Edumatica: Jurnal Pendidikan Matematika
Volume 15 Number 2 Agustus 2025

Submited : 04 June 2025
Revised : 1 August 2025
Accepted : 1 August 2025

DOI: https://doi.org/10.22437/edumatica.v15i2.44894

Mathematics in the Concept of Circles: Creating Digital Learning Tools That Honor Cultural Heritage

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Abstract

This research aims to develop mathematics learning media called ETNOSIKA-AR, which combines visual-interactive concepts with the local cultural values of the Kaliwadas Ancient Well Site in circular materials to improve students' understanding of concepts. Media development is carried out based on the ADDIE model, consists of five systematic stages: needs analysis, design, development, implementation, and evaluation. This research was conducted in June and involved high school students in class X in Cirebon. The validation results by three experts show that this media is included in the very valid category, with percentages of 94.7%, 97.9%, and 96.8%, respectively. A practicality test was conducted involving 31 high school students, and the results showed that 77% of students stated that this medium was practical, and 13% said it was very practical. On the other hand, only 10% consider it less valuable. The analysis showed that 77.42% of students were in the high N-Gain category, and 22.58% were in the medium category, with no students in the low category, with an average N-Gain score of 0.7762. These findings show that ETNOSIKA-AR media effectively improve understanding of circular matter. This media also succeeds in presenting interesting and meaningful learning by integrating cultural and technological aspects.

Keywords: augmented reality; circle concept; ethnomathematics; ETNOSIKA-AR; interactive media

INTRODUCTION

Mathematics is one of the sciences that can be learned and applied daily (Agustino & Susanto, 2024). Because of its significance and relevance in so many aspects of daily life, mathematics is a subject taught at every level of education (Golding, 2018). However, mathematics education in Indonesia faces challenges in bridging students' understanding of abstract concepts that often feel far from everyday life. Many students have difficulty understanding abstract and symbolic mathematical concepts due to a lack of innovation in the learning process (Klorina & Juandi, 2022). On the other hand, the rich diversity of local cultures is rarely used as a contextual learning resource (Razak et al., 2020). As a result, learners view mathematics in the classroom differently from what they encounter in everyday life (Benson-O'Connor et al., 2019). Integrating education and culture can strengthen local identities while improving conceptual understanding through a contextual approach closer to the student experience. This ignores the potential of culture as an authentic source of learning (Sukrin & Ihlas, 2025). Thus, students need to improve their understanding of the importance of preserving culture (Astutiningtyas, 2017; Rahmawati et al., 2023). Integrating Indonesian culture into the teaching and learning process can significantly deepen meaning, increase relevance, and strengthen the effectiveness of students' learning experiences, while fostering appreciation for local cultural values (Oktiningrum et al., 2025). The gap between cultural heritage and modern learning must be bridged through innovations combining both aspects.

One approach that can bridge mathematics and culture is ethnomathematics, which is the study of mathematical practices that live in local traditions and cultures (Febriyanti et al., 2024). Ethnomathematics plays a role in connecting cultural preservation and technological progress through science (Permata et al., 2021) Ethnomathematics functions as an integrative medium that connects the discipline of mathematics with the values, practices, and cultural context of society. Thus, ethnomathematics is defined as an anthropological approach that examines the practice of mathematics in a specific cultural context and its implications for the mathematics education process (Zhang et al., 2021). One example of a culture that can be associated with mathematics learning is the Kaliwadas well site in the Cirebon district, which has an attraction because it has high mathematical and cultural value (Noto et al., 2018). In the context of mathematics learning, the structure of a well can be used as a concrete example to explain the elements of a circle, such as the center point, radius, diameter, and arc. The center point of the well can be assumed to be the center of the circle, with the distance from the center to the wall as the radius. The walls of the well form a circular circumference, and the straight line connecting the two points on the wall through the center is the diameter. The concept of a well is also relevant to understanding the relationship between the central and circumferential angles. By imagining three points on the well wall, two in circumference and one in the center, students can visualize the central angle as an angle formed by two radii and a circumferential angle as an angle formed around it by two lines connecting the three points. The integration of local culture with mathematics makes it easier for students to understand, and shows the role of mathematics in people's lives (Chahine, 2020).

