates, remains sparse. This study aims to fill that gap by utilizing a step-by-step discovery learning process to enhance students' understanding and learning outcomes. On the other hand, this research used a step of discovery learning from Ishartono et al. (2016). Research indicates that these e-modules can enhance students' understanding of plane Pictures (Ramli, 2022). Therefore, this study aims to develop an e-guided discovery module on Cartesian coordinates. The research will benefit educators by providing an interactive tool to support diverse student needs and improve mathematics learning outcomes. The module will be developed using the Plomp Development Model, which includes analyzing student needs, designing the module with discovery learning steps, developing it with multimedia elements, implementing it in classrooms, and evaluating its effectiveness for further refinement.

Research Methods

This research is a descriptive qualitative study conducted at a junior high school (SMP) in Purworejo to develop an e-guided discovery module for mathematics learning. The e-guided discovery module is a technology-based teaching material that facilitates more interactive and practical learning, especially for complex topics such as Cartesian coordinates. This study utilized the Plomp development model, which consists of three main phases: Preliminary Research, Development or Prototyping Phase, and Assessment Phase (Haryati, 2012).

The Preliminary Research phase began with a needs analysis and a literature review. The needs analysis was conducted to understand the field situation related to the challenges faced during the learning process, particularly regarding the teaching materials used. Context analysis was performed by evaluating the Basic Competencies (KD) to identify the Competency Achievement Indicators (IPK) and learning objectives, ensuring that the developed materials align with the current curriculum and the student's learning needs. A literature review was also conducted to find references that support the research and to establish the conceptual framework to be used in the development of the e-module.

In the Development or Prototyping phase, the researchers designed and developed a prototype of the e-guided discovery module based on the preliminary research results. The initial step was to create a prototype that included systematically and attractively designed materials, methods, and evaluation tools. Next, a formative evaluation was conducted involving experts in education and technology. Feedback from this evaluation was used to improve and refine the e-module. The prototype was continuously revised based on feedback to ensure that the developed e-module meets the expected needs and standards.

Table 1. Likert Scale Criteria

No.	Score Range	Criteria
1.	0% - 20%	Very Inappropriate
2.	21% - 40%	It is in accordance with
3.	41% - 60%	Suitable Enough
4.	61% - 80%	In Accordance
5.	81% - 100%	Very Suitable

The Assessment phase aimed to determine the practicality of the e-guided discovery module prototype for the Cartesian coordinate topic. The research subjects included one teacher and 32 students. Data collection techniques used were questionnaire, documentation, and interview guidelines. The questionnaire assessed students' perceptions and experiences with the e-guided discovery module, focusing on content, language, usefulness, and graphical elements. The interview guidelines provided a structured framework for conducting in-depth interviews with teachers and students, allowing for collecting qualitative insights into implementing learning using the e-guided discovery module. Documentation included student work and performance data to validate the findings further. The instruments were validated through expert review to ensure they accurately captured the relevant data and were reliable for the research context. Data analysis in this qualitative study followed the procedures developed by Miles and Huberman, which included data reduction, data display, and data verification. All collected data sources were organized and sorted based on the research criteria in the data reduction stage. The requirements for measurement results using the Likert scale are shown in Table 1. In the data display stage, the researcher systematically summarized the data from respondents' answers to the interview questions. Finally, the data verification stage was conducted to conclude the application of ICT-based learning media on students' understanding of mathematical concepts in the Cartesian coordinate topic. These conclusions were then compared with relevant theories to ensure their validity.

Results and Discussions

This study utilized the Plomp development model, which consists of three main phases: Preliminary Research, Development or Prototyping Phase, and Assessment Phase (Haryati, 2012).

