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Development of E-LKPD Assisted by GeoGebra on Trigonometry Material to Support Students' Understanding of Concepts In Grade XI

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Abstract. *This study aims to design and develop GeoGebra-assisted E-LKPD learning media for trigonometry topics —tangent, cotangent, and reciprocal identities —to foster 11th-grade students' conceptual understanding. This study employed a Research and Development (R&D) approach using the ADDIE model. The research subjects consisted of* 36 *11th-grade students at SMAN 1 Batu. The data analysis techniques used in this study include validity, practicality, and effectiveness analysis. The analysis results indicate that this media is valid, with an average validity score of 3.85 and a material validity score of 3.*75*. The practicality of this media is considered practical based on the student response questionnaire, which yielded an average score of* 3,77*. The effectiveness analysis of this media was based on students' essays on trigonometry material. A total of* 94% *of students achieved scores above* 70*, thus meeting the effectiveness criteria. Therefore, it can be concluded that the GeoGebra-assisted E-LKPD developed is valid, practical, and effective, making it suitable as a mathematics learning medium to enhance students' conceptual understanding of trigonometry.*

Keywords: *E-LKPD, GeoGebra, Trigonometry*

INTRODUCTION

In today's digital era, the application of technology in teaching and learning is crucial, especially in mathematics, where interactive media are essential. With the existence of technology-based interactive media, students can increase their motivation in participating in learning while making it easier for teachers to deliver material (Afiyah et al., 2025.) stated that media functions as an information bridge that includes hardware and software that supports teachers in the teaching process, and acts as a tool that facilitates learning activities so that material can be managed more optimally and learning objectives are achieved effectively.

Rapid technological developments necessitate that the education sector continually adapt to enhance learning quality (D. Novitasari et al., 2021). The widespread use of technology among the public, particularly students, and the ease

of internet access have driven a transformation in learning practices. Technology enables a more interactive and collaborative learning process, leading many schools to shift from traditional to more student-centered approaches (Impron et al., 2025). Furthermore, technological advances have also made significant contributions to the field of education (Afiyah et al., 2025). Technology not only assists teachers in carrying out school tasks, such as processing grades and preparing administration, but also supports the teaching and learning process. According to Utami et al. (2023), one strategy teachers can implement is selecting and utilizing appropriate learning media to attract student interest. In this context, technology is used as a supporting tool for teachers in delivering learning materials. Learning media is a vital tool that supports learning activities, both inside and outside the classroom.

One technology that can support mathematics learning media is GeoGebra. GeoGebra is an interactive software designed to help students understand mathematical concepts more easily, enabling them to learn independently (Cahyana et al., 2024). (Aprilian, 2024) explains that GeoGebra is used to visualize mathematical objects precisely and efficiently. Similarly, state that GeoGebra can display graphs in 2D and 3D. This medium can help improve students' understanding of mathematical concepts.

One of the benefits of using learning media for teachers is its ability to stimulate students' reasoning and encourage them to think creatively and actively (Ariyanti, 2024). For students, learning media provides a space to practice this reasoning in a tangible form, produce innovative work, and increase their involvement in the learning process (Nazarina et al., 2025). Especially in mathematics learning, interactive media is needed so that students can more easily understand concepts. The availability of technology-supported learning media can increase student motivation to participate in the teaching and learning process and make it easier for teachers to deliver material (Aprilia et al., 2023).

Mathematics learning is a field of study that helps achieve educational goals. Mathematics is a crucial field of study, both in educational contexts and in everyday life (Salim Nahdi, 2019). This science is deductive, axiomatic, hierarchical, and abstract, and uses symbolic language to define its concepts (Nafisah & Utami,

2024). However, many students struggle to understand mathematical concepts due to their abstract nature and the use of complex symbolic language. One of the materials taught in mathematics learning is trigonometry. According to Bhoke & Bara (2021), trigonometry is a branch of mathematics that focuses on the elements of triangles —three angles and their sides —and involves trigonometric functions such as sine, cosine, tangent, secant, cosecant, and cotangent, along with their applications.

One way to understand the concept of trigonometry is to use the unit circle. Definition: A unit circle is a circle with a radius of one unit and its center point at $(0,0)$. In the trigonometric identity section, students often struggle with the subtopic of tangent, cotangent, and reciprocal identities because the concepts are abstract and involve numerous symbols. Students often memorize formulas without understanding how to apply them. This hinders in-depth understanding and the ability to solve problems based on conceptual understanding. Conceptual understanding significantly influences solving problems and challenges in mathematics learning.

Additionally, conceptual understanding is a key indicator of success in the learning process, particularly in mathematics (Safitri et al., 2024). The results of observations conducted by researchers during teaching assistance activities revealed that students at SMAN 1 Batu struggled to understand trigonometry problems. In addition, students were also unable to connect the information given in the problem and did not know which formula to apply.