Although promising, the ethnomathematical approach still faces significant challenges in concretely conveying abstract mathematical concepts (Tubondo, 2025). Many teachers still rely on lecture methods and symbols on the whiteboard without visual media to help students concretely build their spatial imagination. As a result, students have difficulty distinguishing and intuitively understanding the position of the center point, radius, and diameter, and how the center angle and circumferential angle are formed and interconnected in a circle (Liang & Castillo-Garsow, 2020). The lack of learning innovation exacerbates students' difficulties because many teachers have not utilized interactive visual media or digital technology (Hanan Pratiwi et al., 2024). Thus, concepts such as the central angle is worth twice the circumference angle are still challenging to understand because they are only explained verbally without visualization or direct experience. Studies (Gusteti et al., 2023) mention that students need visual representation and direct interaction with geometric objects to understand circles better. This condition demands the renewal of learning strategies through interactive media and innovative technologies that present the concept of circles more realistically and meaningfully. Interactive learning media is one of the creative solutions in education (Syafira et al., 2024). Interactive learning media allow students to listen to or read the material but also interact directly with the material (Munawir et al., 2024). More than just a visual aid, interactive learning media integrates audio, visual,

animation, and technology elements that make the subject matter more lively and contextual (Suraya Suraya & Fitry Maharani Siagian, 2024). Therefore, teachers and media developers need to integrate technology in the learning process to visualize and understand abstract material more clearly.

One of the innovative solutions for interactive learning media is the use of Augmented Reality (AR) technology in the development of mathematics learning media (Bulut & Ferri, 2023). As an interactive learning medium, the application of Augmented Reality technology is considered relevant to improve the quality of the teaching and learning process (Rinaldi et al., 2024). Augmented Reality technology promises interesting solutions to increase student learning engagement (Purnama Sari et al., 2024) Augmented Reality plays an essential role in education by presenting interactive and visual content that improves students' understanding of concepts (Fauziyah et al., 2024). With the principles of mathematics learning, students are expected to be able to build their understanding of concepts independently as a basis for solving various mathematical problems (Firmasari et al., 2022). Augmented Reality helps students understand the concept of circles by turning 2D images into 3D objects, allowing them to visualize and manipulate abstract objects in real life through digital devices (Buliali et al., 2022). Thus, interactive learning media provide visualization and interaction that help students understand the concept of the circle more deeply (Nn. L. N. A. Putri et al., 2023).

Previous research has been conducted to explore geometric mathematics materials related to culture, especially in historical sites. For example, (Noto et al., 2018), this study explores ethnomathematical elements at the Kaliwadas Ancient Well site and its relation to mathematics learning in schools. Using a qualitative ethnographic approach, various geometric shapes, n-sides, and limits were found in making wells. Although some studies have addressed the use of technology-based learning media, few specifically integrate local culture or ethnomathematics elements into these media, particularly in mathematics learning. Therefore, this research aims to contribute to developing innovative and effective learning media to support mathematics education integrated with cultural values and technological advancements.

METHOD

This research aims to develop a mathematics learning medium that integrates a visual-interactive approach with local cultural wisdom. This research uses the Research and Development (R&D) method with the ADDIE model approach, which consists of five stages: analysis, design, development, implementation, and evaluation.

This research was conducted at a high school in Cirebon, West Java, Indonesia. This institution functions as a location for media development and a place to test its implementation in the context of research. This study involved 31 tenth-grade students. The following is a research flow diagram, as shown in Figure 1.

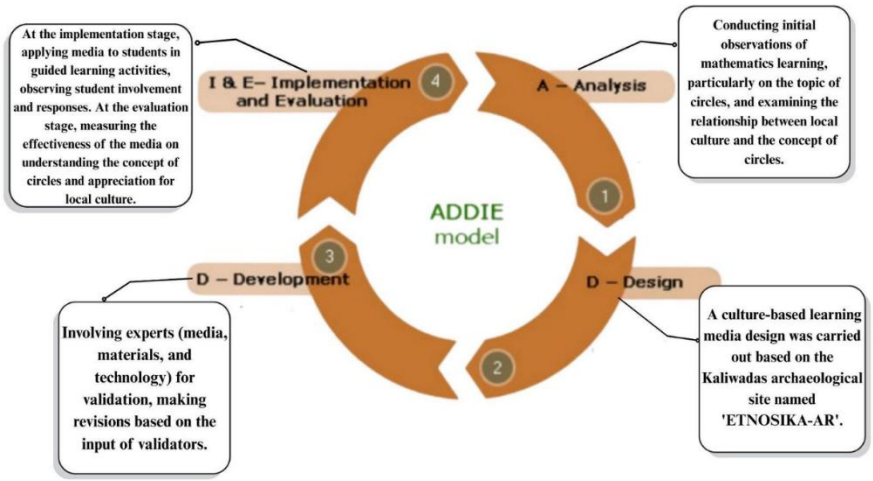


Figure 1. Research Flow of Culture-Based Learning Media on Circle Materials (Aminah et al., 2022)

ADDIE's development research model has five stages of development. The following are the stages of ADDIE development as presented in Figure 1.

1. Analysis

   At this stage, various activities are carried out to identify needs, learning problems, and potential integration between mathematics materials and local cultural elements. The stages of analysis in the development of ETNOSIKA-AR include the following:

   a. Observation of the Learning Process
      Observations were made on class X's mathematics learning process, especially the circle material. This observation aims to discover how learning takes place, what media are used, and the obstacles teachers and students face, especially related to understanding the concept of circles.
   b. Ethnomathematical Studies
      Analyze the relationship between local culture and the concept of circles, such as ancient well sites that use circular elements. These cultural elements were chosen as a context in preparing the material to be closer to the students' daily lives.
   c. Relevant Learning Media Analysis
      Identify the shortcomings of existing learning media, as well as the potential for developing new interactive digital-based media and AR technology that can visually and contextually strengthen conceptual understanding.