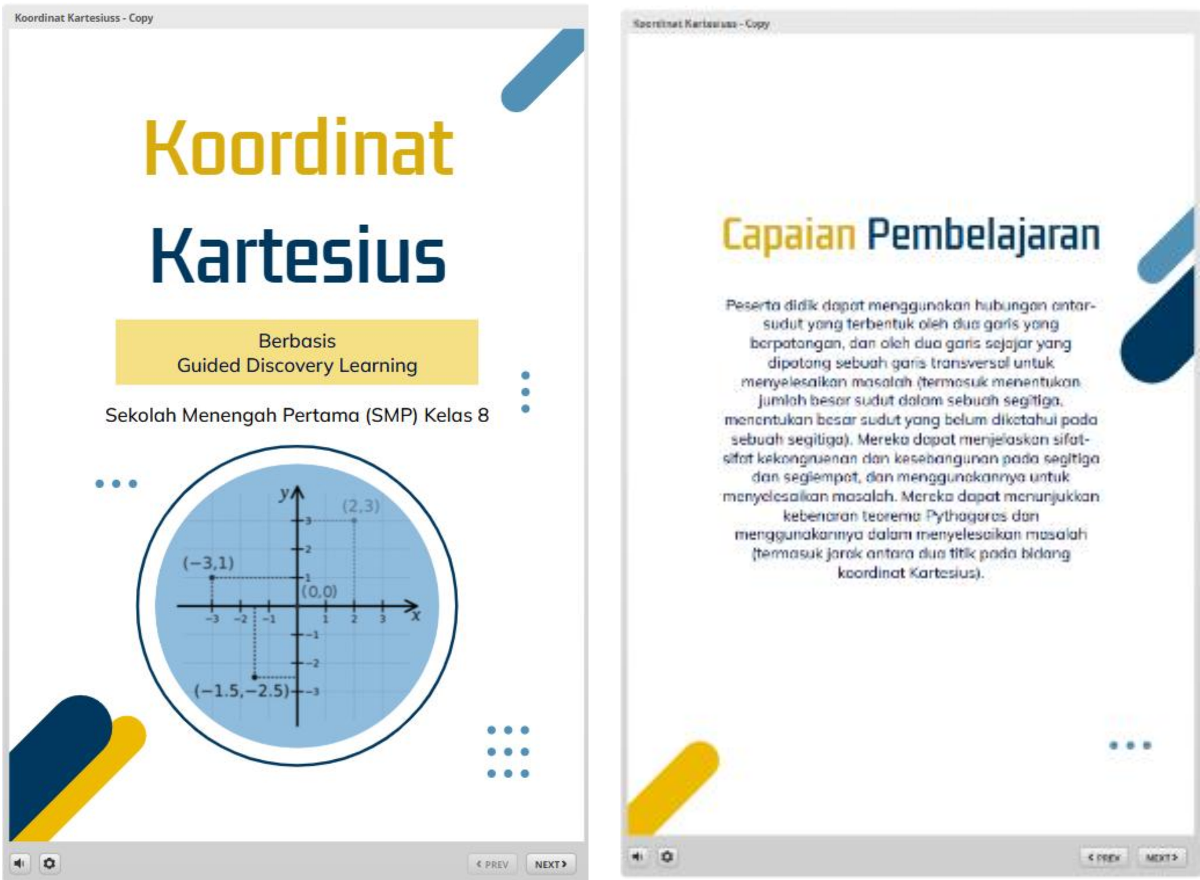
Preliminary Research

In the Preliminary Research Phase, steps were taken to identify the needs, context, and theoretical foundations that would guide the development of the e-guided discovery module. The first step was Needs Analysis, where the results of surveys from teachers and students revealed that some students were struggling to understand the concept of linear equations. Although the teaching process was already student-centered, teachers faced obstacles due to insufficient support from available teaching materials. Additionally, the available teaching materials at school were limited to printed books, Student Worksheets (LKPD), and modules. Therefore, an e-module based on guided discovery learning was needed to support students' self-directed learning. The second step was Context Analysis, where the curriculum and syllabus were evaluated to determine the relevant Learning Outcomes related to Cartesian Coordinate. Learning Outcomes was then elaborated into Learning Objectives Flow. The learning objectives formulated based on these indicators were through the e-module based on guided discovery learning, students would explore information from various learning sources, conduct simple investigations, and process information from various sources. The third step was Literature Review, where, based on literature research, the components found in the e-module included several practical elements for e-module preparation, including structure such as cover, table of contents, introduction, learning activities, exercises, evaluation, answer keys, scoring guidelines, and bibliography. In addition, the syntactic structure of guided discovery learning refers to a mathematics learning model called GDL (Guided Discovery Learning) with elaborated steps, from giving problems to implementing exercises. The Needs and Context Analysis concluded that learning material was needed to help students understand the concept of linear equations independently, which is in line with the demands of 21st-century learning. Therefore, an e-module on Cartesian coordinates was developed, covering the stages of the guided discovery learning model, structured based on practical guidelines for e-module preparation, and produced using the Plomp development model, referring to the book "An Introduction to Educational Design Research." The phases of this model are Preliminary Research, Development or Prototyping Phase, and Assessment Phase.

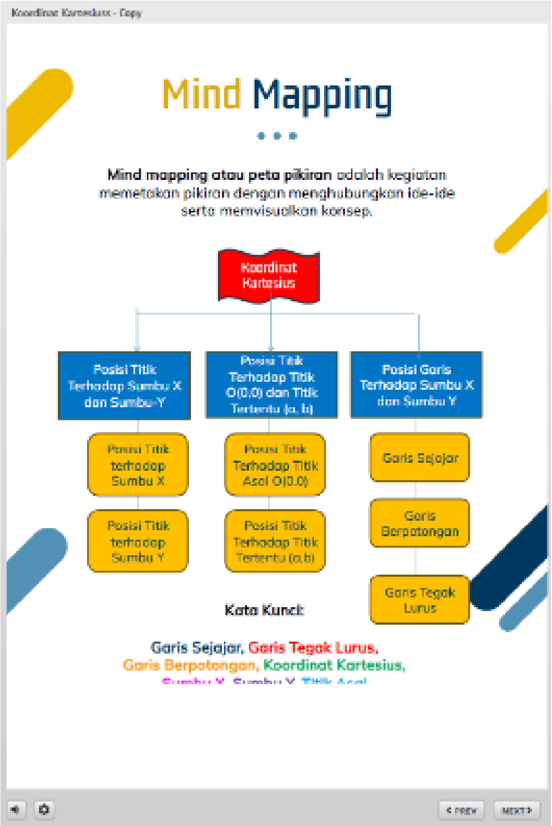
Development or Prototyping Phase

In the Development or Prototyping phase, the researchers focused on designing and refining the e-guided discovery module based on the findings from the preliminary research. The interactive e-module was initially created as an Articulate Storyline and converted into HTML5 format using iSpring Suite 11. After converting the emodule format to HTML5, the e-module is transformed into an Android application format using a website 2 APK builder application. The Android-based E-module is what students can utilize to learn anytime and anywhere. The initial step involved creating Prototype I, an e-module on linear equations using the guided discovery learning approach tailored for eighth-grade mathematics students. This prototype was systematically and attractively designed, incorporating the essential components identified in the literature review and adhering to the guided discovery learning syntax.

