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Article

Innovation Augmented Reality-based Culturally Charged Mathematics Teaching Materials for Students with Physical Disabilities

Junarti[1], Anis Umi Khoirotunnisa[1], Cahyo Hasanudin[2], Anwarul Hidayat[2] and Ayu Fitrianingsih[3]

[1]Mathematics Education, IKIP PGRI Bojonegoro, Indonesia, [2]Indonesian Language and Literature Education, IKIP PGRI Bojonegoro, Indonesia, and [3]English Language Education, IKIP PGRI Bojonegoro, Indonesia

Correspondence: cahyo.hasanudin@ikippgribojonegoro.ac.id

Abstract

Students with disabilities need to receive a lot of attention in learning mathematics in a contextual and renewable way. Therefore, this study aims to develop culturally charged mathematics teaching materials based on Augmented Reality (AR) specifically for students with disabilities. Development was carried out using the Four-D (Define, Design, Develop, and Disseminate) model, which focuses on inclusive and contextual learning needs. Participants include teachers, prospective teachers, subject matter experts, media experts, and inclusion schools. The study's results showed that at the definition stage, teachers with disabilities strongly agreed with the innovation of culturally charged mathematics teaching materials based on augmented Reality. In the design stage, we prepare flowcharts and storyboards and design disability-friendly AR interfaces and interactions. In the development stage, a prototype of teaching materials is produced that is validated by material and media experts with a high level of validity. The product was introduced to inclusion teachers, education volunteers, and prospective teachers in several regions at the dissemination stage. This study concludes that culturally charged mathematics teaching materials based on augmented Reality are very feasible to develop and use by students with disabilities in mathematics learning.

Keywords: *Augmented Reality, Culture, Mathematics Teaching Materials, Physical Disabilities*

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Introduction

Students with disabilities have physical limitations or disabilities (Rohmah, 2022). This physical limitation is caused by a limb defect that causes the limb function to be unable to run normally (Salsabyla et al., 2023). Disability is also often attached to individuals who experience physical abnormalities, especially movement disorders caused by abnormalities in bone and neuromuscular structures (Tetteng et al., 2021). These limitations and abnormalities then result in students with disabilities experiencing difficulties in the learning process (Dacholfany et al., 2023), especially in learning that requires access to physical activity opportunities (Ramos et al., 2025) and complex processes (Khotijah & Wakhyudin, 2025), such as math (Agestingsih et al., 2025).

Obstacles to students with disabilities in learning mathematics are a crucial issue, considering that mathematics is a compulsory subject (Yip et al., 2025) that has practical applications (Zapata et al., 2024) and plays a vital role in almost every field (El Bhih et al., 2024). In addition, learning mathematics can also encourage the formation of mathematical problem-solving skills needed in dealing with everyday problems (Amalina & Vidákovich, 2023). Because of this urgency, innovation is required to accommodate the needs of students with disabilities in mathematics learning, including developing mathematics teaching materials.

Teaching materials used in mathematics learning for students with disabilities must consider several things, such as adaptive aspects (Pebri Fatima et al., 2025) and inclusive (Susilawati, 2025). In addition, the content of the teaching materials can also emphasize contextual elements related to everyday problems (Yani et al., 2022) so that it is closer to the life of students (Taufik et al., 2023). It will make it easier for students to construct knowledge in real life (Nurusyahidah & Zulfadewina, 2022) and encourage students to find concepts independently (Pujiastuti et al., 2021). In addition, integrating contextual aspects can also help facilitate a more realistic learning process (Conci & Zhao, 2025). One of the contextual aspects that can be incorporated into the content of mathematics teaching materials is the cultural aspect.

Using cultural aspects in mathematics teaching materials is a strategic step in introducing local cultural values to students (Suryani & Nurhairunnisah, 2024). This cultural value is considered more relevant to the characteristics and learning needs of students who prioritize the context of values in the community (Meilana & Aslam, 2022) and can be applied in education (Lytvynenko et al., 2025). In addition, cultural values can also provide a more meaningful learning experience (Labibah Azzahra, 2024) and build an inclusive learning environment for students (Zahrika & Andaryani, 2023). It proves that integrating cultural aspects has positive implications for the success of the learning process.

The implementation of culturally charged teaching materials can be done in various ways. One is utilizing technological advances significantly impacting learning activities (Koparan et al., 2023). This technology allows for a learning process with dynamic access (Cunha et al., 2024). In addition, the use of technology can also help answer accessibility challenges (Eltaiba et al., 2025) and personalize the student learning experience more effectively (Sibley et al., 2025). It aligns with studies that state that technology-based learning can encourage creating a more effective, interactive, and fun learning environment (Rahman et al., 2023). Furthermore, the types of technology used in culturally charged mathematics teaching materials are also very diverse, including Augmented Reality.

Augmented Reality is a technology that combines virtual images with the real world (Soto-Ruiz et al., 2025). This technology uses a three-dimensional image model (Câmara Olim et al., 2024) to increase the effectiveness of user perception (Zhou et al., 2025). Augmented Reality uses simulation elements (Buentello-Montoya et al., 2021), allowing users to visualize information on real objects in real-time (Mercier et al., 2025). In addition, users can also actively interact with the virtual elements presented (Candido & Cattaneo, 2025). Not only that, but Augmented Reality also facilitates understanding concepts (Rebello et al., 2024) and provides an immersive experience to its users (Hernández-Rodríguez & Guillén-Yparrea, 2023). It makes Augmented Reality a technological innovation in learning that offers various advantages.

