UIN IMAM BONJOL PADANG

Math Educa Journal 10(1)(2026):95-114

MATH EDUCA

Jurnal Matematika dan Pendidikan Matematika
Website: http://ejournal.uinib.ac.id/jurnal/index.php/matheduca
Email: mej.uinibpadang@gmail.com

DEVELOPMENT OF GEOGEBRA-ASSISTED TEACHING MATERIALS FOR PHASE F

PENGEMBANGAN BAHAN AJAR LINGKARAN BERBANTUAN GEOGEBRA UNTUK FASE F

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Received: February 2026; Accepted: March 2026; Published: April 2026

Abstract

This study aims to develop and produce valid and practical teaching materials on circles using GeoGebra for students and teachers in grade XI at MAN 2 Tanah Datar. The research method used was Research and Development (R&D) by adapting the 4D development model, which was limited to three main stages, namely Define, Design, and Develop. Data collection instruments included a validation sheet for experts and a practicality questionnaire. The data analysis technique used was a percentage formula for validity analysis and practicality analysis. The results showed that the teaching materials developed had a validity level of 87.12% with a very valid criterion. The level of practicality through trials at MAN 2 Tanah Datar showed an average student response score of 85.13% (very practical) and a teacher response of 79.63% (practical). Based on these results, it can be concluded that this GeoGebra-assisted Circle teaching material is feasible and very practical to use as a support for the mathematics learning process at the school. The implication of this research is the availability of interactive learning media that can help students visualize circle concepts with the aid of technology.

Keywords: Circles, Digital Teaching Materials, GeoGebra, Practicality, Validity.

Abstrak

Penelitian ini bertujuan untuk mengembangkan dan menghasilkan bahan ajar materi lingkaran berbantuan GeoGebra yang valid dan praktis bagi siswa dan guru pada kelas XI di MAN 2 Tanah Datar. Metode penelitian yang digunakan adalah *Research and Development* (R&D) dengan mengadaptasi model pengembangan 4D yang dibatasi pada tiga tahap utama, yaitu *Define* (Pendefinisian), *Design* (Perancangan), dan *Develop* (Pengembangan). Instrumen pengumpulan data meliputi lembar validasi untuk ahli serta angket praktikalitas. Teknik analisis data yang digunakan adalah rumus persentase untuk analisis validitas dan analisis praktikalitas. Hasil penelitian menunjukkan bahwa bahan ajar yang dikembangkan memiliki tingkat validitas sebesar 87,12% dengan kriteria sangat valid. Tingkat praktikalitas melalui uji coba di MAN 2 Tanah Datar menunjukkan skor rata-rata respons siswa sebesar 85,13% (sangat praktis) dan respons guru sebesar 79,63% (praktis). Berdasarkan hasil tersebut, dapat disimpulkan bahwa bahan ajar Lingkaran

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p-ISSN: 2580-6726
e-ISSN: 2598-2133

berbantuan GeoGebra ini layak dan sangat praktis digunakan sebagai penunjang proses pembelajaran matematika di sekolah tersebut. Implikasi dari penelitian ini adalah tersedianya media pembelajaran interaktif yang dapat memudahkan siswa dalam memvisualisasikan konsep lingkaran melalui bantuan teknologi.

Kata kunci: Bahan Ajar Digital, GeoGebra, Lingkaran, Praktikalitas, Validitas.

INTRODUCTION

Quality education is a key pillar in the transformation of science, where teaching materials play a crucial role as systematic instructional instruments. Teaching materials not only serve as a medium for conveying information, but must also be able to create an effective, efficient, and adaptive learning atmosphere for students' needs (Abad & Hattie, 2025; Manurung et al., 2023; Wahyuni et al., 2024). Amidst the wave of digitalization, the urgency of developing teaching materials has shifted from conventional print formats to interactive devices capable of integrating multimedia elements to realize more meaningful learning. Mathematics is a field of study that deals with abstract concepts, so innovative teaching methods are needed to translate those abstract concepts into more concrete situations so that students can understand them more easily (Afidatuzzaro et al., 2024). In line with this, the Merdeka Curriculum in Indonesia requires flexibility and the integration of information technology in the learning process to equip students with 21st-century skills (Fitra, 2023; Farid et al., 2024).