2. Design

   Learning media design is carried out based on the results of analysis and potential integration between circular materials, local culture, and technology. The local culture comes from ancient well sites with artifacts and circular building structures, which are ethnomathematical sources named ETNOSIKA-AR. Planning steps include:

   a. Determination of Learning Objectives based on the basic competencies of the circle material.
   b. Select relevant cultural content from the Kaliwadas site, such as ornaments and circular architectural structures.
   c. Preparation of a Digital Book Structure consists of 35 interactive pages containing materials, cultural illustrations, AR instructions, and practice questions.
   d. Visual and Media Design using Canva, with AR elements created in Assemblr Edu to display cultural objects and simulated circles in 2D and 3D.

3. Development

   At this stage, ethnomathematics-based ETNOSIKA-AR learning media were developed with the help of Augmented Reality (AR) technology to facilitate understanding mathematical concepts, especially in circle material. The learning media that have been designed are then validated and discussed by validators, namely material experts, media experts, and technology experts, to get input for development and improvement before being tested on students.

4. Implementation

   At the implementation stage, the ETNOSIKA-AR that has been developed and validated is then tested on students. The trial was carried out while learning mathematics on the topic of circles**.** The implementation of learning using ETNOSIKA-AR with direct assistance to students in accessing digital books and utilizing the Augmented Reality (AR) feature through the Assemblr Edu application. The researcher gives pretest and posttest questions to students to solve problems, and then the user's response to the learning media is used to see the practicality of this media.

5. Evaluation

   The evaluation stage is the final stage of the ADDIE research model. This stage is a process to provide value to the learning program. During the evaluation phase, data analysis was carried out using the pretest and posttest results as a basis for assessing the effectiveness of the media developed during the implementation in the classroom.

The instrument used to measure validity is a validation questionnaire given to expert media lecturers, with several aspects considered for evaluation and feedback related to the design of learning

media, especially for use by high school students. Validity sheets are used to assess the feasibility of data collection instruments before they are used in research. Validation is carried out by media, material, and technology experts in several aspects. Experts are asked to assess media, materials, and technology aspects. The assessment is carried out using a validation sheet with score columns and suggestions for improvement.

Student questionnaires were also carried out to determine the practicality of this learning media design. This is further supported by student interview guidelines, which aim to gather more in-depth information about the application and benefits of this learning media. The effectiveness of media in improving concept understanding is measured using pretest and posttest question instruments to assess students' ability to understand and apply the material after learning the press. The indicators of concept understanding are measured by pretest and posttest questions, as in Table 1.

Table 1. Pretest-Posttest Concept Understanding Indicators

Question Number	Indicator
1	Identify the elements of the circle and explain the reason for the selection of the shape of the circle in the ancient well from a mathematical and cultural point of view.
2	Using the circular area formula to calculate the surface area of the water and relate it to the water discharge.
3	Using the circumference of a circle formula to calculate the length of a fence and explain its application.
4	Explain the difference between the center and circumferential angles in the context of visual observation of the arc.
5	Calculate the area of the jaw based on the center angle and radius, and relate the results to the need for cleaning agents.

The data analysis technique used in this study is descriptive analysis. The percentage score identifies the feasibility level of the product results of this study. The higher the score obtained, the better the feasibility level of teaching media. Assessments from experts and users are analyzed using an interval approach with specific criteria to determine the product's validity level. The evaluation of the practicality of the media was carried out by analyzing the responses obtained from students during the implementation of the limited trial. The effectiveness of the media was analyzed comparatively through a quasi-experimental design of the One-Group Pretest-Posttest Design, by comparing student learning outcomes before and after using learning media. This approach is used to determine the influence of media on improving students' understanding of mathematical concepts. The data of the pretest and posttest results were then analyzed, using the Paired Sample t-Test technique to determine the significance of the difference in scores and calculate the N-Gain Score to measure the effectiveness of improving students' conceptual comprehension.via SPSS version 25.0 for Windows.

RESULTS

Stages of Analysis

Based on the analysis results, it was found that learning in schools still has minimal use of technology-based media that can attract students' attention. This situation affects students' low motivation to learn, especially in mathematics, ultimately leading to the perception that mathematics is a complex and less enjoyable subject. In addition, it was found that school learning has not been optimally integrated with local cultural values. The lack of inculcation of these cultural values can further reduce students' understanding and love for their local cultural heritage.