The use of Augmented Reality in learning has been shown to have a positive impact, such as increasing motivation (Asaumi et al., 2025; Low et al., 2022), creativity (Rizki et al., 2025), reasoning, knowledge, and competence (Huang, 2024), active participation (Pujiastuti & Haryadi, 2024), and student skills (Sezgunsay & Basak, 2025). In addition, the use of Augmented Reality can also increase students' interest in learning (Handoyo et al., 2024). On the other hand, knowing about augmented reality integration also facilitates generalizing knowledge to the real environment, resulting in better performance (Silva et al., 2023).

The various positive impacts that have been presented show that Augmented Reality is the right technology to implement culturally charged mathematics teaching material innovations for students with disabilities. It aligns with qualitative case study research that examines the use of Augmented Reality in mathematics learning in a cultural context (Bertrand et al., 2024). The study results show that Augmented Reality can facilitate culture-based learning more effectively by creating an inclusive and collaborative learning environment. In addition, students' visual and spatial reasoning skills and motivation have also improved.

These results are then supported by research showing that technology in mathematics learning has been proven effective in enhancing the learning outcomes of students with disabilities (Ali et al., 2024). Based on the above explanation, it is essential to innovate culturally charged mathematics teaching materials based on augmented Reality so that they can be used by students with disabilities in learning mathematics.

A Culture That Contains Mathematical Elements

Cultures that contain mathematical elements are part of local heritage that indirectly reflect mathematical concepts in people's daily lives. For example, in traditional batik, carving, weaving, and architecture, these shapes are often found in symmetrical patterns that contain elements of repetition, geometric transformations, and geometric shapes that represent the concepts of flat building and building space (Sape & Syamsuddin, 2025). Cultural activities such as traditional ceremonies, traditional counting systems, inheritance division, and measurements in cooking also reflect the use of mathematical logic, numbers, counting operations, and measurement (Nasution et al., 2025; Par & Prasetyo, 2024; Rina et al., 2025) by understanding that culture stores mathematical values, teachers can make cultural context a contextual approach to mathematics learning that is more meaningful for students (Sulistyawati, 2020).

Cultural forms that contain mathematical elements include the Kayangan Api cultural heritage in Bojonegoro Regency, East Java, Indonesia, traditional houses, and traditional musical instruments. These three forms of culture can be described as follows.

Kayangan Api Cultural Heritage

Kayangan Api Cultural Heritage is a unique geological phenomenon and natural cultural heritage located in Sendangharjo Village, Ngasem District, about 20–25 km from the center of Bojonegoro. Kayangan Api has been developed as a geological and cultural tourism attraction by the Bojonegoro Regency Government. The facilities include a walking path, a pendopo, and a simple stall. It is often used at night for art performances and traditional rituals during the full moon or Friday Pahing. The form of Kayangan Api cultural heritage is as follows.

Figure 1. Entrance to the Kayangan Api Cultural Heritage

The image above focuses on the shape of the door. The Kayangan Api Cultural Heritage entrance is directly attached to the temple ornament. This door is in the middle of the cultural heritage site. The shape of the door on the main gate contains the element of a flat building square. It can be seen from the shape of the door, which has four sides equal in length, each corner measuring 90 degrees (Puspitarani, 2025).

Figure 2. Temple Roof

The picture above shows the temple's roof. It is stepped and arranged in nine layers. Each layer is different; the further it goes, the wider it gets. The temple roof's shape contains elements of a flat building, a Trapezoid. This shape is visible from most layers. The bottom and top of the roof are parallel sides of the trapezoid, while the side of the roof forms two symmetrical trapezoid sloping sides (Mailani et al., 2024).

Figure 3. Meditation Sites

The picture above is a place of meditation. This meditation place is one piece to the left of the eternal fire location; a guardrail bounds this place. Inside this complex is a building that is believed to be a place of meditation for Eyang Kriyokusumo. At first glance, this building resembles a tent made of wood. When viewed from the front, the meditation place contains elements of a flat building geometry triangle. It can be seen from the shape of the building, which has three sides and three corners, with the total number of angles being 180 degrees (Mustika & Ismiasih, 2025).

Traditional House

The design of traditional houses in Indonesia reflects a blend of cultural values, the natural environment, and scientific principles, including mathematics. Each ethnic group in Indonesia has a conventional house with different shapes, structures, and symbolic meanings. Still, all of them are built with calculations and logic to meet local needs. In addition, the use of carving patterns and architectural decorations in traditional houses often contains mathematical motifs such as flat plane geometry (Maulida et al., 2025) and translation, rotation, and reflection that can be directly related to geometric transformation in mathematics (Irianti, 2022). Thus, traditional houses, as part of local culture, have aesthetic and cultural value and contain mathematical value (Mailani et al., 2025), which is a rich learning resource to integrate mathematical concepts in a contextual and meaningful way for students (Nurjanah et al., 2024). Examples of traditional houses in Indonesia that contain geometric concepts are Joglo houses from Java and Rumoh Aceh from Aceh.

Figure 4. Joglo Traditional House Building

The picture above is a modified joglo traditional house building. However, this house still retains the original shape of the roof of the Joglo house. When viewed from the front, the roof of the Joglo house is trapezoidal (Kholisa, 2021). The shape of this trapezoid can be studied through plane geometry, such as the measurement of the area, height, and angles that make up the flat building. In addition, the symmetry and proportions of the Joglo roof indicate the application of traditional mathematical principles in construction, which are passed down from generation to generation.