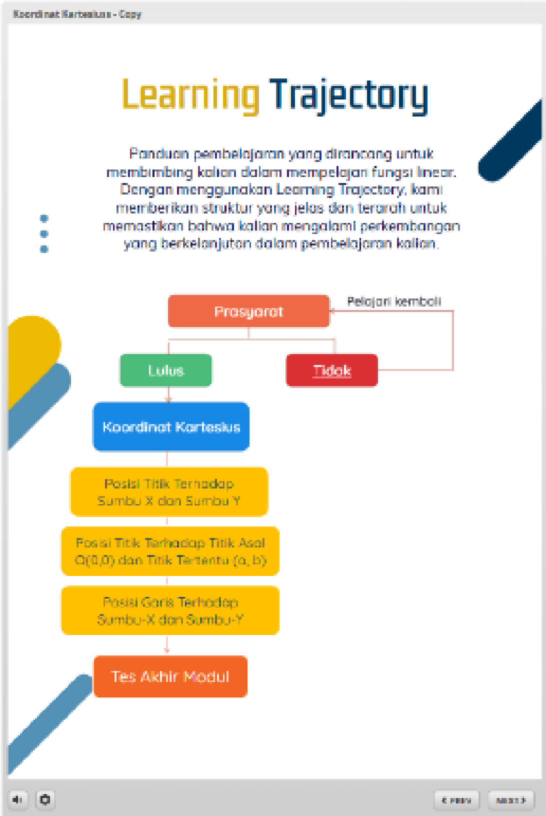
Following the development of Prototype I, a self-evaluation was conducted to ensure the inclusion of all necessary components. This evaluation revealed that some elements were missing, necessitating revisions. The resulting changes led to the creation of Prototype II. Some elements of this module are shown in Picture 1.



(a) (b)



(c)



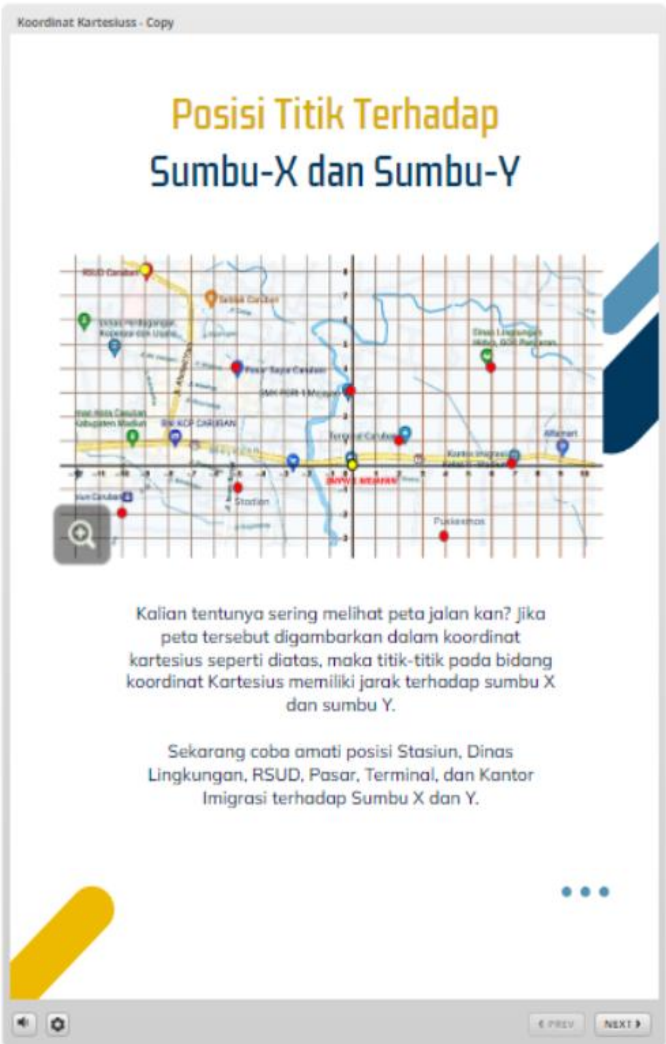
(d)

(e)

Picture 1. Elements of e-guided discovery module (a) Cover, (b) Learning Outcomes, (c) Mind Mapping, (d) Learning Trajectory, and (e) Prerequisite material test

Prototype II was subjected to further evaluation, highlighting the importance of visual and linguistic elements such as color selection, font clarity, and adherence to the Indonesian language rules (Ejaan Bahasa Indonesia - EBI). These enhancements aimed to improve the module's appeal and readability. Additionally, an Expert Review was conducted by educational practitioners and mathematics teachers. This review included both content validation, to ensure the e-module's alignment with guided discovery learning principles and scientific accuracy, and construct validation, focusing on content, language, usefulness, and graphical elements.