However, the reality on the ground often shows a discrepancy between curriculum requirements and practical implementation. The technological conditions at MAN 2 Tanah Datar reflect the paradox of digitization; on the one hand, the school has basic infrastructure such as internet networks and adequate supporting devices, but on the other hand, this potential has not been fully utilized in mathematics learning. The instructional process is still dominated by conventional methods that rely on a single textbook. Limited access to reference books relative to the number of students exacerbates mathematical literacy, making it difficult for students to internalize theoretical material and triggering cognitive ambiguity. This is evident from preliminary data showing that student learning outcomes on circle material are still below the mastery criteria. Specifically, out of 36 students observed, 60% of them failed to reach the minimum mastery score of 75, leading to an average class score of 78 or below. This low academic performance occurs because students often struggle to truly internalize the theoretical material; they merely memorize formulas without understanding the underlying geometric concepts. Consequently, when faced with non-routine geometry problems, they experience a gap in understanding. Introducing learning activities that trigger cognitive ambiguity is therefore essential. This ambiguity acts as a conceptual catalyst, forcing students to confront their misconceptions and actively reconstruct their mathematical reasoning. By navigating and resolving this cognitive conflict, students develop a

deeper, more robust conceptual understanding, which ultimately leads to significantly improved learning outcomes on circle material.

This obstacle stems from the incompatibility between teaching media and the characteristics of students at MAN 2 Tanah Datar. The results of observations indicate that the majority of students have a strong visual-audio learning style. They have better information retention abilities when interacting with dynamic representations of mathematical objects. Furthermore, from a cognitive perspective, students in Phase F are transitioning into formal operational stages where they are expected to perform advanced mathematical reasoning, logical proofs, and abstract conceptualization. Unfortunately, abstractions in geometry, especially the concept of elements in circles, often fail to be visualized through static media. This makes it difficult for students to construct an understanding of abstract concepts related to circles, such as tangents and the relationship between central angles, which are core cognitive demands in the Phase F curriculum. Appropriate visualizations are essential for bridging these mathematical abstractions, as effective instructional materials should be able to foster abstract thinking through dynamic visual representations (Afriyani et al., 2024). The use of interactive learning media has been shown to significantly improve student learning outcomes compared to conventional methods, where students' active engagement in manipulating digital objects is the key to instructional success (Maulana, 2017). Without tools capable of addressing these visual and cognitive needs, students struggle to develop a deep conceptual understanding, especially since today's students are digital natives who are more familiar with technology than with traditional teaching methods (Afidatuzzaro et al., 2024).

As a mitigation effort for these issues, the integration of GeoGebra dynamic software in the development of teaching materials is a highly relevant solution. GeoGebra offers the ability to visualize geometric concepts interactively and in real time, allowing students to perform visual manipulations and complex calculations in an exploratory manner (Simbolon, 2020; Sati et al., 2024). The use of GeoGebra in geometry instruction provides students with opportunities for independent exploration. Although the effectiveness of GeoGebra in teaching geometric elements has been widely discussed, previous studies still leave substantial gaps that need to be explored. A study by Ratuanik & Feninlambir (2022) has explored the use of GeoGebra in circle materials, but the study remains limited to static written instructions and focuses on the junior high school level. Meanwhile, Purnama et al., (2022) emphasized in their research that the use of mathematical software often fails to achieve maximum results due to the lack of in-depth self-guidance for students, causing them to remain dependent on direct instructions from teachers. In addition, research from Fauzy et al., (2023) shows that many technology-assisted teaching materials that

have been developed have not fully integrated GeoGebra's dynamic features in real-time for abstract concepts at the high school level, such as the position of a line relative to a circle or a common tangent line that requires high visuality. To address this critical gap, this study focuses on the development of specialized instructional materials for high school students (Phase F) that fully integrate interactive, real-time GeoGebra applets. Unlike previous studies, this research integrates guided exploration steps into the instructional materials, enabling students to independently manipulate digital objects to resolve cognitive ambiguities without having to rely on constant teacher guidance, particularly when abstracting complex concepts related to circles, such as tangents.

This study aims to fill this research gap by developing GeoGebra-assisted teaching materials on circles that are specifically adapted to the cognitive characteristics of Phase F students at MAN 2 Tanah Datar. The novelty of this study lies in the integration of comprehensive and systematic GeoGebra instructional tutorials in video format. Unlike conventional teaching materials, this product not only presents static representations in the form of text and images, but also combines dynamic visualizations with tutorial videos that allow students to learn independently at their own pace (self-paced learning). Through this development procedure, it is hoped that teaching materials that meet the development quality criteria will be produced. The validity criteria in this study refer to the accuracy of the material standards, presentation standards, design standards, and graphic standards (Kemendikbudristek, 2022). Meanwhile, the practicality criteria in this study refer to the aspects of ease of use, benefits, attractiveness, and clarity of teaching materials. The presence of this valid and practical product is projected to be a solution to visualization constraints and learning resource limitations, which ultimately contributes to improving the quality of mathematics learning holistically.