Figure 5. Visualization of Aceh Traditional Houses

The picture above is a visualization of traditional houses in Aceh. This house is called Rumoh Aceh or Krong Bade. This traditional house has architectural decorations like a flat rhombus at the top. The decoration can be shown through the three white circles (from the researcher) present at the top. Culturally, the rhombus motif in Acehnese traditional houses is often associated with a symbol of balance and protection (Rachmadani et al., 2025). From a mathematical perspective, rhombus shapes teach the concepts of plane geometry, such as equal sides of length, equal angles, folding symmetry, and rotational symmetry, as well as the calculation of area and circumference (Liberna et al., 2023).

Traditional Musical Instrument

Traditional musical instruments have shapes inside spatial and flat shapes that can be analyzed through geometric approaches in mathematics. In this context, the physical forms of musical instruments reflect mathematical properties such as sides, angles, circumference, area, and volume. The visual elements of traditional musical instruments contain a systematic and repetitive pattern of flat and spatial construction, so they can be used as concrete and innovative learning objects to develop students' thinking skills (Sitanggang, 2021). In addition, the regularity in design, proportions of size, and symmetry of the structure suggest that mathematical values have been indirectly internalized in creating musical instruments by traditional societies. The elaboration of this musical instrument form becomes a bridge to integrating mathematics with local culture that can provide a contextual, comprehensive, and meaningful learning experience for students (Raza et al., 2025). There are traditional musical instruments in Indonesia, such as flutes, puck-puck, saron, and many more.

Figure 6. Visualization of the traditional musical instrument of the Saron

The traditional musical instrument of the Saron is part of the gamelan apparatus; this instrument has a physical form that can be associated with building a block room. The main body of the saron is elongated and boxy, with the sides flat, parallel, and perpendicular to each other. This characteristic is the hallmark of building a block room. This structure consists of six rectangular sides facing each other in pairs and has a length, width, and height that can be measured mathematically. The relationship between the traditional Saron musical instrument and the building of the block room can be used in mathematics learning to introduce the concepts of volume, surface area, and dimensional measurement in a contextual manner. Thus, Saron, as part of traditional musical instruments, not only functions as a medium of art and cultural expression but can also be used to integrate geometry materials in local culture-based learning (Sari, 2024) concretely and contextually (Nufus et al., 2025).

Related Work

Several relevant studies have been conducted in developing mathematics learning media related to the innovation of Augmented Reality-based culturally charged teaching materials for students with disabilities. The first research on the development of culturally integrated learning media for students with special needs, including the visually impaired, showed an improvement in students' literacy skills (Gading et al., 2024), but the media used in this study is still in the form of physical media and has not taken advantage of technological aspects such as Augmented Reality. Furthermore, the research results related to the development of Augmented Reality-based learning media with the integration of local wisdom have been proven effective in improving problem-solving skills and Multiple representation students (Alfianti et al., 2023). Still, this study does not focus on mathematics content and has not accommodated students with special needs. Then, subsequent research showed that cultural integration into mathematics learning can improve student achievement (Johnson et al., 2022). Still, this study has not taken advantage of Augmented Reality and does not focus on the inclusive aspect. In addition, other research results on using Augmented Reality in mathematics learning have been proven to improve students' mathematical spatial abilities (Arifin et al., 2020). Still, this research has not met the inclusive aspect and does not use a cultural approach. Meanwhile, other research shows that using Augmented Reality for students with disabilities can increase student enthusiasm during learning (Buliali & Andriyani, 2021), but this study has not included cultural content. Based on the results of several studies that have been presented, it can be said that teaching material innovation with the integration of artistic content and Augmented Reality technology for students with disabilities is urgently needed as a contextual, fun, and interactive inclusive learning solution.

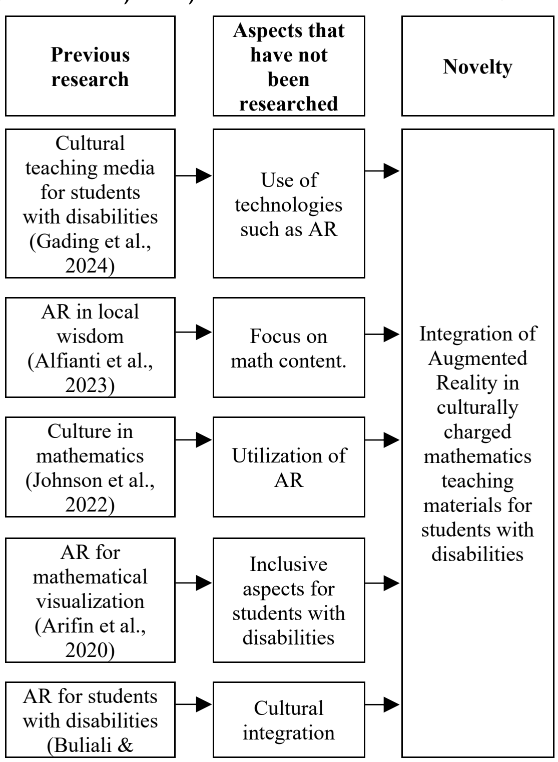

Figure 7. Novelty

Methodology

Research Design and Procedure

This research uses a development research design to innovate mathematics teaching materials. The development design used is the four-D (4-D) model. The four-D (4-D) model sequence starts with defining, designing, developing, and disseminating (Thiagarajan et al., 1974). The implementation of the four-D (4-D) model in this research can be explained as follows.

At the definition stage, conduct a needs analysis for teachers with disabilities by providing a questionnaire on needs, literature studies on difficulties in learning mathematics in students with disabilities, identification of cultural values in Indonesia that can be integrated in mathematics learning, and curriculum analysis to determine relevant basic competencies.

In the design stage, make flowcharts and storyboards, make image designs, design augmented reality displays and interactions, design material concepts, and evaluation models.

In the development stage, prototypes of teaching materials are developed, such as converting images into 3D and compiling augmented reality concepts, then conducting validation tests with material and media experts, and revising.