This learning model was integrated into the e-module as guided discovery that contains 6 stages (Ishartono et al., 2016). The first is giving problems. In the Giving Problems step, the teacher presents a problem, and students seek solutions independently. The given problem should include guidance on the direction and goals for students to find solutions independently. In the e-guided discovery module, students are presented with a problem related to Cartesian coordinates. They are asked to determine the distance between a point on a map, adjusted according to the Cartesian coordinates and the X and Y axes. This is illustrated in Picture 2.



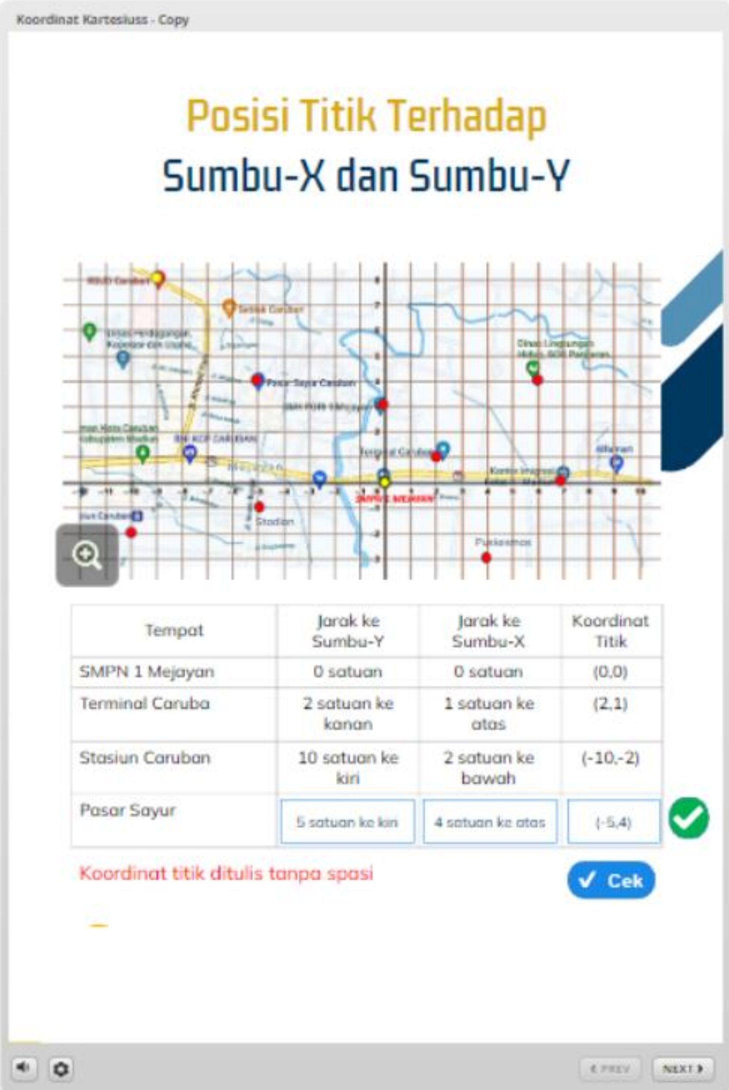
Picture 2. Examples of the Giving Problem Stage in the E-Module

In this problem, students are expected to determine the coordinates on the Cartesian plane by finding the distance of the point from the X and Y axes. The stimulation involves providing problems through questions, book recommendations, or other activities to stimulate students' curiosity to investigate independently (Mawaddah & Maryanti, 2016).

The second is Data Development. Students are asked to find additional data to continue the known data at this stage. Students are given examples of the distance from a place to the X and Y axes and then asked to find the distance from a place to the X and Y axes from the Market (Picture 3). The purpose is to gather as much relevant information as possible (Mawaddah & Maryanti, 2016).