RESEARCH METHOD

Research Type

This research is a type of Research and Development (R&D) research. This type of research aims to produce a specific product while testing its effectiveness (Sugiyono, 2011). The product developed in this study is a mathematics learning material assisted by GeoGebra software. Referring to the product quality criteria according to Nieveen in Mahmuzah et al., (2023). A development product must meet the aspects of validity, practicality, and effectiveness. However, the scope of this study is limited to the practicality test stage of the product.

Time and Place of Research

The research was conducted in two sessions, on Thursday, November 13, 2025, and Tuesday, November 18, 2025. The research took place in class XI-B1 and the teacher's room at MAN 2 Tanah Datar.

Research Targets and Subjects

The target of this study is the availability of interactive mathematics teaching materials for 11th-grade students. The research subjects involved three mathematics teachers at MAN 2 Tanah Datar as field practitioners to assess the practicality from the educator's perspective, as well as 23 students from class XI-B1 as user subjects to assess the response and ease of use of the product.

Research Procedures

This research is a research and development (R&D) study aimed at producing GeoGebra-assisted mathematics teaching materials on the subject of circles. The development model adapted is the 4D model (Define, Design, Develop, Disseminate) developed by Thiagarajan. However, this study is limited to three main stages, namely define, design, and develop, due to adjustments to the scope of product implementation at MAN 2 Tanah Datar. The define stage begins with a needs analysis through observation and interviews to identify learning dominance, followed by an analysis of the curriculum, material, and learning objectives to align the content with the learning outcomes of phase F of the Merdeka Curriculum. In the design stage, the format was selected, and the initial design of teaching materials integrating GeoGebra features was prepared. Next, the development stage focused on product realization and quality testing through validity and practicality tests.

The validation process involved three mathematicians who evaluated the standard aspects of the material, presentation standards, design, and graphics based on instruments adapted from the standards (Kemendikbudristek, 2022). After being declared valid through a series of revisions, the product was tested on teachers and students at MAN 2 Tanah Datar to measure its practicality. Practicality data were collected using a questionnaire instrument that included components of ease of use, usefulness, attractiveness, and clarity of teaching materials. All collected data were then analyzed descriptively to ensure theoretically and practically valid quality standards for use in learning.

Research Instruments

Data collection in this study was conducted using two main types of instruments, namely teaching material validation sheets and practicality questionnaires.

1. Teaching Material Validation Sheet

   The assessment of the validation and practicality of the instrument was measured using a Likert scale to avoid central tendency bias. The instrument scoring was categorized into four weight levels, namely: score 4 for the strongly agree (SS) category, score 3 for the agree (S) category, score 2 for the disagree (TS) category, and score 1 for the strongly disagree (STS) category (Vela et al., 2021). The quantitative data obtained were then converted into qualitative data to determine the level of validity and practicality of the teaching materials.

2. Practicality Sheet

Table 1. Practicality Questionnaire

Number	Aspect	Data Collection Methods	Instrument
1	Ease of use component	Questionnaire	Questionnaire for educators and students
2	Benefit component		
3	Attractiveness component		
4	Clarity of the teaching materials component		

The practicality instrument used in this study was constructed using a Likert scale. Each item in the questionnaire, responded to by educators and students, was given the following assessment scores: 4 points for the category Strongly Agree (SS), 3 points for Agree (S), 2 points for Disagree (TS), and 1 point for Strongly Disagree (STS) (Vela et al., 2021). The quantification of data through this scoring aims to produce definitive data, which is then transformed into qualitative data to accurately interpret the level of practicality of teaching materials.

Data Analysis Techniques

The data analysis technique in this study was conducted using descriptive quantitative methods to evaluate the quality of the teaching materials developed. Data obtained from the validation sheet and practicality questionnaire were calculated using a percentage formula:

$$P = \frac{\sum score\ for\ each\ item}{maximum\ score} \times 100\%$$

The results of the validity percentage calculation are then interpreted based on five categories, namely: 0% - 20% (Not Valid), 21% - 40% (Less Valid), 41% - 60% (Sufficiently Valid),

61% - 80% (Valid), 81% - 100% (Highly Valid) (Munawaroh et al., 2023). Teaching materials are categorized as suitable for use if they meet the minimum "Valid" criteria, while results below this standard require revision according to the validator's suggestions.