An interview with a mathematics teacher at SMAN 1 Batu revealed that students' low performance was due to various factors, including a lack of understanding of trigonometry concepts and the limited media used by the teacher. During the learning process, the mathematics teacher utilized digital links as a learning medium. However, these media required students to log in and have stable internet access, which often posed challenges. The teacher hoped to find more practical, accessible media that were free of technical issues. The teacher also noted that students' trigonometry skills were still far from satisfactory. Consequently, the

main weakness in this learning activity was students' lack of focus during learning and poor conceptual understanding.

To address these issues, innovation and development are necessary in the learning system, including the use of learning media (Riza et al., 2022). One such learning medium is the Electronic Student Worksheet (E-LKPD). Interactive electronic student worksheets are a way to connect knowledge with technology in today's digital age. The advantage of this medium lies in its ability to create a more dynamic learning environment and encourage students to actively engage with concepts (Halimah et al., 2024). This allows teachers to ensure that students are not simply watching during lecture-based learning. By combining various media, including text, images, and animations designed according to the learning method, this multimedia-based learning medium creates an interactive learning experience (Nabilla et al., 2022).

Previous research (Yustiani & Nasution, 2022) developed online Student Worksheets (LKPD) using GeoGebra Book for trigonometric function graphs. However, several weaknesses persisted. The tangent, cotangent, and reciprocal identities were not discussed; the visual approach using the unit circle was not directly used; and GeoGebra integration did not support students' interactive exploration. Furthermore, assessment of learning outcomes was limited to validity and practicality, without encompassing students' comprehensive conceptual understanding. This study offers novelty by developing an interactive E-LKPD that uses GeoGebra as a medium to explore tangent, cotangent, and reciprocal identities. Although the integration is achieved through links, the activity design in this E-LKPD aims to visually and independently build conceptual understanding.

The use of GeoGebra media is highly suitable for supporting visual-based exploratory learning, particularly in understanding trigonometry using the unit circle. Research by Yustiani & Nasution (2022) shows that developing online student worksheets (LKPD) using GeoGebra Book yields highly valid and practical results. However, this research did not cover the material on tangent, cotangent, and reciprocal identities, and did not integrate GeoGebra activities directly into the student exploration process. Similarly, research by D. Novitasari et al. (2021) also

developed GeoGebra-based student worksheets with a scientific approach to enhance students' understanding of mathematical concepts. The results showed that the developed student worksheets were valid and effective, improving students' understanding through visual, interactive technology-based activities. Based on these two studies, it can be concluded that the use of GeoGebra in learning media, especially in the form of E-LKPD, has great potential to support conceptual understanding. Based on these studies, this study aims to develop an E-LKPD in GeoGebra, specifically designed to help students visually and independently explore trigonometric identities using the unit circle.

Based on the problems described, the researcher intends to develop an E-LKPD learning media assisted by GeoGebra, specifically designed to help students understand trigonometry material, particularly the sub-material of tangent, cotangent, and reciprocal identities. The selection of this sub-material is based on previous research, which shows that trigonometric identities, especially tangent and cotangent, are often considered difficult because they are abstract and require understanding the relationships among trigonometric functions (Torang Siregar, 2025). A visual approach using the unit circle is believed to help students connect mathematical symbols with geometric representations, thereby strengthening conceptual understanding. The use of GeoGebra is particularly relevant in this context because it can visualize these relationships interactively and dynamically (Torang Siregar, 2025). Therefore, this study aims to determine the process and outcomes of developing a GeoGebra-assisted E-LKPD for trigonometry material, with the hope that the resulting product will be valid, practical, and effective. Furthermore, this study is expected to help students build an understanding of trigonometry concepts while providing interactive learning media that is appropriate to the demands of the digital era.

RESEARCH METHODS

This study used the Research and Development (R&D) method. R&D focuses on the process of creating new products and enhancing or adding features to existing ones (Sholeh et al., 2024). The development of E-LKPD in this learning media uses

the ADDIE development model (Chowdhury et al., 2022). The selection of the ADDIE model aims to produce or refine products that improve learning quality and meet field needs (Widahyanti & Utami, 2024). The ADDIE development model consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Hanifah et al., 2020), as illustrated in Figure 1.

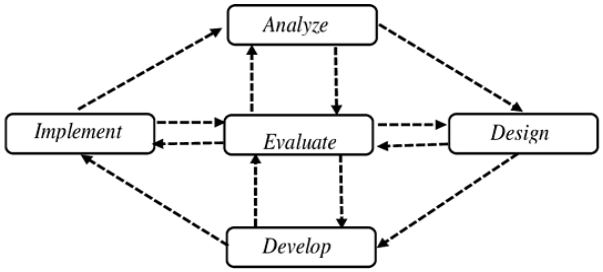

Figure 1. ADDIE Development Stages
Source: (Chowdhury et al., 2022)

The research stages in the ADDIE development model include five stages that must be passed, namely:

1. In the analysis stage, researchers conduct a needs analysis to understand the mathematics learning situation in the classroom, including student learning outcomes, the learning media used, and the curriculum and materials. This needs analysis is obtained through observations and interviews with mathematics teachers or mentor teachers during teaching assistance. The analysis stage aims to identify the problems encountered and determine their causes(Utami et al., 2023).
2. In the design stage, researchers design the media and content based on the previous needs analysis. At this stage, researchers also create validation sheets for the media and materials, as well as questions and assessment rubrics, student response questionnaires, teaching modules, and product descriptions and displays, all arranged in a flowchart design prototype.
3. During the development stage, the GeoGebra-assisted E-LKPD was validated by mathematics teachers, who served as subject-matter and media experts, to assess the product's validity. Researchers used the E-LKPD validation sheet instrument to measure the validity of the development.
4. In the implementation stage, the developed media is implemented in the mathematics learning process to evaluate the effectiveness and practicality of the

GeoGebra-assisted E-LKPD media. The media's effectiveness is assessed based on students' essay work, while its practicality is assessed through student response questionnaires after using it.

5. At the evaluation stage, activities include revising media based on suggestions, criticism, and input from mathematics teachers who serve as media experts and material experts at each stage of creating E-LKPD.

This research was conducted at SMA Negeri 1 Batu during teaching assistance activities. The research subjects were 36 students in grades XI-11 at SMAN 1 Batu. The validation sheet and response questionnaire used a Likert scale divided into 4criteria : (4) Strongly Agree, (3) Agree, (2) Disagree, and (1) Disagree, while the essay questions were in descriptive form (Siregar et al., 2024). The data obtained in this study included qualitative and quantitative data. The data obtained in this study consisted of qualitative and quantitative data. Qualitative data were presented in the form of descriptive accounts, obtained from suggestions, criticisms, and input from mathematics teachers, as well as through response questionnaires, to improve the media that had been developed. Meanwhile, quantitative data were obtained from scores on the validation sheet, response questionnaires, and students' essay results.

The validation results were assessed using a formula taken from (Siregar dkk al., 2024) as follows:

$$Va = \frac{\sum_{i=1}^{n} A_i}{n}$$

Description:
Va = Product validity score
A_i = The average value for the validity aspect of the-i
n = Many aspects

Based on the scores obtained, the data can be categorized as shown in Table 1, presented below.

Table 1. Validity Criteria Media

Achievement	Qualification
$Va = 4$	Sangat Valid
$3 \leq Va < 4$	Valid
$2 \leq Va < 3$	Kurang Valid
$1 \leq Va < 2$	Tidak Valid

Source: (Irianti & Qohar, 2019)

GeoGebra-assisted E-LKPD media is considered valid if its validity score $Va \geq 3$.

Meanwhile, the results of the student response questionnaire are assessed using the formula below:

$$I_o = \frac{\sum_{i=1}^{n} K_i}{n}$$

Description:
I_o = Product validity score
K_i = The average value for the practical aspect of the-i
n = Many aspects

Based on the score results obtained, the data can be categorized according to Table 2 presented below:

Table 2. Media Validity Criteria

Achievement	Qualification
$I_o = 4$	Very High
$3 \leq I_o < 4$	Tall
$2 \leq I_o < 3$	Law
$1 \leq I_o < 2$	Very Law

Source: (Irianti & Qohar, 2019)

GeoGebra-assisted E-LKPD media is considered practical if it achieves a high practicality score. $I_o \geq 3$, or if the product's practicality criteria are high.

The effectiveness of GeoGebra-assisted E-LKPD was analyzed through students' essay questions. (Surur, 2017) stated that the effectiveness of the media can be formulated as follows:

$$P = \frac{\sum x}{\sum x_i} \times 100\%$$

Description:
P = Percentage of effectiveness
$\sum x$ = Number of students who obtained the minimum KKM score
$\sum x_i$ = Total number of students

GeoGebra-assisted E-LKPD media is considered adequate if the percentage of students who achieve the minimum KKM score ≥ 70% from the total maximum score of 100 in essay work is (Surur, 2017).

RESULT AND DISCUSSION

The final result of this research is a GeoGebra-assisted E-LKPD, developed using the ADDIE method, which includes 5the following development stages:

1. Analysis Stage

Researchers conducted observations, interviews, and needs analysis to understand conditions and problems in the field. From observations and interviews with one of the mathematics teachers, it was found that mathematics instruction still uses a one-way approach. The learning media used include PowerPoint and GeoGebra. However, there are several weaknesses in the use of these media, such as the lack of facilities and infrastructure, including LCD and projector screens in each class, which causes longer preparation times. Additionally, using GeoGebra requires stable internet access, which can often be an obstacle for students.

In the current learning process, SMAN 1 Batu utilizes an independent curriculum for grades XI-XII. Interviews with mathematics teachers indicate that grade XI-11 students have not yet mastered trigonometry concepts. The developed media aims to help students understand the material. The following analysis will focus on the material shown in Figure 2.