It was found that students in Stage E had difficulty learning about the circle material. This difficulty is due to the nature of the material, which contains many abstract concepts, such as radius, diameter, arc, and center angle, which are difficult to understand without adequate visualization. In addition, the learning approach tends to be procedural. It focuses on mastering formulas without connecting them to real-life contexts, which makes it difficult for students to relate concepts to their everyday experiences. This condition highlights the importance of learning innovations that integrate mathematical concepts with the local cultural context to increase understanding and interest in learning.

One of the relevant elements of local culture that can be incorporated into the circular material is the Ancient Well in Kaliwadas. This well has a circular basic structure that can serve as a visual illustration and concrete context in geometry learning, especially on circles.

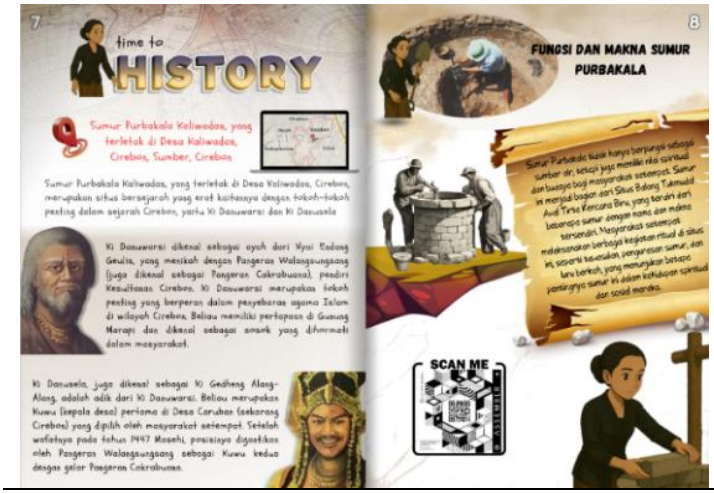
Design Stage

At the design stage, the media is developed based on the analysis of student needs by planning the structure, content, display, and features of ethnomathematical learning media supported by Augmented Reality (AR) technology, and named ETNOSIKA-AR. This stage aims to develop interactive learning concepts and media that help students understand the circle concept through the lens of local culture.

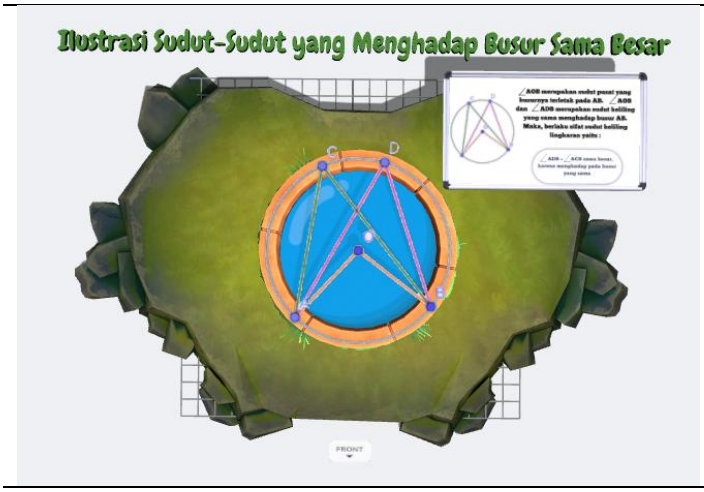
Formulating learning objectives is a component designed at this stage, referring to the Learning Outcomes (LO) Phase E of the Independent Curriculum. The main goal is for students to understand the circle concept and relate it to local cultural representations, such as the basic structure of the Ancient Well.

Table 2. ETNOSIKA-AR Design Display

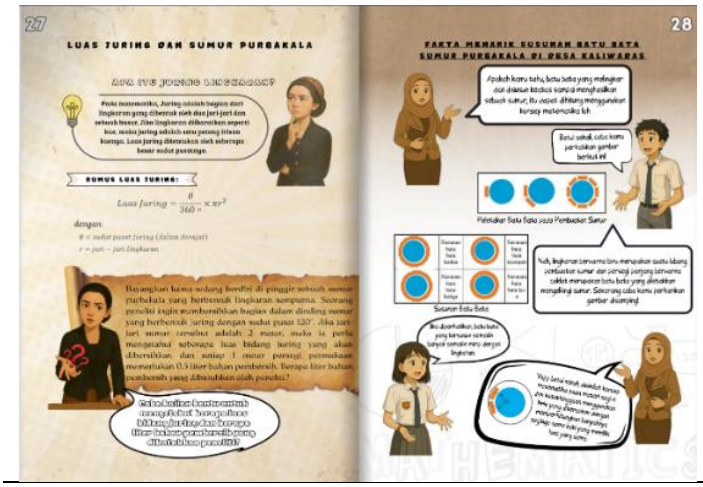
Design	Description
	The cover design features cultural illustrations inspired by ancient wells. The design combines authentic visual documentation of ancient wells with animated elements depicting wells and figures of women dressed in traditional regional clothing. In addition, the back cover presents essential information related to the content and identity of the media.
	This media includes instructions for ease of use by students and is equipped with instructions for using the AR feature.