A similar analysis was conducted to measure the level of practicality based on the responses of educators and students. The practicality criteria were divided into the following categories: 0% - 20% (Impractical), 21% - 40% (Less Practical), 41% - 60% (Quite Practical), 61% - 80% (Practical), 81% - 100% (Very Practical) (Munawaroh et al., 2023). The product was declared to have successfully met the development requirements if the analysis results showed a minimum level of practicality in the "Practical" category.

RESEARCH RESULTS AND DISCUSSION

Results

The process of developing teaching materials on circles using GeoGebra was analyzed in three stages. The first stage was an in-depth definition stage to map the urgency of the problem at MAN 2 Tanah Datar. The results of the analysis in this definition stage revealed a discrepancy between the availability of static teaching materials at the school and the need for abstract circle concepts at MAN 2 Tanah Datar. Exclusive reliance on textbooks with conventional (one-way and limited in quantity) teaching by teachers has resulted in low student achievement, with an average student score of ≤ 78 due to weak mastery of dynamic geometric concepts. This vulnerability is evident when students struggle to visualize geometric transformations and invariant properties; for instance, they can calculate a circle's tangents or central-to-inscribed angle relationships using fixed formulas, but fail to comprehend how these components dynamically change when points on the circumference are moved. Because static textbooks cannot illustrate these fluid positional shifts, students develop rigid, rote-memorization habits rather than a flexible conceptual grasp. Although students have adequate digital literacy, this potential has not been facilitated by interactive and adaptive media for the independent curriculum. Therefore, the development of GeoGebra-assisted teaching materials is a didactic urgency to transform the presentation of material from static 2D representations to dynamic visualizations in order to significantly improve students' conceptual understanding and learning independence.

Based on the findings in the definition stage, the research continued to the design stage, which focused on developing teaching materials on circles using GeoGebra technology. The resulting product was designed in the form of multimodal teaching materials for Grade 11 Phase F of senior high school/MA, which combined various modes of information, including text, visuals, and digital technology, to create a comprehensive learning experience. Technically, aesthetic

development was carried out using the Canva and Microsoft Word platforms, while dynamic geometric visualization was built through GeoGebra software as the main exploration instrument. This teaching material positions GeoGebra as an exploration partner where students can directly manipulate objects to discover mathematical relationships independently, such as observing the constant distance of the radius on the circumference of a circle through visual proof of precise numerical values.

To support student independence, each activity unit is equipped with a step-by-step GeoGebra tutorial video produced using CapCut, which can be accessed instantly by scanning a QR code or via a direct link to the YouTube channel. In addition, these teaching materials can be accessed officially via the institution's website: https://banjar.uinmybatusangkar.ac.id/. All parts of the learning display in these teaching materials are systematically arranged with reference to the Learning Outcomes (CP) and Learning Objectives (TP) of the Merdeka Curriculum, which covers seven meeting units, complete with the "Let's Understand" feature as a problem-solving model, as well as the "Let's Practice" and "Evaluation" instruments as means of strengthening competencies, the detailed structure and visual display of which can be seen in Table 2.

Table 2. Display of Teaching Materials on Circles Using GeoGebra

Number	Display	Description
1		**Teaching Material Title** This product is titled "GeoGebra-Assisted Mathematics Teaching Material on Circles," a label that explicitly represents the integration of geometry content with dynamic technological instruments. This title is designed to emphasize the paradigm shift from conventional learning to digital exploration in line with the vision of the Merdeka Curriculum. Visually, the cover design combines modern aesthetics with contextual illustrations of a Ferris wheel as a concrete representation of the concept of a circle, in order to increase the appeal and relevance of the material. The inclusion of formal attributes and curriculum identity on the cover reinforces the legitimacy of the product as an innovative learning medium that is structured, interactive, and student-centered. **Subject** The subject of Mathematics in this development serves as the core discipline and curriculum framework that focuses content on logical reasoning, quantitative analysis, and the exploration of spatial relationships, particularly in the domain of circle geometry.