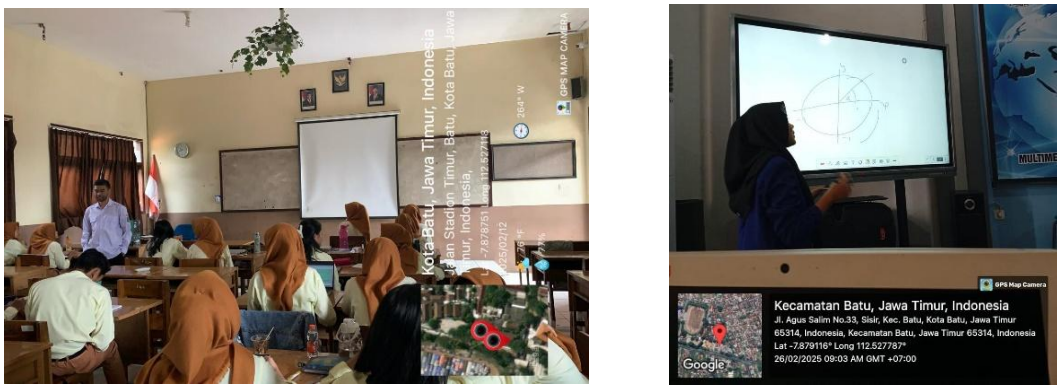

Figure 2. Observation or pre-survey

Figure 2 shows that the mathematics material for grades XI-11 includes angles in the Cartesian plane, trigonometry in the Cartesian plane, and trigonometry

with the unit circle. The interactive learning media needed by teachers are those that focus on trigonometry material, particularly the unit circle, and include sub-material on tangent, cotangent, and reciprocal identities. The selection of this material is based on the numerous trigonometric formulas that students find difficult to remember. In addition, the second problem is the lack of facilities to support learning trigonometry material using the unit circle, as well as the limited use of media.

This is evident in students' difficulties in understanding the concepts of tangent, cotangent, and reciprocal identities. Therefore, researchers developed GeoGebra-assisted electronic student worksheets (LKPD) for mathematics lessons. The material contained in the E-LKPD is tailored to the learning outcomes set by mathematics teachers. Furthermore, the E-LKPD is designed to support conceptual understanding and provide a more interactive, independent learning experience. According to Nabilla et al. (2022), the use of E-LKPD can positively impact students' interest and motivation to learn, thereby increasing their engagement in the learning process.

2. Design Stage

After analyzing the material, the researcher proceeded to the design stage, designing learning activities aligned with the set learning objectives and compiling material and question designs for implementation in the E-LKPD. This was done using the Canva application and the GeoGebra website. The questions used were related to trigonometric identities with the unit circle. The learning model applied was Discovery Learning, as it aligns with the characteristics of the material being taught. With the Discovery Learning model, students can develop critical thinking skills and strive to solve problems (Muhammad & Juandi, 2023). Canva was chosen for the development of the E-LKPD because it can enhance its visual appeal through its various features (Sholeh et al., 2024). The researcher designed the E-LKPD equipped with GeoGebra links and attractive images.

The following is a prototype of the flow design in E-LKPD, developed with GeoGebra, as shown in Figure 3.

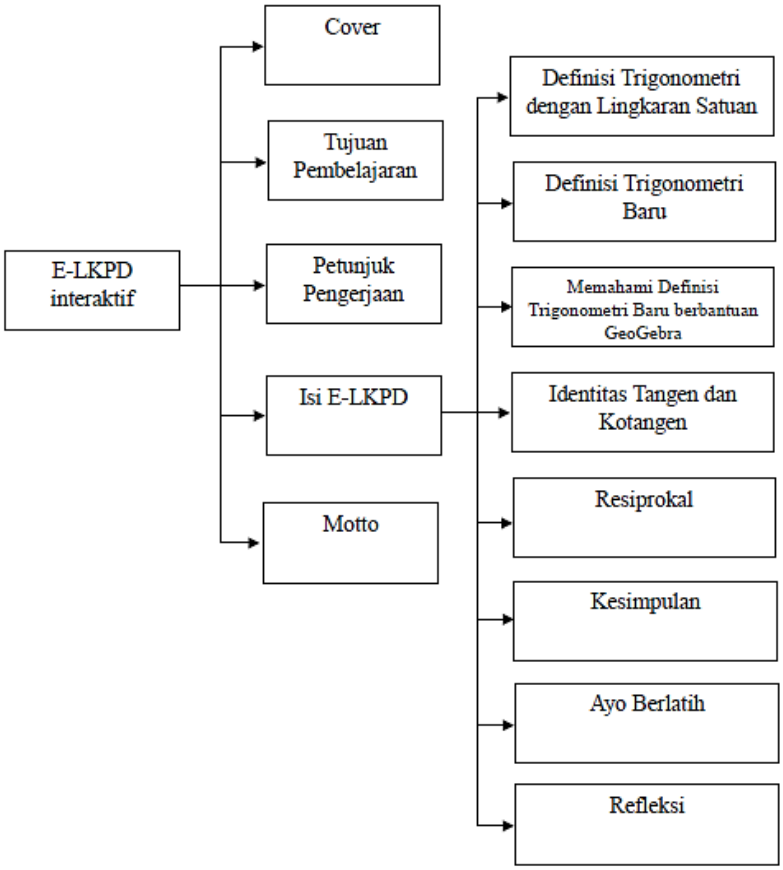

Figure 3. Flow Design Prototype

Based on Figure 3, the flowchart is written per slide to facilitate researchers' implementation in the E-LKPD, which will be tested on a limited basis with students. Meanwhile, an example of the prototype material design is shown in Figure 4.