At the dissemination stage, disseminate the products developed to inclusion schools, volunteers, and prospective teachers at inclusion schools.

Participant

Participants in the definition stage involved 175 teachers and prospective teachers. The design level involves two material experts and two media experts. The dissemination stage involved inclusive elementary schools in Indonesia's BJN, LMG, BLR, and TBN districts.

Table 1. Teacher Needs Analysis Instrument

No Question	Indicators
1	Use of technology-based media
2	The urgency of introducing ethnomathematical concepts
3	Compatibility of learning media with ethnomathematical concepts

4	Mathematical concepts relevant to the context of Cultural Heritage
5	Competencies developed in the context of Cultural Heritage

This instrument is then made into a questionnaire question with agreeable, neutral, disagreeable, and intensely disagreeable answers. This questionnaire was distributed to teachers with disabilities using Google Form.

The research instrument will conduct a validation test of subject matter experts using the following instruments.

Table 2. Material Expert Validation Instruments

No Question	Aspects assessed	Score
1	Content suitability	
2	Cultural integration	
3	Accommodation for students with disabilities	
4	Integration with Augmented Reality media	
5	General feasibility of the material	

The subject matter expert's validation instrument involved two validators. The first is a validator of mathematical material experts, and the second is a validator of disability learning experts.

The research instrument is for the validation test of media experts, which utilizes the following instruments:

Table 3. Media Expert Validation Instrument

No Question	Aspects assessed	Score
1	Display design	
2	Interactivity and navigation	
3	Suitability of the media with the material	
4	Technical aspects	
5	Accessibility aspects	
6	General eligibility of the media	

The media expert validation instrument involves two validators. The first is a learning media expert validator, and the second is an information technology expert validator. Validators of material and media experts can fill in the assessment instrument using the Likert scale, namely 4 = Excellent, 3 = Good, 2 = Adequate, and 1 = Less.

Data Validation Techniques

The data validation technique for the questionnaire on the needs of teachers with disabilities began by testing the reliability and validity of the questionnaire items. The reliability of the questionnaire instrument items was tested using the Cronbach's Alpha (α) method with the formula.

$$\alpha = k/(k-1)\ (1- \Sigma\sigma_i^2/((\sigma_t^2)\ )) \qquad (1)$$

The formula above describes k = the number of items, σi^2 = the variance of each item, σt^2 = the total variance (the variance of the total score of all items per respondent), $\sum$and σi^2 = the variance of each item.

Meanwhile, the validity of the questionnaire items was assessed using the Pearson correlation item validity test and the feasibility test with Kaiser-Meyer-Olkin (KMO) & Bartlett's Test. The Pearson correlation formula is

$$r = (n\sum XY-(\sum X)(\sum Y))/\sqrt{}([n\sum X^\wedge 2-(\sum X)^\wedge 2][n\sum Y^\wedge 2-(\sum Y)^\wedge 2]) \qquad (2)$$

The description of the above formula is r = Pearson's correlation coefficient, n = the number of data pairs, X, Y = the two quantitative variables connected, ΣX, ΣY = the sum of the values X and Y, ΣXY = the sum of the multiplication of X and Y, ΣX^2, ΣY^2 = the sum of the squares of X and Y.

The results of the questionnaire that the teacher has filled out are then tested for statistical significance using the one-sample t-test and the linear regression test. The one-sample t-test is tested using formulas.

$$t = (\bar{X} - \mu)/(s / \sqrt{n}) \qquad (3)$$

The description of the above formula is t = t-calculated value, $\bar{x}$ = sample average, μ = comparator hypothesis value (neutral value on the Likert scale), s = standard sample deviation, n = number of respondents (sample size).

A linear regression test using a formula.

$$Y=a+b1X1+b2X2+b3X3 \qquad (4)$$

The description of the formula above is Y = Dependent variable (bound), a = Intercept (constant), X_1, X_2, X_3 = Independent variable (independent), b_1, b_2, b_3 = The regression coefficient of each independent variable (indicating the magnitude of the influence on Y).

The data validation technique from the assessment of subject matter and media experts uses Aiken's V formula.

$$V = (\sum S)/(n(c-1)) \quad (5)$$

The description of the above formula is V = Aiken Index, s = the score of each expert for each item minus the lowest value of the scale. The formulas can be searched using $s = r - l$, where r = the value given by the expert, and l = the lowest scale value. n = number of members, c = number of categories on the rating scale. To determine the validity level of expert value, it is necessary to look at the criteria developed by Akker (Hasanudin et al., 2024) as follows.

Table 4. Validity Criteria for Expert Tests

No.	Average Score	Validity Level
1	$0.8 < V \leq 1.0$	Very valid
2	$0.4 < V \leq 0.8$	Quite valid
3	$0 < V \leq 0.4$	Invalid

Results/Findings

The results of this research can be explained according to the research design used, starting from defining, designing, developing, and disseminating. The four results can be described as follows.

Results of Analysis of the Needs of Teachers with Disabilities in Daksa for Innovation of Culturally Charged Mathematics Teaching Materials Based on Augmented Reality

The reliability test results of the questionnaire instrument using Cronbach's Alpha (α) method can be explained as follows.

Table 5. Reliability Test Results

Construct	Cronbach's Alpha (α)	Interpretation
Mathematics Teaching Materials (5 items)	0.892	**Highly reliable** ($\alpha > 0.7$)

Based on the table above, the value of α = 0.892 shows that the five items consistently measure the needs of teachers with disabilities regarding the innovation of culture-charged mathematics teaching materials based on augmented Reality. Therefore, it can be recommended that no items be removed because they all correlate highly with the primary construction.