Picture 3. Examples of the Data Development Stage in the E-Module

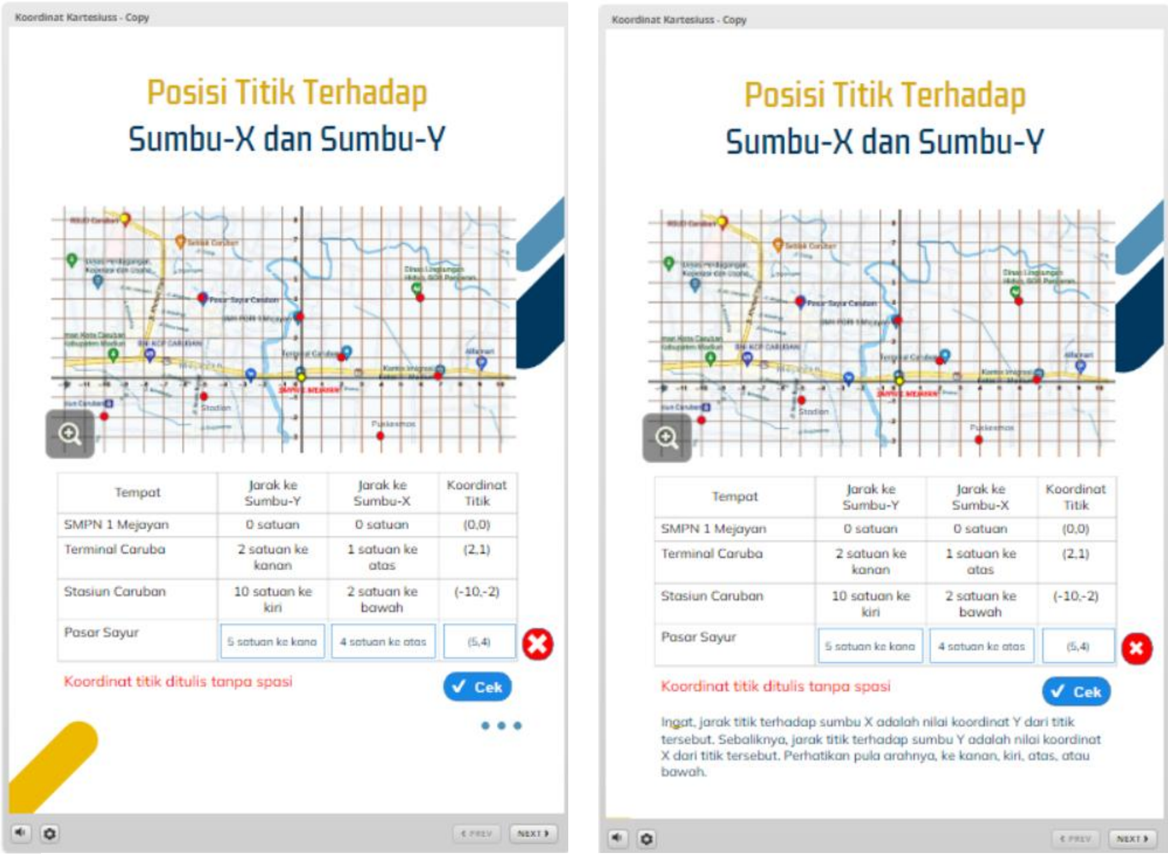
Some students may immediately understand the instructions in the e-module during this phase. Based on the implementation results, bright students could independently find the answers to the given problems. Table 4 is an example of a correct student answer.



Picture 4. Example of Correct Student Answer

Meanwhile, students who could not find the answers to the given problems needed guidance from the teacher. This aligns with Ishartono et al. (2016) statement that an intelligent student can find the answer to a problem without guidance. In contrast, students who cannot find the answers will need initial guidance. Guidance is provided in the form of questions developed from simple questions or hints. Thus, based on the implementation results, the e-module needs to facilitate the provision of guidance in the form of developmental questions, starting from the simplest ones at the Data Arrangement stage.

In data Arragement Stage, students organize the data obtained from the previous steps. Those who find the answers to the problem are asked to verify the accuracy of their answers. If they struggle, guidance in the form of developmental questions should be provided. Initially, the teacher provided this guidance, but the e-module now includes built-in assistance. Picture 5 shows the interface before and after revision.