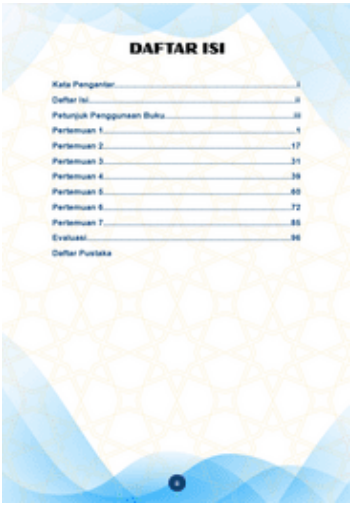
2

Competencies to be Achieved

Target competencies are formulated hierarchically with reference to Phase F Learning Outcomes (CP), which are then derived into four measurable Learning Objectives (TP) covering the identification of elements, analysis of relationships between elements, application of geometric properties, and analytical contextual problem-solving. The implementation of these competencies is integrated into seven GeoGebra-based meeting units, which are systematically designed to guide students from mastering basic concepts to complex application skills. Through the use of dynamic features, this teaching material facilitates the construction of a deep understanding to ensure that students are able to solve circular geometry problems comprehensively and systematically.

3 a. Foreword

b. Table of Contents



c. Instructions for Use

Supporting Information

a. Foreword

The foreword serves as a methodological justification that positions GeoGebra as a visual innovation to bridge abstract concepts of circles through independent discovery. In addition to explaining the urgency of balancing conceptual and practical aspects, this section presents a systematic flow of material in line with the active learning principles of the Merdeka Curriculum to improve student learning outcomes.

b. Table of Contents

The table of contents is organized systematically to help users navigate the structure of the instructional materials. This section includes user guidelines, competency instruments (CP and TP), as well as content on the elements and relationships within the circle, all organized systematically by lesson unit.

c. Instructions for Use

The instructions for use are designed as an operational guide to optimize the use of teaching materials, from reviewing competency targets (CP and TP) to the evaluation stage. This component aims to facilitate student independence in learning through structured and systematic instructions in exploring all available features.

4

Procedural Video Tutorial Guide

To support student learning independence, this section presents video clips of tutorials on how to use GeoGebra, which were produced in depth using the CapCut application. The visualization in the table shows the integration of QR codes and YouTube links that serve as strategic operational guides for students in comprehensively mastering GeoGebra features. These videos are consistently provided in each activity unit across all seven sessions available in the teaching materials. Specifically, these visual guides are available from the material discussion stage to provide an initial overview, to the 'Let's Understand' feature as a concept reinforcement tool. Thus, these tutorial videos serve as digital assistants that guide students in understanding the flow of construction and manipulation of geometric objects in each learning session, thereby minimizing technical obstacles in using the software.

5 a. Construction Phase

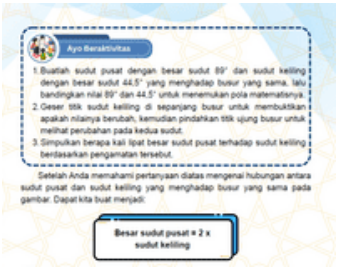
b. Manipulation Stage

Stages of Using and Exploring GeoGebra

This section shows the operational stages of using GeoGebra in exploration activities:

a. Construction Phase

In this teaching material, the construction stage refers to the initial activities of students when operating the GeoGebra software to build basic geometric objects of circles. For example, operationally, this stage begins with setting point O as the center point of the circle. Students are then instructed to construct the circumference of the circle, which is the location of points at a constant distance from the center. Students are then instructed to construct specific points such as A, B, and C on the curved line of the circle. Through this



c. Discovery Stage

precise construction process, students can independently validate that the distance of each point to the center O has the same numerical value.

b. Manipulation Stage

In the implementation of this teaching material, the manipulation stage focuses on utilizing GeoGebra's interactive features that allow students to actively interact with the material. Based on the guidelines in the “Let's Get Active” section, students do not simply observe geometric objects, but conduct experiments by shifting certain variables to test the properties of circles dynamically. For example, in the visualization, manipulation is carried out by observing changes in the position of points on the circumference of the circle, where students can verify in real time that even though the points are moved, the relationship between the distance (radius) and the center remains precise. This stage is designed to bridge abstract concepts into functional understanding through independent discovery, supported by the problem-solving model in the “Let's Understand” feature.

c. Discovery Stage

The numerical validation stage in this teaching material is a crucial phase in which students verify mathematical theories through quantitative data generated with precision by GeoGebra software. This stage explicitly presents dynamic visualizations that allow students to directly observe the relationships between circle elements, such as through the “Let's Understand” feature, which serves as an operational demonstration of concept application. For example, when students find the numerical value of the circumference angle ∠ACB=38° on the GeoGebra interface display, they are directed to observe the automatic changes in the related central angle values. Through this accurate presentation of data, an abstract understanding of the relationship between central angles and circumference angles can be bridged to concrete visual evidence, thereby helping students build mathematical conclusions independently and systematically.