The results of each item's validity test against the total score can be seen in the following table.

Table 6. Item Validity Test Results

Q	Correlation value (r)	Decision
1	0.781	**Valid** (r > 0.3)
2	0.763	**Valid**
3	0.742	**Valid**
4	0.768	**Valid**
5	0.794	**Valid**

Based on the table above, all items correlate strongly (r > 0.7) with the total score, making them valid. It can be seen in the following heatmap graph of the correlation between questionnaire items, which is:

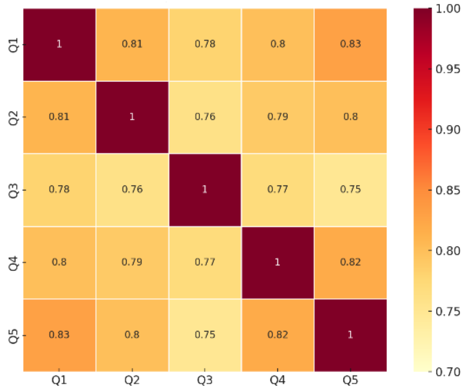

Figure 8. Correlation Heatmap Graph Between Questionnaire Items

The results of the factor analysis test with the KMO test and Bartlett's Test can be explained in the following table.

Table 7. Results of Factor Analysis

Test	Value	Interpretation
SME Measure	0.876	**Eligible** (KMO > 0.6)
Bartlett's Test (p-value)	0.000	**Significant** (p < 0.05)

The table above explains that the data fits factor analysis because the SME > 0.6 and Bartlett's Test are significant. The results of factor analysis showed that the dominant factor (eigenvalue > 1) explained 72.3% of the variance, indicating that all items measured the same construct (support for the innovation of culture-charged mathematics teaching materials based on augmented Reality).

The results of the analysis of the needs of teachers with disabilities based on the results of the questionnaire that has been filled out can be explained as follows.

Table 8. Descriptive Statistical Table of the Likert Scale

Q	Percentage (%)					$\bar{x}$	And	Mo	σ
	ST	S	N	TS	STS				

1	161 (92%)	12 (6.9%)	2 (1.1%)	0 (0%)	0 (0%)	4.82	5	5	0.41
2	154 (88%)	18 (10.3%)	3 (1.7%)	0 (0%)	0 (0%)	4.75	5	5	0.53
3	149 (85%)	22 (12.6%)	4 (2.3%)	0 (0%)	0 (0%)	4.68	5	5	0.61
4	151 (86%)	20 (11.4%)	4 (2.3%)	0 (0%)	0 (0%)	4.71	5	5	0.57
5	158 (90%)	15 (8.6%)	2 (1.1%)	0 (0%)	0 (0%)	4.79	5	5	0.45

Based on the table above, their average score is >4.68 or close to 5, which means that they agree very much. The standard deviation is low (0.41-0.61), which shows the teacher's consistency in answering the questionnaire. Data mode is above 5 for all items with a percentage of more than 85% (strongly agree).

The results of the one-sample t-test on comparing the mean to neutral values can be seen in the following table.

Table 9. One-Sample T-test Results

Q	$\bar{x}$	t-value	p-value	decision
1	4.82	48.91	0.000	**Significant** ($p < 0.05$)
2	4.75	42.67	0.000	**Significant**
3	4.68	38.24	0.000	**Significant**
4	4.71	40.12	0.000	**Significant**
5	4.79	45.83	0.000	**Significant**

Based on the table above, all items have a p-value of 0.000 or < 0.05, which means that the average score is significantly higher than the neutral value (3).

The results of the linear regression test with dependent variables in the form of support for AR innovation (total score) and independent variables of AR use (X1), urgency of cultural elements (X2), and media suitability (X3) can be seen as follows.

Table 10. Results of Linear Regression Tests

Predictor	Coefficient (b)	p-value	Interpretation
Constant (a)	0.521	0.003	-
AR Usage (X_1)	0.312	0.000	**Significant** ($p < 0.05$)
Urgency of cultural elements (X_2)	0.285	0.000	**Significant**
Media match (X_3)	0.241	0.000	**Significant**
Constant (a)	0.521	0.003	-

Based on the table above, R2 is 0.741, or 74.1% of the variance of support explained by the three factors. Thus, the strongest predictor is the urgency of the cultural element (X2) and the use of AR (X1).

The main findings of the questionnaire on the needs of teachers with disabilities are that a) the questionnaire item instrument is guaranteed in terms of reliability and validity because the Cronbach's Alpha value = 0.892 (high consistency) and all items are valid (correlation > 0.7), b) the support of teachers with disabilities is very high considering the mean of all items >4.68 (close to "Strongly Agree") and the significant t-test (p=0.000), c) the parling factor that influenced was the use of AR (b=0.312) and the urgency of cultural elements (b=0.285). A conclusion can be drawn from the results of the needs analysis questionnaire: teachers with disabilities strongly agree with the innovation of culturally charged mathematics teaching materials based on augmented Reality.

Results of Innovative Design of Culture-Oriented Mathematics Teaching Materials Based on Augmented Reality

The first step at the design stage is to create a flowchart. The flowchart for using augmented Reality in teaching materials can be explained in the following figure.