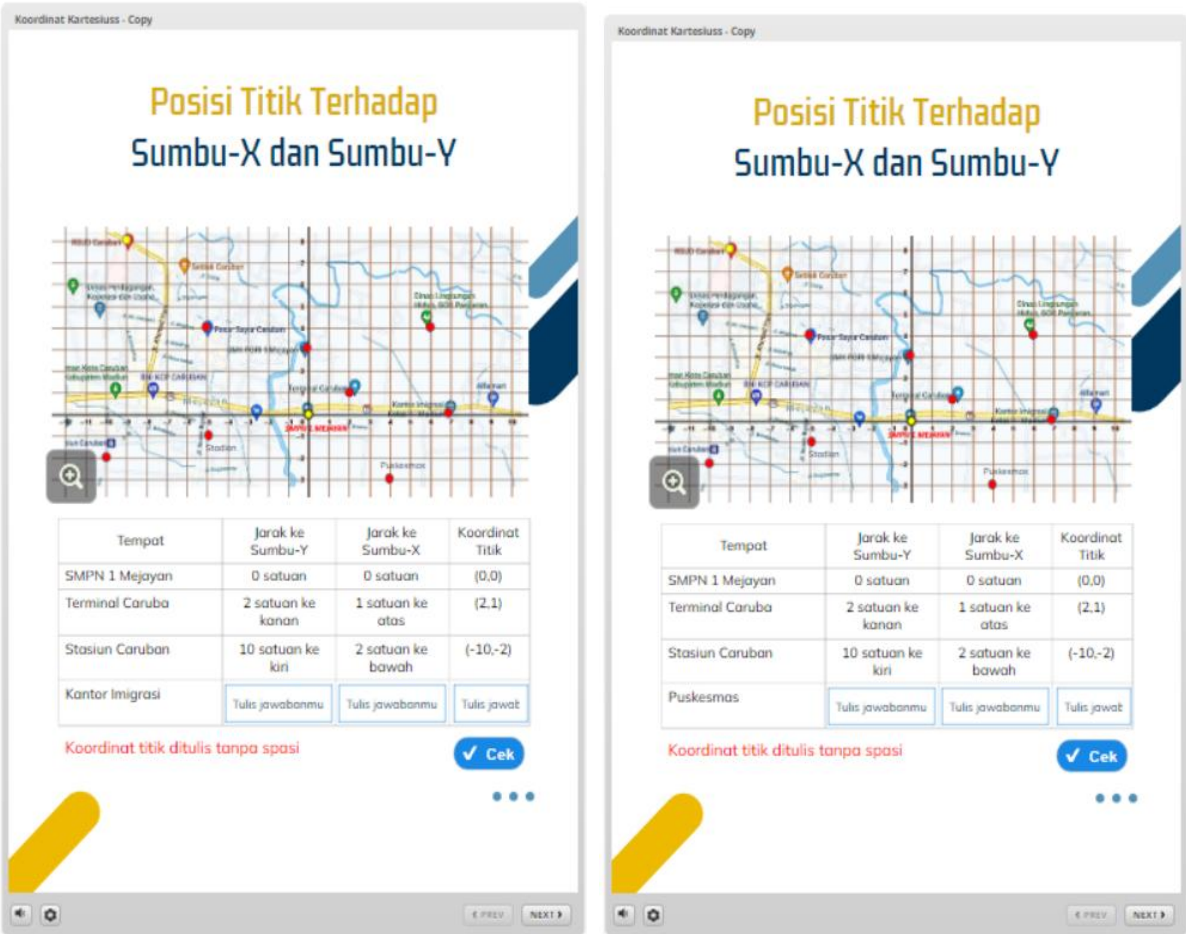


(a) (b)

Picture 5. Examples of the Data Arrangement Stage in the E-Module: (a) Before Revision and (b) After Revision

According to Ishartono et al. (2016), after the first guidance is provided, students who can obtain answers to the problem are asked to verify the correctness of their answers using the available data. Meanwhile, a second guideline is given to students who can still not obtain answers after the first guidance. The second guidance consists of questions to prepare the already listed data.

Then is data addition. Students in this stage are guided through adding new data, leading them to the concept or formula. This guidance hopes that students can find the intended formula or concept. For students who complete this activity, they can directly verify it in the next stage. In contrast, those who cannot complete this activity can consult with the teacher or peers who have completed it. Picture 6 shows the data addition stage in this e-module. The purpose is for students to gather example answers for various problems.