6

Worksheets

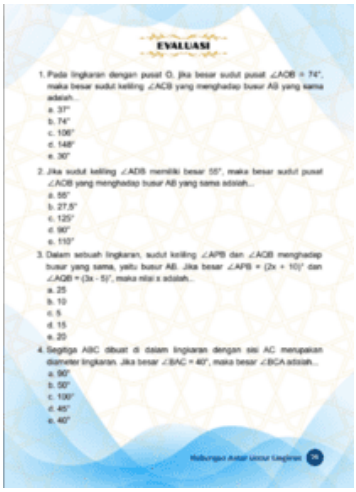
The “Let's Understand” feature serves as a post-exploration concept reinforcement tool available for each of the 7 sessions. This section presents comprehensive solutions that combine GeoGebra visualizations with formal manual calculations to validate students' findings, ranging from the relationship between central angles and circumferential angles to common tangents. Through this synchronization of visual and algebraic methods, the teaching materials ensure that mastery of digital tools remains in line with valid and accurate mathematical procedural skills.

7

Exercises

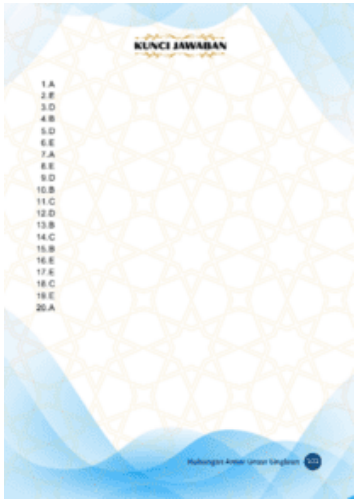
The “Let's Practice” component serves as a self-evaluation tool in the form of multiple-choice questions strategically placed at the end of each unit. This section is designed to verify students' mastery of competencies after the discovery phase, covering testing angle relationships, analyzing bowstring quadrilaterals, calculating arc length and sector area, and applying the Pythagorean theorem to tangents of circles. Through this variety of small summative instruments, students can independently measure their competency readiness before continuing to the next material.

8



Evaluation

The evaluation section serves as a summative assessment through 20 comprehensive multiple-choice questions to measure students' achievement of competencies in all circle-related material. In addition to being a measurement tool, this component serves as a diagnostic tool for teachers and a means of self-assessment for students through the inclusion of answer keys as instant feedback.



The product's feasibility was then tested through the development stage, which involved expert validation and practical testing by practitioners. The comprehensive assessment results conducted by the three validators on this GeoGebra-assisted circle teaching material are presented in detail in the table below. The validators are two mathematics lecturers from UIN Mahmud Yunus Batusangkar and one lecturer from Tadris Matematika UIN Sjech M. Djamil Djambek Bukittinggi. The data includes the accumulated scores from various feasibility indicators to determine the validity level of the developed product.

Table 3. Product Validation Results

Number	Validity Indicators	Validator			Amount	Maximum Score	Percent	Category
		1	2	3				
1	Material Standards	43	44	43	130	132	98.48	Highly Valid
2	Presentation Standards	10	11	10	31	36	86.11	Highly Valid
3	Design Standards	9	11	10	30	36	83.33	Highly Valid
4	Graphics Standards	10	9	10	29	36	80.57	Highly Valid
	Amount	72	75	73	220	36		
Average							87.12	Highly Valid

Based on Table 3, this GeoGebra-assisted circle teaching material obtained an average validity percentage of 87.12% with a Very Valid category. This achievement is the accumulation of a comprehensive assessment of the material standard indicators, presentation standards, design standards, and graphic standards that have met the standard requirements of grade XI phase F students at MAN 2 Tanah Datar.

After undergoing a revision process based on the validator's suggestions, the product was tested on teachers and students of class XI-B1 at MAN 2 Tanah Datar. This trial aimed to see the extent of the ease of use and efficiency of the media in the context of real learning in the classroom.