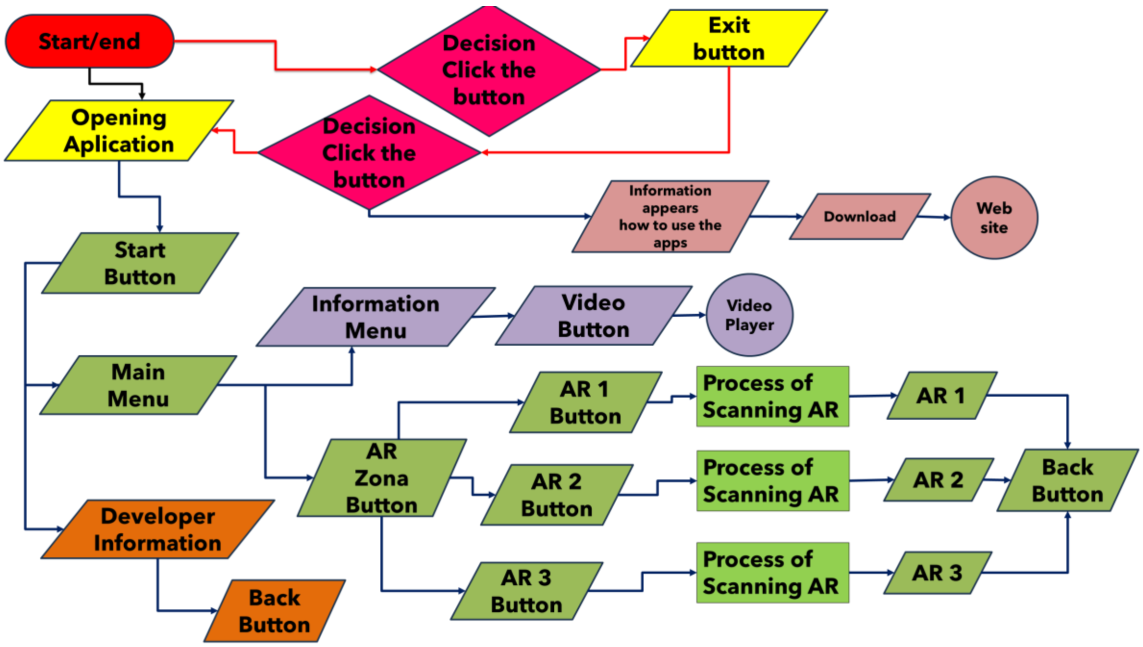

Figure 9. Flowchart for the Utilization of Augmented Reality in Mathematics Teaching Materials

Then, compile the storyboard as shown in the following picture.

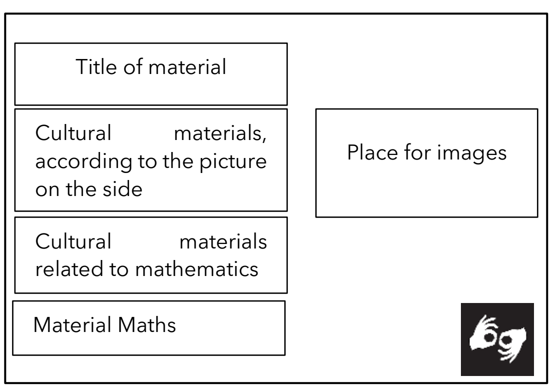

Figure 10. Storyboard of Mathematics Teaching Materials

Then, the augmented reality display and interaction will be designed by paying attention to the User Experience (UX) and User Interface (UI) phases. In the User Experience (UX) phase, it is necessary to pay attention to 1) creating a user flow to describe how users will use the app, 2) creating a wireframe design, and 3) creating an application structure. Meanwhile, in the User Interface (UI) phase, it is necessary to pay attention to the selection of appropriate colors, the selection of primary, secondary, and tertiary color compositions, the choice of fonts for design typography, the selection of icons for applications, the creation of UI design conceptions, the collection of images, illustrations, and vectors, and the introduction of precedents.

The material is designed in eight chapters, starting from the material of counting (1-10), simple addition and subtraction operations, simple multiplication, simple division, number patterns, fractions, flat shapes, and space shapes.

Finally, design an evaluation model. The evaluation model can be in the form of a choice of true or false and matching answers. The right-of-fault model provides a concise, fast, accessible, and non-physically burdensome evaluation of students and is very suitable for technology-based applications such as augmented Reality. The matchmaking evaluation model benefits students with disabilities by minimizing physical barriers and optimizing cognitive strength through a simple, visual, and intuitive format.

Results of Developing Innovation in Culture-Oriented Mathematics Teaching Materials Based on Augmented Reality

In the development stage, prototypes of teaching materials are developed. This development leverages Canva, Unity (Unity Hub & Unity Engine), and Vuforia SDK applications. Canva is used to create wireframes, process flows, and user interfaces (UIs) in the app. Unity (Unity Hub & Unity Engine) integrates programming, design, and 3D models into an application. The Vuforia SDK provides access to the Unity

Engine to display augmented Reality. The form of the user interface can be seen as follows.

Figure 11. Shape of the Augmented Reality User Interface

3D models are made using the Unity application, as shown in the following image.