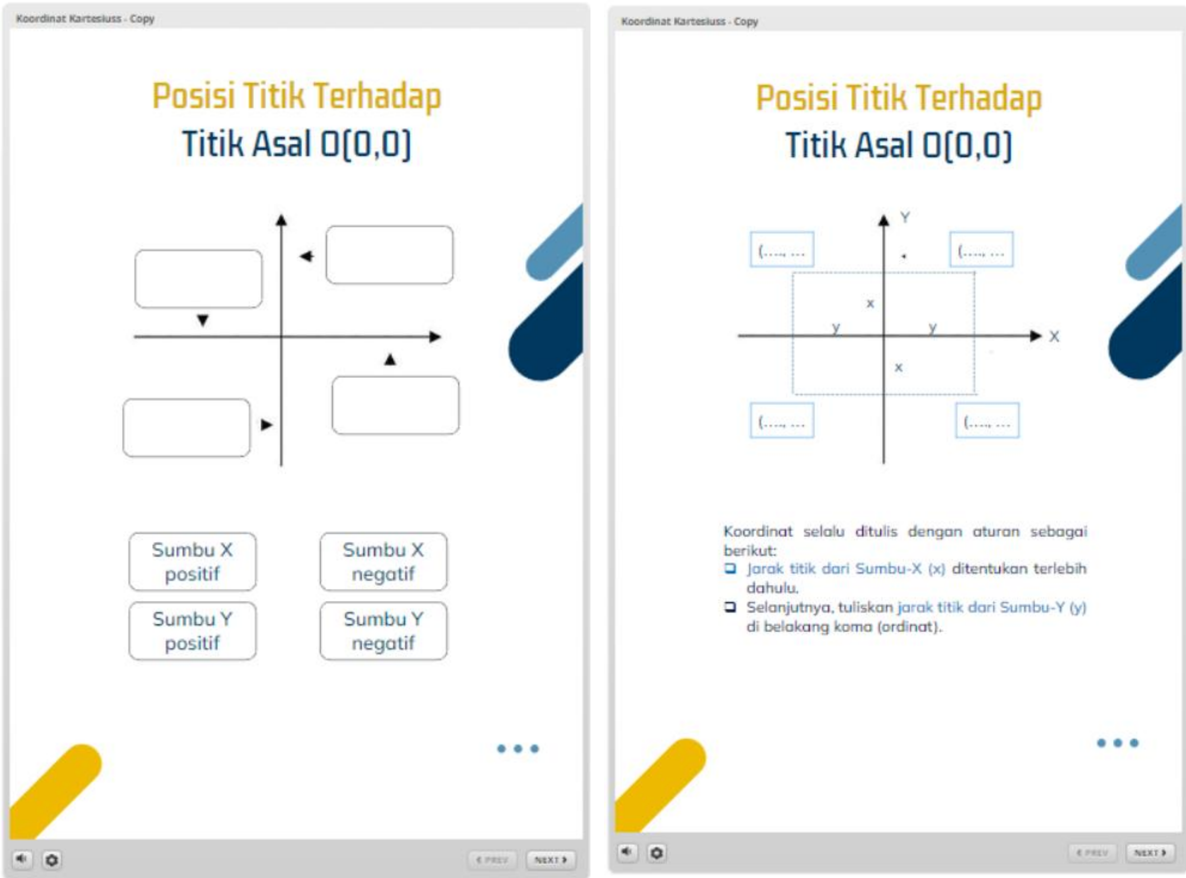


Picture 6. Examples of the Data Addition Stage in the E-Module

After that, it is in the verify stage. Students are asked to verify the formula or concept they discovered during the Data Addition activity. This is because, according to Ishartono et al. (2016), the answers to the task criteria are still hypothetical and need to be verified, so the teacher needs to confirm that the answers obtained by the students are correct. Previously, students were given the concept of Cartesian coordinates in this stage, as shown in Picture 7.

Picture 7. The Verify Stage in the E-Module (Before Revision)

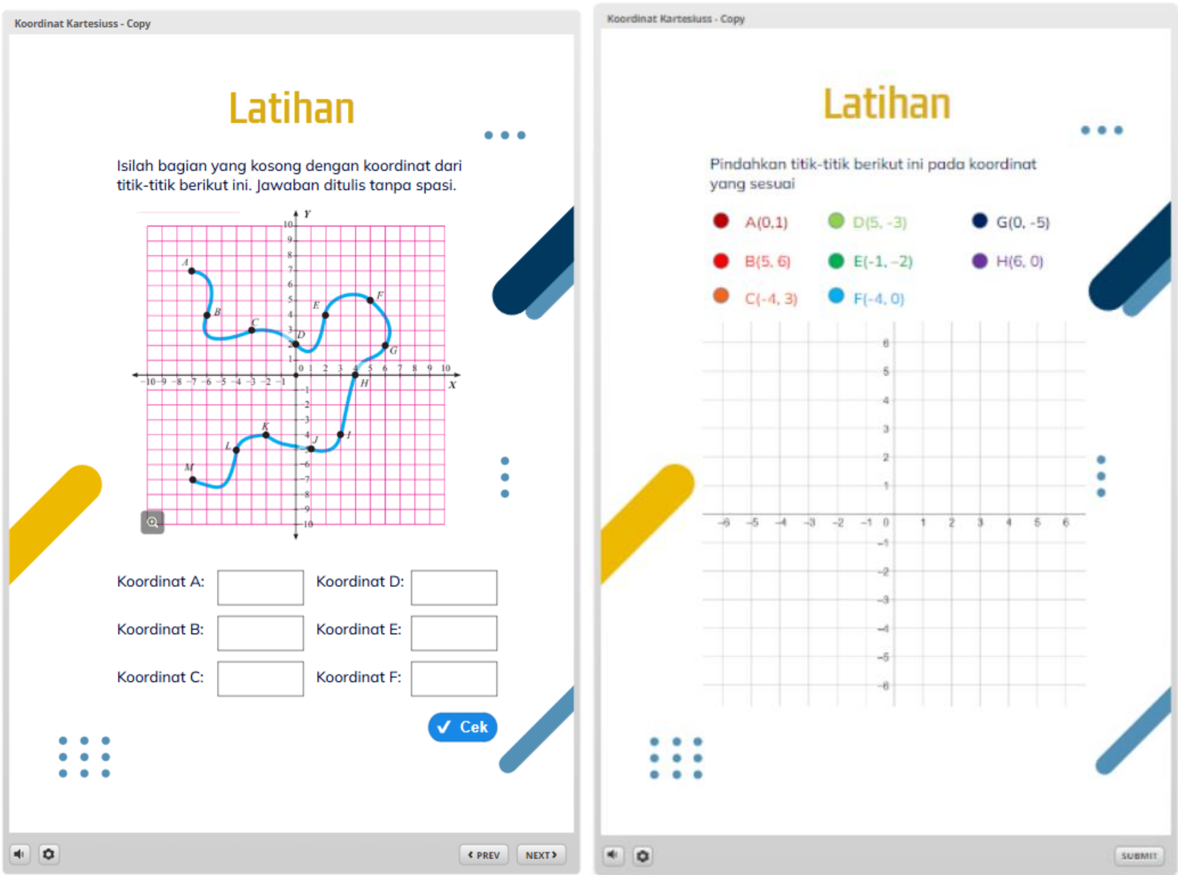
Based on the implementation results, the teacher suggested that students should be able to discover the concept on their own. If the students' verification results are correct, they can proceed to the implementation activity. Meanwhile, those who are incorrect are asked to review their work from the data addition stage and consult with the teacher or peers who have completed the verification stage. The revised results are shown in Picture 8.