This page features the Kaliwadas Ancient Well as Cirebon's historical heritage related to figures such as Sunan Gunung Jati and Prabu Wadirectsang. In addition to historical value, these circular wells are relevant for learning mathematics, especially geometry concepts. Through an ethnomathematical approach, students can understand the material contextually while appreciating the local culture.



This illustration features a model of an ancient circular well to explain the concept that the center corner and a circumferential angle facing the arc are equally significant. Circumferential corners such as ∠ACB and ∠ADB appear to be of the same magnitude, while the center angle ∠AOB is twice as large as its circumferential angle. Through the Kaliwadas well-based historical AR approach, this illustration becomes an interactive medium that combines mathematical concepts with local culture in a contextual and meaningful way.



This page shows a learning module that connects the concept of circle area with the Kaliwadas Ancient Well. Students are invited to calculate the well cap's area and contextually understand the circular bricks' arrangement. This approach helps students understand geometry while appreciating local cultural heritage.

This image shows students using the Assemblr Edu application to access the Kaliwadas Ancient Well AR by scanning a QR code that can be checked using Google Lens. The content of the QR is in the form of an explanatory video about the history of the Kaliwadas Ancient Well. These media include interactive media that blend technology, local cultural history, and contextual learning to help students understand concepts more realistically and engagingly.

Development Stage

At the development stage, this medium is considered suitable for use. This assessment is based on feedback from experts who were asked to evaluate the feasibility of ETNOSIKA-AR, as shown in Table 3.

Table 3. Media Validation

Criteria	Validator 1	Validator 2	Validator 3
Aspects of Teaching Materials	31	31	32
Material Aspect	40	43	41
Technological Aspects	20	20	20
Total	91	94	93
Percentage (%)	94.7	97.9	96.8
Category	Very Valid	Very Valid	Very Valid
Average	3.7	3.9	3.8

Table 3 shows that the percentage of ETNOSIKA-AR feasibility assessment by the first validator is 94.7%, which is considered very valid. The rate of the second validator reached 97.9% and was also considered very valid. Meanwhile, the assessment of the third validator showed a percentage of 96.8%, which was also categorized as very valid.

However, based on validator feedback, this ETNOSIKA-AR requires some revisions, especially in AR design and technology. The revision includes adjustments to the illustrations to represent the content better.

(a) (b)

Figure 2. (a) Before revision, (b) After revision

The ETNOSIKA-AR cover is revised in stages to improve its visual appeal and harmony with the learning material. Figure 2(a) shows the initial cover design, which remains simple, depicting only an ancient well from below without any information about the book or learning elements. In the first revision, the animation of the person was modified to be more traditional, in line with Indonesian culture, to attract the attention of high school students. In the second revision, as shown in Figure 2. (b), the design is clarified by adding the title 'on Circle Material' so that the focus of the content is visible, as well as information about the ETNOSIKA-AR book.

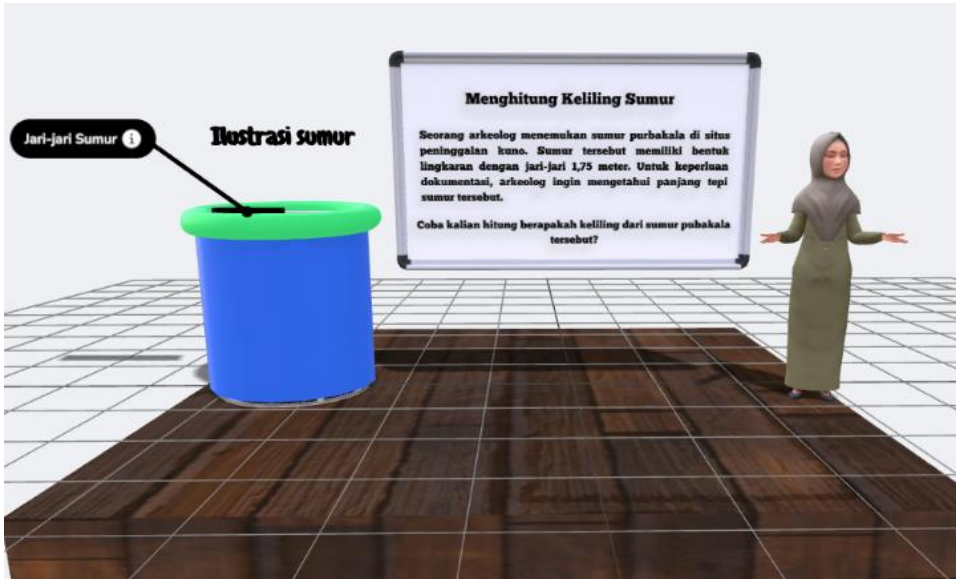


Figure 3. Revision of the Question Display in AR

This image results from revising the questions displayed in the AR media as a follow-up to the media validation. This question relates the concept of the circumference of a circle to the context of ancient wells, accompanied by illustrations of the radius of the well to facilitate understanding. This revision aims to clarify the problem and strengthen the interaction between mathematics and local culture.