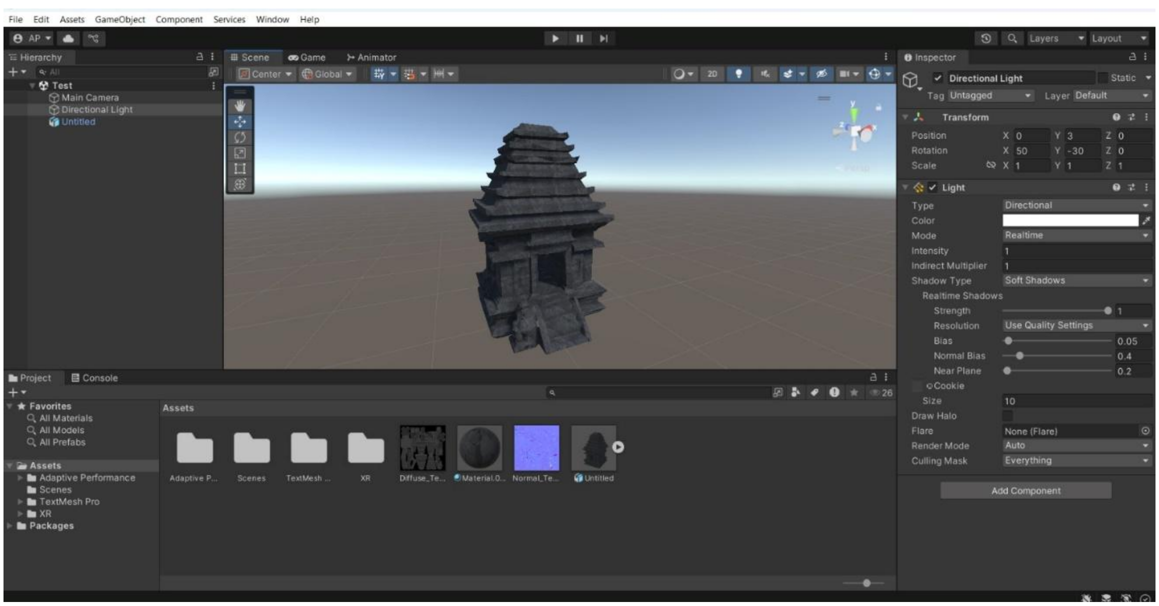

Figure 12. The Process of Creating a 3D Model with the Unity Application

One of the 3D images of the Unity application results can be seen as follows.

Figure 13. 3D Drawing of Unity Application Results

The next step is to insert the 3D image into augmented Reality using the Vuforia app. Below, you can see how to create augmented Reality with the Vuforia application.

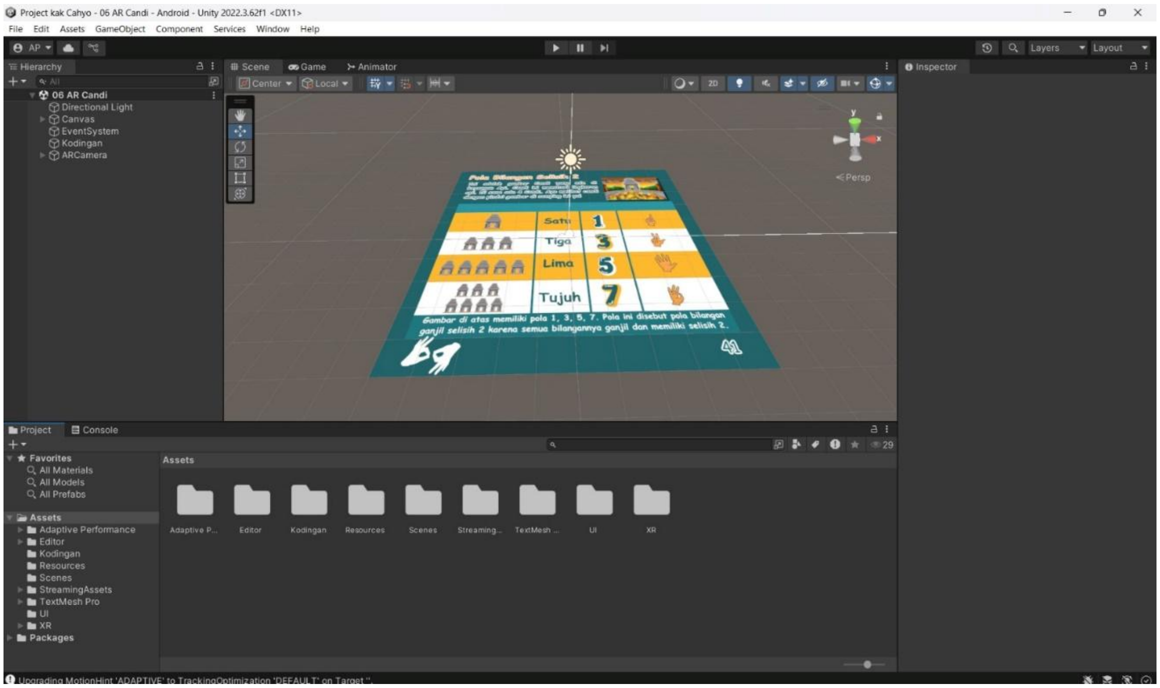

Figure 14. Augmented Reality Creation with Vuforia Applications

The last development step is to conduct a validation test of material and media experts. The test results from the material expert validators are shown in the following table.

Table 11. Results of the Material Expert Validator Test

Q	V1	V2	S1	S2	Σs	Aiken's V
1	4	4	3	3	6	1.00
2	4	4	3	3	6	1.00
3	4	3	3	2	5	0.83
4	4	4	3	3	6	1.00
5	4	4	3	3	6	1.00
6	4	4	3	3	6	1.00
7	4	3	3	2	5	0.83

Q	V1	V2	S1	S2	Σs	Aiken's V
8	4	4	3	3	6	1.00
9	4	4	3	3	6	1.00
10	4	4	3	3	6	1.00
11	4	3	3	2	5	0.83
12	4	4	3	3	6	1.00
13	4	4	3	3	6	1.00
14	4	3	3	2	5	0.83

The average Aiken's V of the entire item is 0.95; this means that the whole item is in the very valid category. Thus, the material in the mathematics teaching materials that contains local culture based on AR for students with disabilities is very feasible to use. However, the first validator noted that the difference in the number pattern 2 in the material needs to be summarized. Meanwhile, the second material expert validator suggested adding some symbols for disabilities. The results of revising this teaching material can be seen as follows.