Picture 8. The Verify Stage in the E-Module (After Revision)

Verification examines the processed data (Mawaddah & Maryanti, 2016). The verification activity aims to determine whether the hypothesis formulated by the students based on the previous steps is correct. In this step, according to Fisher (2022)), students need to link their hypothesis results with the data processing results independently (Picture 8). The concluding activity means formulating a general principle and applying it to all similar problems (Mawaddah & Maryanti, 2016). Additionally, the module still summarizes conclusions that students should reach as part of confirming their verification results (Picture 8).

The last is Implementation Exercises. In this final stage, students solve application problems using the newly learned concepts (Picture 9).



Picture 9. Examples of the Implementation Exercises Stage in the E-Module

Successfully solving these problems indicates that students have effectively built their knowledge of the studied concept. According to Fisher (2022), the questions in the examples and exercises reflect mathematical problem-solving abilities.

Assessment Phase

The implementation occurred on Tuesday, May 21, 2024, in a junior high school in Purworejo. Students attempted to use the E-guided Discovery Module independently with teacher guidance in the classroom (Picture 10).

Picture 10. Implementation Process

Based on the interviews, students expressed that "The module is quite interesting and challenging, but there are some system errors," "The color selection is aesthetic, but the video lacks clarity," and "Good, it can help me understand the material better." However, some aspects need improvement. This is consistent with several studies where guided discovery has enhanced students' motivation and conceptual understanding (Maulidar et al., 2016; Sapitri et al., 2023). Luthfiani and Yerimadesi (2022) also found that e-modules based on guided discovery learning effectively improved student learning outcomes. The increase in learning outcomes of the experimental class using guided discovery-based e-modules was significantly higher than that of the control class without using e-modules. Based on the student questionnaire, the score of students' responses using this module is shown in Table 2.

Table 2. Students' Respons

No.	Aspect	Score	Category
1.	Content	79,22%	Suitable
2.	Language	80,19%	Very Suitable
3.	Usefulness	79,17%	Suitable
4.	Graphical Elements	84,37%	Very Suitable
Average		80,73	Very Suitable

Based on the implementation results, several comments were obtained and improvements were made, as outlined in Table 3.

Table 3. Students' Comment and Improvement

No.	Students' Comment	Improvement
1.	The module is quite interesting and challenging, but there are some system errors.	Fix bugs or errors in the module system to ensure a better user experience. Conduct comprehensive testing to identify and fix technical issues.
2.	The color selection is aesthetic, but the video lacks clarity.	Add volume control options to the video or improve the sound quality for clearer audio.
3.	The text and background are the same, so it's difficult to read and not visible.	Change the background color or text for more apparent contrast and readability, and consider using larger and clearer fonts.
4.	The instructions on how to work on the problems are unclear.	Clarify instructions with more detailed steps and possibly add visual guides or video tutorials to aid understanding.
5.	Reduce the text, as most students are too lazy to read.	Use concise formats, bullet points, or infographics to convey information. Add more visual or multimedia elements to attract interest.
6.	Provide detailed examples.	Add more detailed and clear examples in each module or exercise, including step-by-step solutions and in-depth explanations.

In addition to student comments and improvements, some adjustments were based on teacher feedback tailored to the stages of Guided Discovery conducted. Fixing bugs and system errors in the module was a primary concern, as these technical issues can disrupt the learning process and reduce the module's effectiveness. Improvements were made by identifying and fixing bugs and conducting comprehensive testing to ensure a better user experience. The quality of the video was also enhanced by adding volume control options and improving sound quality, enabling students to follow the presented material better. Additionally, improvements in visual contrast and instruction clarity were made to ensure all students could read and understand the material more easily. This e-guided discovery model offers more advantages due to its interactivity than printed modules. One significant advantage is that students can review learning material independently as needed (King & Robinson, 2009; Sugianto et al., 2017;

Thuneberg et al., 2018). E-modules can integrate images, audio, video, animation, and quizzes in one information technology-based device (AlAli et al., 2023; Dewi & Primayana, 2019; Rahmadila et al., 2022; Rochsun & Agustin, 2020). The interactivity of e-modules positively impacts the learning process and student outcomes (Suwatra et al., 2018). These modules facilitate flexible, high-mobility information technology-based learning (Solikin, 2018). They are most effective when used with blended learning systems for online and offline sessions (Istuningsih et al., 2018).

Conclusions and Suggestions

An e-guided discovery module on Cartesian coordinates was developed using the Plomp development model. It is an interactive Android-based module that was designed and underwent several stages of evaluation and revision. The development of this module incorporates several discovery aspects that support independent learning and enhance student understanding: giving problems, data development, data arrangement, data addition, verification, and implementation exercises. The study results indicate that this module is helping the students independently understand the concepts of Cartesian coordinates and linear equations. However, some technical aspects, such as system errors and video clarity, need improvement. This module offers an effective solution to support independent student learning and enhance their understanding of the taught mathematical concepts. Therefore, this e-guided discovery module must be implemented in teaching to achieve better learning outcomes and meet the needs of modern education. Further research is recommended to continue developing modules and guided discovery learning methodologies, focusing on enhancing student interaction and support.

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