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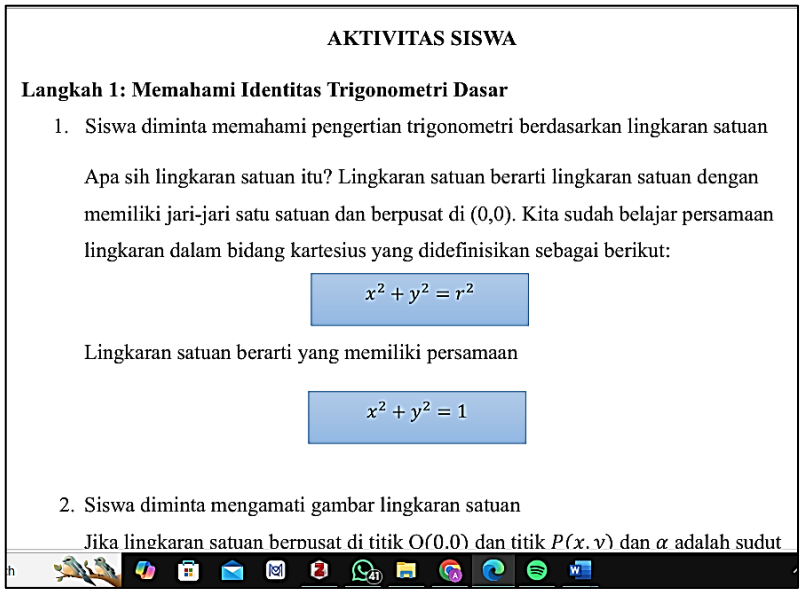


AKTIVITAS SISWA

Langkah 1: Memahami Identitas Trigonometri Dasar

1. Siswa diminta memahami pengertian trigonometri berdasarkan lingkaran satuan

   Apa sih lingkaran satuan itu? Lingkaran satuan berarti lingkaran satuan dengan memiliki jari-jari satu satuan dan berpusat di (0,0). Kita sudah belajar persamaan lingkaran dalam bidang kartesius yang didefinisikan sebagai berikut:

   $$x^2 + y^2 = r^2$$

   Lingkaran satuan berarti yang memiliki persamaan

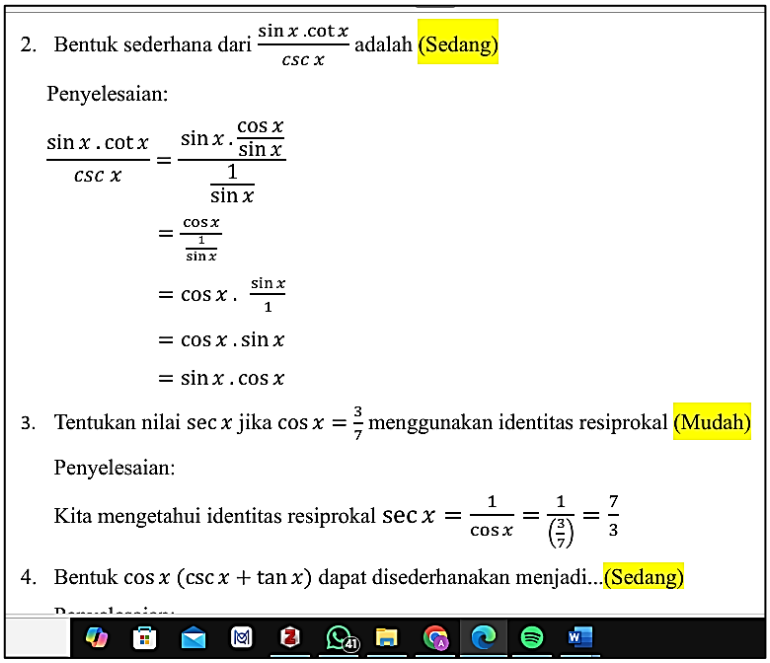
   $$x^2 + y^2 = 1$$

2. Siswa diminta mengamati gambar lingkaran satuan

   Jika lingkaran satuan berpusat di titik $O(0,0)$ dan titik $P(x, y)$ dan α adalah sudut

Figure 4. Trigonometric Material Design with Unit Circle

Figure 4 shows the design of the trigonometry material used in the E-LKPD. This material refers to the student textbook recommended by the mathematics teacher who served as a guide during the Teaching Assistant program. An example of the problem design is shown in Figure 5.