Implementation Stage

At this stage, the media will be implemented in small group learning involving five high school students to test the effectiveness and response of students, before a trial in a large group as a further evaluation stage, as shown in Table 4. In this activity, students are asked to fill out a questionnaire designed using a Likert scale of 1-4, representing their level of agreement with aspects such as ease of use, clarity of presentation, and comprehension of the material.

Table 4. Small Group Test

Criteria	Score
Aspects of Interest and Learning Motivation	90
Design Aspects and Media Quality	76
Content and Language Suitability Aspects	45
Cognitive Aspects and Learning Facilitation	59
Total	270
Percentage (%)	75
Category	Practical
Average	3

Table 4 shows the results of a small group of ETNOSIKA-AR media trials with a total score of 270 or 75 percent and an average score of 3. The aspects of interest and motivation to learn received a score of 90, media design 76, learning facilitation 59, and content and language suitability 45. ETNOSIKA-AR media is declared practical and suitable for use. After conducting a small group test,

the assessment of the practice of ETNOSIKA-AR learning media was carried out in a large group trial involving 31 high school students, as shown in Table 2.

Table 2. Results of large-group practicality analysis

Criteria	Score
Aspects of Interest and Learning Motivation	515
Design Aspects and Media Quality	451
Content and Language Suitability Aspects	276
Cognitive Aspects and Learning Facilitation	368
Total	1.610
Percentage (%)	72.13
Category	Practical
Average	2.89

The results of the practicality analysis showed that the learning media developed obtained a total score of 1,610 with a percentage of 72.13%, included in the "Practical" category. The assessment consisted of four aspects: interest and motivation to learn to obtain a score of 515, design and quality of media obtained a score of 451, suitability of content and language obtained a score of 276, and cognitive aspects and learning facilitation obtained a score of 368. The overall average value is 2.89. The highest score on the learning motivation indicates that this medium is attractive to students, while other elements also support the effective use of media. Thus, this media is considered practical to be used in the mathematics learning process in the classroom.

After going through the practicality test stage, the next step is to evaluate the effectiveness of ETNOSIKA-AR media by analyzing differences in student learning outcomes before and after using the press. The analysis involves comparing students' pretest and posttest scores, which are then processed using the N-Gain formula, which calculates the difference between pretest and posttest scores compared to the maximum achievable score. The results of the N-Gain calculation were then analyzed to see an increase in learning effectiveness, referring to the percentage of students in each N-Gain category based on the set interval, as shown in Table 4.

Table 3. Results of Pretest-Posttest Assessment

Category	Interval N-Gain	Frequency	Percentage (%)
High	$g > 0.7$	24	77.42
Middle	$0.3 \leq g \geq 0.7$	7	22.58
Low	$g < 0.3$	0	0
Total		31	100

Based on the results of the N-Gain analysis presented in Table 2, it was found that 24 students, or approximately 77.42%, were in the high category ($g > 0.7$). This percentage shows that most students experience a significant improvement in learning outcomes after using the 'ETNOSIKA-AR' media. In addition, seven students, or 22.58%, were in the intermediate category ($0.3 \leq g \leq 0.7$), indicating sufficient improvement in learning outcomes. Interestingly, none were categorized as low ($g < 0.3$), suggesting that all students experienced increased scores.

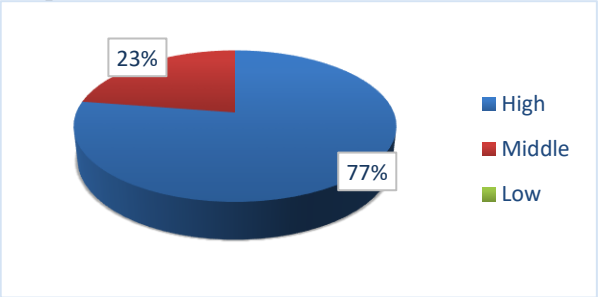


Figure 4. Results of the Pretest-Posttest Assessment

Figure 4 is a pie diagram that displays the results of students' pretest and posttest assessments after using learning media. The diagram shows that 77% of students are in the high category and 23% in the medium category, with no students in the low category. This indicates that learning media effectively increases students' understanding of the material.

Evaluation Stage

In this evaluation stage, students' answers were analyzed to assess the extent of their understanding of the concept of the circle material, especially in applying the juring concept in a real-life context. The questions used involve contextual situations, where students are asked to calculate the area of the juring field from the wall in a circular well with a center angle of 120° and a radius of 2 meters. Next, students must determine the need for cleaning agents based on the information that every 1 square meter of surface requires 0.5 liters of material. The students' answers to the questions can be seen in Figure 5.