Figure 15. Improvement of Materials in Mathematics Teaching Materials

The test results from the media expert validators can be seen in the following table.

Table 12. Results of Media Expert Validator Test

Q	V1	V2	S1	S2	Σs	Aiken's V
1	4	3	3	2	5	0.83

2	4	4	3	3	6	1.00
3	3	4	2	3	5	0.83
4	4	4	3	3	6	1.00
5	4	3	3	2	5	0.83
6	4	4	3	3	6	1.00
7	4	3	3	2	5	0.83
8	4	4	3	3	6	1.00
9	3	4	2	3	5	0.83
10	4	4	3	3	6	1.00
11	4	3	3	2	5	0.83
12	4	4	3	3	6	1.00

The average Aiken's V of the entire item is 0.92, which means that the whole item is in the very valid category. Thus, learning media for students with disabilities in the form of mathematics teaching materials that contain AR-based local culture is very feasible. However, the first validator provides a note to add a name to the application icon. It can be seen as follows.

Before after revision

Figure 16. Augmented Reality App Icon

The second validator provides suggestions on the main menu display. The menu must be supplemented with local cultural icons, such as traditional houses. The results of the revision of the main menu can be seen below.

Figure 17. Augmented Reality App Main Menu

Results of Disseminating Innovation of Culture-Charged Mathematics Teaching Materials Based on Augmented Reality

The dissemination of innovations in culturally charged mathematics teaching materials based on augmented Reality has been carried out in a structured manner in four regions, namely Regency (BJN), LMG (BLR), and TBN. This dissemination involves various groups, including education volunteers, inclusion teachers, and prospective teachers from schools that apply an inclusive education approach.

Based on the results of the focus group discussions (FGDs) and feedback, the participants stated that this teaching material was fascinating and relevant, as it presented concrete and interactive mathematics content and integrated local cultural values familiar to students.

The inclusion teachers highlighted that using Augmented Reality was beneficial in visualizing mathematical concepts for students with special needs, especially those with disabilities, because it reduced the motor load in the learning process. Education volunteers welcome a culturally based contextual approach that reinforces local identities in learning. Meanwhile, the prospective teachers stated that this innovation is a concrete example of the integration of technology, culture, and pedagogy that can be adopted in teaching practices in the future.

This dissemination shows that these innovative teaching materials are well-received and seen as a potential solution to improve the inclusivity and effectiveness of mathematics learning in various regions. It aligns with previous research results showing that innovations in mathematics learning that utilize Augmented Reality technology, integrating local cultures, can improve students' numeracy skills and learning motivation (Nurhami et al., 2024). Then, the following study also showed a similar thing, where the use of Augmented Reality with cultural integration can increase student engagement and participation during the learning process (Puspitaningsih et al., 2024). With a comparable topic, other research shows increased student learning outcomes in culture-based mathematics learning using Augmented Reality (Kamid et al., 2025). However, these three studies are still focused on regular students and have not accommodated the needs of students with disabilities in mathematics learning. However, the results of several studies imply that the innovation of mathematics teaching materials with local culture by utilizing Augmented Reality technology is significant because it has various positive impacts on learning, so that it can be an effective and inclusive mathematics learning innovation for students with disabilities.

Discussion

Augmented Reality (AR) technology in mathematics learning can provide a more effective learning experience, especially for students with disabilities. (Kellems et al., 2020). (Li, 2024) AR can integrate visual and audio elements into learning materials, helping students better understand mathematical concepts through direct experience. In this context, the innovation of AR-based mathematics teaching materials is expected to enhance students' motivation and understanding of the taught material.

In addition, integrating cultural elements into AR-based mathematics teaching materials can provide a more relevant context for students. Materials that contain cultural values can enhance students' sense of identity and pride in their cultural heritage. (Wijayanti, 2025). By integrating culture, students learn mathematics and gain a deeper understanding of their social and cultural contexts, thereby increasing their engagement, motivation to learn, developing positive character, and improving students' learning outcomes (Hindaryatiningsih et al., 2025).

However, some previous studies have pointed out several limitations. One of them is the lack of research specifically discussing how the use of AR and cultural content in mathematics learning can accommodate the specific needs of students with physical disabilities, especially in the context of Indonesia, which has cultural diversity, as in the study by Kellems et al. (2020). This study shows that the collaboration between AR and mathematics learning is extraordinary for the success of student learning. However, the innovation applied in this study has not been incorporated into learning for students with disabilities. The study also did not involve cultural engagement as a content that can increase student motivation.

There is also research by Syamsi & Tahar (2021) that examines how culture affects the development of students with disabilities. The study's results clearly show the positive impact of culture-based learning on students with disabilities. However, the focus of the study did not fully refer to mathematical abilities or the advances in the use of AR technology.

Therefore, as an innovation in the world of education, this study is needed to determine how AR-based mathematics teaching materials that contain cultural elements can be expected to become a more inclusive and effective learning alternative for students with disabilities.

Conclusions

This research shows that the innovation of culturally charged mathematics teaching materials based on augmented Reality is feasible to be developed and used in learning, especially for students with disabilities in inclusive schools. Through defining, designing, developing, and disseminating, the development process produces relevant content and visually appealing products, supporting inclusive and interactive learning. The implications of this research provide a new direction for the development of learning media that not only pay attention to students' academic needs but also accessibility and local cultural diversity. AR in teaching materials provides a more concrete and enjoyable learning experience and encourages the active participation of students with physical barriers. Hopefully, this research can expand the development of applications in the future by adding additional accessibility features and enriching cultural content from various regions in Indonesia so that it can be implemented more widely in an inclusive education environment.

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