The results of the subjective assessment of teachers and students regarding the practicality of the GeoGebra-assisted circle teaching material are presented in detail in Table 4.

Table 4. Results of Product Practicality Testing by Teachers

Number	Practicality Indicators	Teacher Score	Maximum Score	Percent	Categories
1	Ease of Use Component	39	48	81.25	Highly Practical
2	Benefit Component	28	36	77.78	Practical
3	Attractiveness Component	40	48	83.33	Highly Practical
4	Clarity of Teaching Materials Component	64	84	76.19	Practical
	Average			79.63	Practical

The data in Table 4 show that the developed teaching materials meet the Practical criteria with an average percentage of 79.63%. The highest scores were found in the attractiveness (83.33%) and ease of use (81.25%) indicators, indicating that the integration of GeoGebra into teaching materials provides attractive visual stimuli and offers user-friendly operations for both teachers and students.

Although the components of teaching material clarity (76.19%) and usefulness (77.78%) fall into the practical category, these results confirm that the material has transformed abstract concepts of circles into more concrete ones through interactive simulations. Comprehensively, the teachers' assessment shows that this teaching material is suitable for use as a supporting medium for mathematics learning at MAN 2 Tanah Datar because of its high functionality in helping to deliver the independent curriculum material dynamically and innovatively.

Table 5. Results of Product Practicality Tests by Students

Number	Practicality Indicators	Student Scores	Maximum Score	Percent	Categories
1	Ease of Use Component	230	276	83,33	Highly Practical
2	Benefit Component	234	276	84,78	Highly Practical
3	Attractiveness Component	163	184	85,58	Highly Practical
4	Clarity of Teaching Materials Component	540	644	83,85	Highly Practical
	Average			85,13	Highly Practical

Based on Table 5, the results of the practicality test by teachers showed an average percentage of 85.13% in the Very Practical category. In detail, the attractiveness indicator received the highest score of 88.58%, indicating that the integration of GeoGebra dynamic visualization and teaching material layout design was able to stimulate enthusiasm and attention in the instructional

process. The usefulness indicator (84.78%) shows that this product is effective in helping teachers transform abstract geometric concepts into more concrete ones that are easier to articulate to students.

Meanwhile, the clarity (83.85%) and ease of use (83.33%) components confirm that the flow of material presentation and operational instructions in the teaching materials has been systematically arranged, thereby minimizing technical barriers during implementation. The high scores on all these indicators prove that GeoGebra-assisted circle teaching materials meet the criteria of functionality and efficiency as an innovative learning medium that is adaptive to the needs of the school curriculum.

These results indicate that GeoGebra-assisted circle teaching materials have met operational feasibility standards for widespread implementation in school learning ecosystems. The practicality of this medium is not only represented by its technical functionality, but also by its effectiveness in transforming abstract and complex geometric concepts, such as the relationship between circle elements and tangents, into more intuitive and attractive dynamic visualizations. Thus, the presence of this teaching material can be a significant alternative solution in overcoming the limitations of conventional teaching aids. In addition, this product serves as a supporting instrument that facilitates teachers in evaluating student competency achievement in a more systematic, objective, and measurable manner.

Discussion

The definition stage revealed that there was a discrepancy between the availability of digital infrastructure at MAN 2 Tanah Datar and instructional practices that were still conventional and teacher-centered. Exclusive reliance on a single textbook resulted in low student visualization skills for abstract geometric concepts, which had an impact on the average test score below the pass rate (78). This condition confirms the findings (Dewi & Widodo, 2016; Ferdiyansyah et al., 2025) the lack of variety in static learning resources often fails to facilitate students' spatial understanding of circle material.

Further analysis of the Phase F curriculum shows that the mechanistic presentation of material and focus on formulas hinders the achievement of Learning Objectives (LOs) that require relational reasoning. Geometry material requires a dynamic representation to bridge the transition in students' thinking from the informal to the formal deductive level. Therefore, integrating GeoGebra into teaching materials is crucial for transforming abstract objects into dynamic entities that can be manipulated in real time. This step is projected to revitalize learning retention and student independence in exploring, in line with the characteristics of today's digital-native learners (Ratuanik et al., 2024).