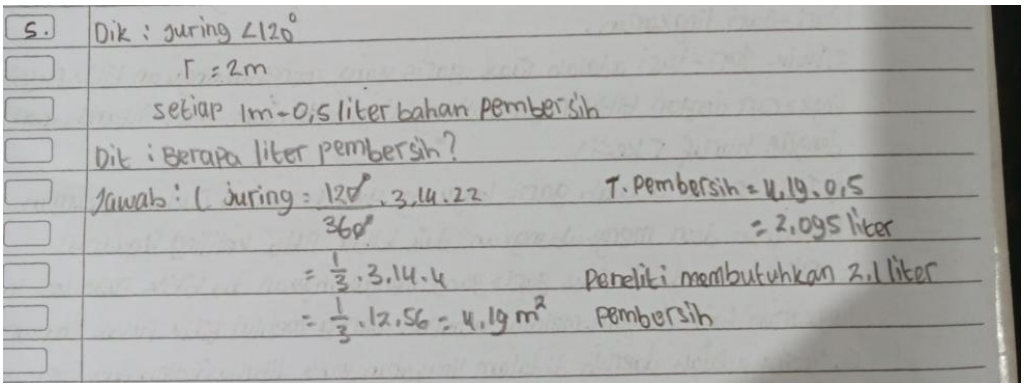


Figure 5. Results of the Pretest-Posttest Assessment

The results of the students' work shown in Figure 5 indicate that the students strongly understand the juring concept, demonstrated through formulas. $L = \frac{\theta}{360^\circ} \times \pi r^2$ Precise and accurate calculations. Students could relate the wide range of results to the need for cleaning agents, so a total of 2.1 liters was obtained. The accuracy of the steps and the relevance of the answers show mastery of concepts and application capabilities in authentic contexts.

Furthermore, data analysis was carried out using pretest and posttest results as the basis for assessment. Final scores were analyzed using the Paired Sample t-Test and the N-Gain test, with data processing performed via SPSS software version 25.0 for Windows, to assess students' improvement in conceptual understanding after media use, as presented in Figure 4.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Pretest - Posttest	-55.548	13.418	2.410	-60.470	-50.626	-23.049	30	<,001

Figure 4. Paired Sample t-Test test results

The results of the analysis of the Paired Samples t-Test showed that there was a significant difference between students' pretest and posttest scores. The average difference between the pretest and posttest is -55.548, with a standard deviation of 13.418 and a standard error mean of 2.410. The 95% confidence interval for the average difference ranges from -60.470 to -50.626. The t-value was calculated as -23.049 with a degree of freedom (df) of 30, and a significance value (Sig. 2-tailed) of < 0.001. Significance values much smaller than 0.05 indicate that the difference between pretest and

posttest scores is statistically significant. In addition, N-Gain analysis was also performed to see learning improvements, as shown in Table 4.

Table 4. Results of the N-Gain Test Score Calculation

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
NGain_Score	31	.39	1.00	.7762	.12553
NGain_Percentage	31	38.75	100.00	77.6209	12.55319
Valid N (listwise)	31				

Based on the descriptive analysis of the N-Gain score from 31 respondents, an average N-Gain score of 0.7762 was obtained, with a standard deviation of 0.12553. The lowest N-Gain value is 0.39, and the highest reaches 1.00. When converted to percentages, the average N-Gain reaches 77.62% with a standard deviation of 12.55%.

According to the N-Gain interpretation criteria proposed by previous studies, an average N-Gain score of 0.7762 falls into the high category ($g > 0.7$) (Hake, 1999) This indicates that improving participants' learning outcomes after receiving treatment or intervention is highly effective. In other words, the teaching methods or strategies have significantly improved students' understanding of the concept.

DISCUSSION

ETNOSIKA-AR Media combines cultural elements with Augmented Reality technology to provide an interactive visualization of the concept of a circle. This technology has been shown to improve students' understanding of abstract concepts, showing that using Augmented Reality in geometry education helps students visualize and understand spatial shapes in a more concrete way. way (Syahputra et al., 2024) With 3D visualization, students can directly explore the structure of circles, including radius, diameter, and center angles. This is very important because one of the main challenges in learning geometry is the limitations of students in imagining abstract objects (Hanan & Alim, 2023). AR technology in ETNOSIKA-AR media has succeeded in overcoming these limitations.