2. Bentuk sederhana dari $\frac{\sin x \,.\cot x}{csc\, x}$ adalah (Sedang)

   Penyelesaian:

   $$\frac{\sin x \,.\cot x}{csc\, x} = \frac{\sin x \,.\, \frac{\cos x}{\sin x}}{\frac{1}{\sin x}}$$
   $$= \frac{\cos x}{\frac{1}{\sin x}}$$
   $$= \cos x \,.\, \frac{\sin x}{1}$$
   $$= \cos x \,.\sin x$$
   $$= \sin x \,.\cos x$$

3. Tentukan nilai $\sec x$ jika $\cos x = \frac{3}{7}$ menggunakan identitas resiprokal (Mudah)

   Penyelesaian:

   Kita mengetahui identitas resiprokal $\sec x = \frac{1}{\cos x} = \frac{1}{\left(\frac{3}{7}\right)} = \frac{7}{3}$

4. Bentuk $\cos x\,(\csc x + \tan x)$ dapat disederhanakan menjadi...(Sedang)

Figure 5. Example of Question Design

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Figure 5 shows the question design used in the E-LKPD. The questions used in the E-LKPD have been validated by mathematics teachers who teach in grades XI-11.

3. Development Stage

During the development stage, researchers conducted several activities, including product creation, validation, and revision. The product creation process was carried out based on the prototype developed in the previous stage. The development of GeoGebra-assisted E-LKPD was carried out in PDF format, allowing access on a computer or laptop. The E-LKPD creation process began with designing the cover in the Canva application, as shown in Figure 6. After the cover was completed, the next slide included the name, learning objectives, and work instructions, as shown in Figure 7. On this slide, students were given an overview of the learning objectives for tangent, cotangent, and reciprocals.

Figure 6. E-LKPD Cover

Figure 7. Learning objectives

The following slide in the GeoGebra-assisted E-LKPD is the material slide. On this slide, students can review the previously learned material, as shown in Figure 8, which explains the definition of trigonometry with a unit circle, accompanied by a picture of the unit circle in the E-LKPD. The following slide presents material on new trigonometry definitions (secant, cosecant, and

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cotangent), as well as tangent, cotangent, and reciprocal identities, and their conclusions, as shown in Figure 9.

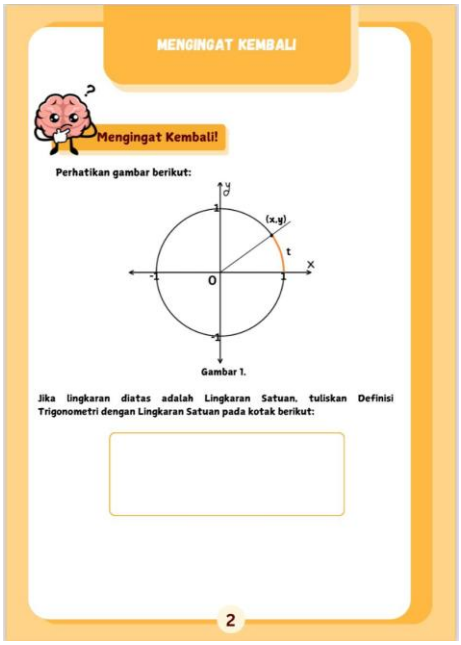

Figure 8. Recall Page

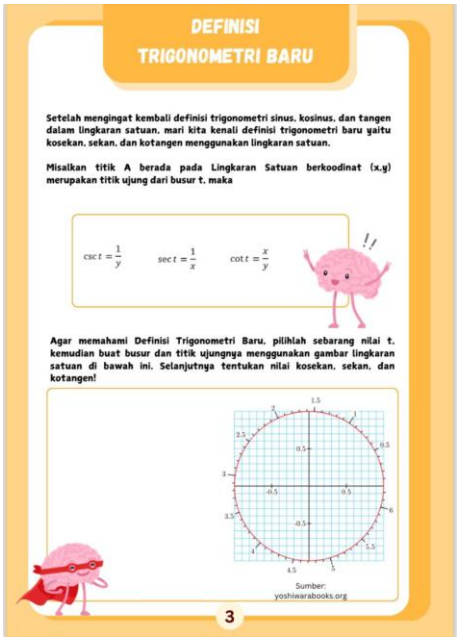

Figure 9. Example of E-LKPD Content Page

Figure 9 shows an example of an E-LKPD material page. The material in E-LKPD is presented as activities that support student understanding through GeoGebra, as shown in Figure 10. In this activity, there are instructions that state, "To understand the new trigonometric definition, choose any value t, then draw an arc and its endpoints using the unit circle image in GeoGebra. Next, determine the values of the cosecant, secant, and cotangent." For example, students find the values $\sec(4{,}71)$ as shown in Figure 11.