As a solution to the problems encountered in the definition stage, the design stage produced a multimodal teaching material prototype that integrates text, GeoGebra dynamic simulations, and QR Code-based video tutorials. Product development utilizes the synergy of the Canva platform for visual design, GeoGebra for geometric visualization, and CapCut for operational guidance. This multimedia integration is designed as cognitive scaffolding to facilitate diverse learning styles while reducing the cognitive load on students in understanding abstract concepts. The teaching material structure is systematically arranged, which includes identity components, competency targets (CP/TP), supporting information, and evaluation instruments.

The main innovation lies in the “Let's Get Active” feature, which applies the guided discovery method, allowing students to manipulate geometric objects independently to discover the relationships between circle elements empirically. Visually, the use of blue as the dominant color in the product design aims to create a stable learning atmosphere conducive to student concentration (Rizky & Marssellina, 2025). The use of GeoGebra in this design has been theoretically proven to transform conventional learning into dynamic exploration that improves memory retention and relational understanding (Aisyah et al., 2025). In addition to the main product, at this stage, teacher and student response questionnaires that have met the criteria of construct and content validity through expert review have also been prepared, so that they are ready to be used to measure the practicality of the product in the next stage of development.

Furthermore, the development stage shows that the teaching materials developed meet very high theoretical feasibility criteria. Expert validation results gave an average score of 87.12% (Highly Valid), with the material indicator achieving the highest score (98.48%), confirming the accuracy of the concepts and curriculum alignment. These findings are consistent with the development of video-based media, which also achieved a rating of “highly valid” with a score of 83%, where clear visual quality and the appropriateness of the content are the key factors determining the suitability of digital learning media (Hasna et al., 2025). This is supported by the results of the validation of ethnomathematics-based interactive media by (Yenti et al., 2022), which yielded an average score of 78.39% (Valid), with content quality and visual presentation serving as key indicators in meeting product quality criteria. Although the graphics (80.57%) and design (83.33%) aspects were lower, both were still categorized as highly valid in supporting digital accessibility. The researchers conducted formative revisions to the layout and consistency of GeoGebra terminology to minimize students' cognitive load in accordance with the principles of multimedia coherence (Lakusa et al., 2023).

The practicality test at MAN 2 Tanah Datar confirmed the effectiveness of the product in the field with a student response score of 85.13% (Very Practical) and an educator response score of

79.63% (Practical). Students rated the visual appeal and benefits of GeoGebra visualization as the most outstanding aspects in clarifying the abstract concept of circles. This high level of positive response aligns with the findings of Yenti et al., (2022), who reported that the use of interactive media resulted in a practicality rating of 82.5% among students and 87.5% among teachers due to its systematic, clear, and user-friendly nature. This is supported by a study by Hasna et al., (2025), which shows that interactive learning media are considered highly practical because they are easy for students to use and save teachers time in the classroom. Meanwhile, teachers emphasized the ease of operation and efficiency of teaching materials as a source of independent learning. Overall, this synergy of validity and practicality proves that the product is not only technically feasible but also pedagogically effective in improving the quality of interactive geometry learning (Hidayati et al., 2022).

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study produced a teaching material on circles that systematically integrates GeoGebra technology to transform static geometric concepts into dynamic visualizations. Based on the development test results, this teaching material was declared highly valid with an average validity percentage of 87.12%, covering the feasibility of the material, presentation, language, and graphic design aspects. In addition to meeting validity standards, this product is also very practical, with a score of 85.13%, confirming its ease of navigation, clarity of operational instructions, and efficiency in facilitating independent concept discovery. Although the content is in line with the Learning Outcomes (CP) of Phase F of the Merdeka Curriculum, this teaching material is positioned as an innovative instrument that strengthens students' digital literacy and spatial visualization skills, while also being an effective solution for educators in overcoming the abstraction of geometry material at the high school/MA level.

Recommendations

The implementation of these teaching materials is expected to be optimized by educators through the use of GeoGebra's dynamic features and QR Code integration to facilitate independent discovery while overcoming obstacles in visualizing abstract geometric concepts. The support of school institutions is crucial in ensuring the availability of digital infrastructure and disseminating the product to fellow teachers to expand the use of the media at the educational unit level. From the students' perspective, active participation in the exploration feature is strongly encouraged to strengthen spatial visualization and intuitive conceptual understanding. For future researchers, it is recommended to conduct in-depth effectiveness tests to demonstrate the product's significance in

improving the quality of student learning outcomes in the field. In addition, the development of similar media should be extended to other high-level abstractions, such as trigonometry, to enrich the variety of digital learning resources that are adaptive to students' needs.

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