Based on the study's results, experts declared the feasibility of ETNOSIKA-AR in circular material very valid. The validation results by the three validators showed each a score percentage of 93.7%, 97.9%, and 96.8%, all of which were in the range of 80%-100%, thus categorizing them as very valid. Validation by experts is a critical process to ensure the quality and success of technology-based learning media (Astuti et al., 2021) The assessment results show that ETNOSIKA-AR meets the required content quality standards, visual design, and technology integration, making it suitable for implementation in secondary school mathematics teaching. Augmented reality-based encyclopedia media has received the 'very feasible' criterion and can proceed to the next stage (Srisusanty et al., 2024)

Based on the results of the practicality analysis from small and large group trials, ETNOSIKA-AR learning media is declared practical and feasible to be used in mathematics learning. The small group test obtained a score of 270 with a percentage of 75% with an average of 3.00, while the significant group test showed a score of 1,610 with a rate of 72.13% with an average of 2.89, both in the "Practical" category. The aspects of interest and motivation to learn consistently received the highest scores, followed by media design, learning facilitation, and content and language suitability. These results show that ETNOSIKA-AR is attractive, easy to use, and effective in understanding mathematical concepts. Intuitively designed Augmented Reality-based learning media, combined with well-structured instructional content, exhibit a high level of practicality, as demonstrated by a practicality score of 88.40% (Jafnihirda et al., 2023) Similarly, well-designed Augmented Reality media can improve students' understanding of concepts, with a level of practicality achieved by students of 87% (Urrahmah et al., 2025) Factors that support the practicality of ETNOSIKA-AR include a user-friendly interface, easy navigation, and an attractive and easy-to-understand presentation of material. The importance of designing efficient and effective Augmented Reality-based learning media lies in its ability to improve the overall teaching and learning experience. (Meilisa, 2025) In addition, the results of student

interviews support the idea that this media is considered interesting and helps students understand abstract mathematics concepts.

Based on the results of the Paired Sample t-Test, it is known that there is a significant increase in learning outcomes after the application of learning media. The average posttest score is higher than the pretest, as shown by the negative difference value (pretest–posttest), which indicates an increase in students' understanding of concepts. A high t-value accompanied by a minimal significance (< 0.001) reinforces that the increase did not occur by chance, but was the result of the use of the developed learning media. The effectiveness of ETNOSIKA-AR media was further strengthened through N-Gain analysis, where 77.42% of students were included in the high improvement category ($g > 0.7$) and 22.58% in the medium category ($0.3 \leq g \leq 0.7$), and no students were included in the low category ($g < 0.3$). The average N-Gain score of 0.7762 with a standard deviation of 0.12553 shows that this medium effectively improves students' understanding of the material. These results are in line with previous research showing that Augmented Reality-based media enhances student understanding and engagement, as evidenced by an N-Gain score of 0.71 in the experimental group compared to 0.47 in the control group (Aminudin et al., 2024) In addition, previous research has shown that using Augmented Reality-based learning media significantly improves student learning outcomes, with learning scores. The average increased from 54.21 to 83.10 after treatment (Rohani et al., 2021).

The effectiveness of ETNOSIKA-AR is also strengthened by previous research, which states that the use of interactive media significantly improves students' understanding of concepts (Kurniawan et al., 2025) ETNOSIKA-AR, with three-dimensional visualization and interactive animations, allows students to build a deeper understanding of concepts. Previous research supports this, where students who learn using interactive media show a more substantial and more lasting sense of concepts compared to conventional methods, and have an essential role in improving students' understanding of concepts (Mandalina, 2024; Nurdin et al., 2024) The immersive aspect of interactive media helps students form more precise representations of abstract concepts.

Therefore, considering the results of the N-Gain test and supporting evidence from previous research, it can be concluded that ETNOSIKA-AR is suitable, user-friendly, and effective in improving students' conceptual understanding. This research is limited to material about circles that are integrated with the ethnomathematics of the Kaliwadas Archaeological Site. The potential of this media as a technology-based learning innovation is very high and feasible. Therefore, it is recommended that future research develop this media at various levels of education to test its effectiveness, and the integration of Augmented Reality technology can continue to be developed to be more adaptive to digital devices used by students.

CONCLUSION

This research succeeded in developing a culture-based ETNOSIKA-AR learning media of the Kaliwadas Well Site to improve understanding of circles visually and interactively. This media not only conveys mathematical concepts concretely, but also introduces local wisdom as a learning context. Developed through the ADDIE model, ETNOSIKA-AR is validated as feasible by experts, considered practical and attractive by users, and proven effective in improving understanding of concepts. In the future, it is recommended that similar media be developed for other materials and different levels of education, and to increase the integration of AR technology to make it more compatible with digital devices.

ACKNOWLEDGMENTS

The author would like to express his deepest gratitude to the Mathematics Education Study Program of Swadaya Gunung Jati University and high schools in the Cirebon area for the invaluable support and facilities provided during this research.

DECLARATIONS

Author Contribution	:	NA, SF, LJ, CN : Researching, Collecting Data, Processing, Analyzing Data, and Checking Articles. (https://www.elsevier.com/authors/policies-and-guidelines/credit-author-statement)
Funding Statement	:	This research was funded by Swadaya Gunung Jati University through the final project research scheme to support and fund this research.
Conflict of Interest	:	The authors declare no conflict of interest.
Additional Information	:	Additional information is available for this paper.

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