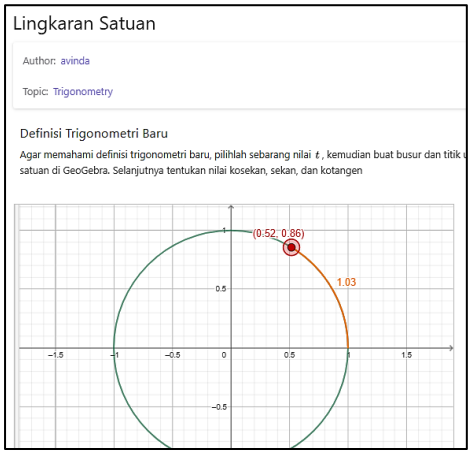

Figure 10. GeoGebra

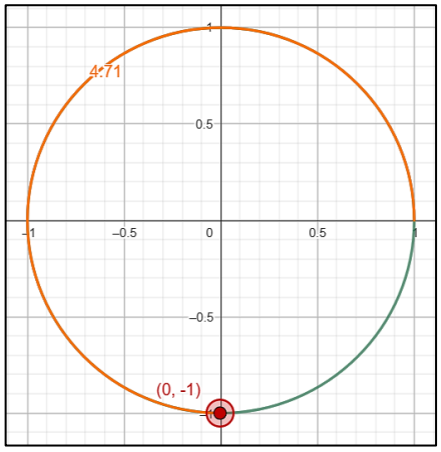

Figure 11. Example of GeoGebra Activity

Figure 11 shows an example of student activity in GeoGebra to find the value of $\sec(4{,}71)$. To do this, move the red dot. Until the length of the orange arc becomes 4,71, so that the red point is at coordinates $(0, -1)$. Thus, we obtain $\sec(4{,}71) = \frac{1}{x} = \frac{1}{0}(undefined)$.

After the GeoGebra-assisted E-LKPD was developed, researchers validated the media by involving nationally certified mathematics teachers as experts. The media validation results are presented in Table 3.

Table 3. Media Validation Result

Statement	Average Score
Media is easily accessible via computer or laptop devices	4
The font color, type, and size are appropriate and comfortable to read.	4
GeoGebra's interactive features work well and are easy to operate	4
Instructions for using E-LKPD are easy for students to understand	4
The use of E-LKPD is effective and efficient in learning	3
Students can efficiently operate E-LKPD with the help of GeoGebra	4
Images, graphs, and illustrations according to trigonometry material	3
The display of results in GeoGebra is accurate and easy to understand	4
The use of media helps students understand material concepts through independent exploration	4
Average Validity Score	3,85
Validity Criteria	Valid

Table 4. Material Validation Result

Statement	Average score
Conformity between material and learning outcomes	4
The material provided supports students in achieving learning objectives.	4
The material supports students in discovering the concept of trigonometric identities with the unit circle.	4
The material is presented interestingly and interactively.	3
Practice questions according to the material and using GeoGebra	4
Appropriate use of mathematical symbols and notation	4
Accuracy in the application of mathematical terms	4
The use of language is clear, communicative, and easy to understand	3
The language used conforms to the General Guidelines for Indonesian Spelling (PUEBI)	4
Average Validity Score	3,75
Validity Criteria	Valid

Based on the product validity results in Table 3, a validity score of 3.85 was obtained. Therefore, the GeoGebra-assisted E-LKPD is considered valid for

learning. Meanwhile, the material is also considered valid, with an average validity score of 3.75, as shown in Table 4.

4. Implementation Stage

This media was then trialed at SMAN 1 Batu in grades XI-XII, consisting of 36 students. This trial aimed to collect data on the effectiveness and practicality of GeoGebra-assisted E-LKPD. The trial began during the Teaching Assistant program on April 10, 2025. The discovery learning method was applied throughout the learning process, as shown in Figure 12.

Figure 12. Implementing the E-LKPD product

Students in grades XI-11 demonstrated a pleasant learning experience and demonstrated enthusiasm in understanding the material. The use of E-LKPD has been shown to facilitate understanding of mathematical concepts. Furthermore, students provided positive feedback regarding mathematical concepts throughout the learning process, as shown in Figure 13.

Figure 13. Students using E-LKPD

Figure 13 shows that students began to feel that learning mathematics was more enjoyable, which motivated them to study more seriously. This reflects their positive experience with understanding Trigonometric Identities using the Unit Circle material, supported by exploration activities, discussions, and the use of GeoGebra-assisted E-LKPD.

After completing the learning activities on the identities of tangent, cotangent, and reciprocal, students were asked to complete a response questionnaire. The results of the questionnaire for grade XI-11 students are presented in Table 5. From the questionnaire results, a practicality score of 0.377 was obtained, indicating that this medium is practical and meets high criteria. On the other hand, students' comments after using E-LKPD assisted by GeoGebra showed that they found it easier to understand the material concept. However, some students expressed difficulty in moving the endpoints of the arc in GeoGebra.

Table 5. Student Response Questionnaire Results

No.	Statement	Average Score
1.	Ease of use of media.	3,89
2.	Clarity of media use guidelines.	3,78
3.	Media is easily accessible on computers or laptops.	3,78
4.	Media can be used at any time and in any place during learning.	3,78
5.	The material in the media is transparent.	3,78
6.	The media display design is attractive and comfortable to look at.	3,78
7.	*font* type and size are appropriate, and the writing is easy to read.	3,67
8.	The images, graphics, and colors used are attractive.	3,89
9.	The appropriateness of media in increasing student motivation and learning outcomes.	3,89
10.	The use of media can train students' critical and creative thinking.	3,78
11.	The language used in the media is easy to understand.	3,67
	Practicality Score	3,77
	Practicality Criteria	Tall

5. Evaluation Stage

At this stage, the researcher made improvements or revisions to the GeoGebra-assisted E-LKPD product based on suggestions, criticisms, and input from mathematics teachers who acted as media experts and material experts at each stage of making the E-LKPD, which is shown in Figure 14, to obtain media that is suitable for use and assess the effectiveness of using the GeoGebra-assisted E-LKPD.

Figure 14. E-LKPD media consultation with Supervisor Teachers

The improvements include revising the prototype design flow to better align with the material being presented. In addition, the developed E-LKPD was improved through several steps, namely: (1) adding media identity on the first page; (2) including a new trigonometry definition in the learning objectives; (3) adding recall material to previous material; (4) improving the use of mathematical sentences and symbols; (5) adding a motto or closing sentence on the last page. For the developed GeoGebra, improvements include adding color to arbitrary points t, then creating arcs and their endpoints. In addition, researchers assessed the effectiveness of the GeoGebra-assisted E-LKPD by measuring students' essay results. The essay results showed that 34 out of 36 students, or 94%, achieved the same or higher score than the KKM. These findings suggest that GeoGebra-assisted E-LKPD is an effective learning medium for learning activities.

Using E-LKPD, students can improve their understanding of the tangent, cotangent, and reciprocal identities. This is evident in the 94% of students who have completed E-LKPD 36, which is considered complete. This success is due to the use of E-LKPD, which can be accessed without spatial limitations and is supported by digital technology. As stated by D. Novitasari et al. (2021), GeoGebra-assisted E-LKPD can be accessed via a smartphone, allowing users to use it anytime without relying on a computer, making it more practical and efficient. In addition, E-LKPD developed in PDF format attracts students' interest in learning, supported by an

attractive and motivating media display for students, as expressed by Pratama et al. (2024)

The advantage of using GeoGebra-assisted e-LKPD in the learning process is that students can use it repeatedly. This provides students with an opportunity to learn independently and review the material as needed. As stated by F. Novitasari & Puspitawati (2022), the GeoGebra-assisted e-LKPD is equipped with comprehensive features. These include discussion activities to recall previous material, learning objectives, presentations, and practice questions that can be accessed and completed repeatedly. These features help students understand the material more easily.

Based on the results of validity, practicality, and effectiveness tests, it can be concluded that the developed GeoGebra-assisted e-LKPD meets the criteria for a valid, practical, and effective learning medium for use in trigonometry learning. The findings of this study align with the results of previous studies (D. Novitasari et al., 2021), which stated that the use of GeoGebra can enhance students' understanding of mathematical concepts through visual and interactive learning. However, the findings of this study differ in a key respect from those of previous studies. The E-LKPD developed in this study integrates GeoGebra's exploratory activities directly into the learning process on the tangent, cotangent, and reciprocal identities, using a visual approach based on the unit circle. This approach has not been applied in previous studies, which generally focus only on the visualization of trigonometric functions without involving independent exploration of concepts. Thus, this study makes a new contribution to the development of technology-based learning media by emphasizing the integration of interactive visual exploration, which can enhance students' conceptual understanding more deeply.

However, the development of this GeoGebra-assisted E-LKPD still has several limitations. One of them is the need for a separate link to access GeoGebra for unit-circle visualization and the dependence on a stable internet connection. This condition sometimes hinders the smoothness of classroom learning. Therefore, further research is recommended to develop a GeoGebra-assisted E-LKPD that is directly integrated with unit circle visualization, eliminating the need for an external

link, and to expand the trial to include classes and schools with diverse infrastructure conditions. These efforts are expected to produce more efficient and inclusive learning materials that support the understanding of trigonometry concepts.

CONCLUSION

Based on the research results that have been presented, it can be concluded that the GeoGebra-assisted E-LKPD learning media on trigonometry material is proven to be valid, practical, and effective in supporting the conceptual understanding of grade XI-11 students, especially on the sub-material of tangent, cotangent, and reciprocal identities. The validation scores obtained from the validator indicate the validity of this media, with scores of 3.85 $for\ the\ media\ and$ 3.75 for the material, indicating that this media is considered valid. In addition, the practicality of this media, as shown by the student response questionnaire, indicates that the GeoGebra-assisted E-LKPD media is considered practical, with an average positive response from students of 3.77. The effectiveness of this media is measured by students' essay results, with 94% achieving scores above 70. Therefore, GeoGebra-assisted E-LKPD can be deemed feasible and effective for improving students' conceptual understanding of trigonometry material.

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