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DEVELOPMENT OF AN AUGMENTED REALITY-BASED MAGAZINE TO REDUCE MISCONCEPTIONS ABOUT THREE-DIMENSIONAL SHAPES AMONG ELEMENTARY SCHOOL STUDENTS

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ABSTRACT
Mathematics is important for training logical thinking, but the media is still limited. This study aims to develop an Augmented Reality (AR)-based media program, "Jelajah Dunia Bangun Ruang" which is specifically designed to reduce misconceptions about spatial building materials in elementary schools. This study uses the Research and Development (R&D) method with the ADDIE model. The research sample consisted of 41 fifth-grade students of the Ki Hajar Dewantara Banjarnegara Cluster (20 control class students and 21 experimental class students). Data were collected through validation questionnaires, experts, diagnostic tests of misconceptions based on the Certainty of Response Index (CRI), and documentation. Data analysis was carried out using SPSS, which includes validity, reliability, normality, homogeneity, and hypothesis testing. The results showed that the augmented reality (AR)-based magazine was very suitable for use in spatial building materials (media 93.84%, material 95.71%, language 95.56%). The experimental class obtained higher results (13.86) than the control (11.90). The Mann–Whitney test showed a significant difference ($p < 0.05$) with an effect size of r 0.63 (large category), indicating a strong influence on improving understanding and reducing misconceptions. Overall, AR-based media effectively improved conceptual understanding and reduced misconceptions in spatial geometry. Teachers need to implement AR media in stages to improve conceptual understanding and reduce misconceptions.

INTRODUCTIONS

Geometry is a branch of mathematics that studies shapes, sizes, space, and the relationships between objects in a visual and logical manner (Sinclair et al., 2016; Lowrie et al., 2019). In elementary school learning, geometry plays an important role as a foundation for introducing students to spatial concepts that are closely

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related to everyday life (Ili & Ashari, 2023). One of the main topics in geometry is three-dimensional shapes, which are objects that have length, width, and height and are composed of elements such as faces, edges, and vertices (Mulligan et al., 2020; Azizah & Purwaningrum, 2021). Understanding three-dimensional shapes is important because it develops students' spatial visualization skills in recognizing and mentally representing objects as a whole.

In practice, learning about three-dimensional shapes in elementary schools often faces challenges due to the abstract nature of the topic, which requires strong spatial visualization abilities (Juanti et al., 2021). Students frequently struggle to understand three-dimensional forms, identify their elements, and apply concepts such as volume and surface area (Khoirunnisa et al., 2020). In addition, misconceptions in geometry learning are still found among students, both in understanding concepts and solving mathematical problems (Nuraina & Rohantizani, 2023). Limitations in learning media also affect students' conceptual understanding (Syaifuddin et al., 2022; Istinabila & Fardah, 2022). Based on initial observations of fifth-grade students in the Ki Hajar Dewantara Cluster, Banjarnegara, mathematics learning particularly on three-dimensional shapes is still dominated by lecture-based instruction, limited use of visual media, and low student engagement, which leads to misconceptions in understanding the concepts of three-dimensional shapes.

To address these issues, instructional innovation is needed to help students understand the concepts of three-dimensional shapes in a more concrete and meaningful way (Anggoro, 2017). One technological advancement widely used in education is Augmented Reality (AR), which integrates virtual three-dimensional objects into the real environment so that abstract material can be observed more concretely (Arena et al., 2022; Nurhasanah et al., 2023). In addition, AR helps students understand difficult concepts through more realistic and engaging visual representations (Meilindawati et al., 2023; Yang et al., 2022). In the context of mathematics learning, particularly geometry, AR can help students understand spatial concepts more clearly because it allows for the visualization of objects in three-dimensional form that can be directly observed (Muhammad et al., 2021).

Furthermore, the development of learning media in the form of digital magazines has also shown positive results in increasing student engagement and understanding through systematic and engaging presentation of material (Zulfarina et al., 2021; Listyarini et al., 2022; Lestari & Ramadan, 2025). The integration of digital magazines with AR further strengthens the effectiveness of learning media because it combines text, images, and 3D objects in a single interactive platform that is more meaningful to students (Sungkono et al., 2022). This has the potential to strengthen students' ability to understand concepts (Althibyani, 2023; Çevik & Gök, 2026) and help reduce misconceptions by providing students with more accurate and interactive representations of concepts (Hidayah et al., 2024; Rahman & Halim, 2025).

Several studies have developed augmented reality-based media and digital magazines in mathematics learning, but most still focus on improving learning outcomes or students' spatial abilities and have not been specifically directed at reducing misconceptions in spatial geometry material in elementary schools. This indicates a research gap in the focus and objectives of media development. Based on these conditions, the novelty of this research lies in the development of an augmented reality-based magazine specifically designed to reduce misconceptions in spatial geometry material in elementary schools. This effort is important because misconceptions are a major problem in geometry learning that impacts students' conceptual understanding.

The research question of this study is, *"Is the development of an augmented reality (AR)-based magazine effective in reducing students' misconceptions about three-dimensional shapes in elementary school?"* The objective of this study is to develop an AR-based magazine to reduce students' misconceptions in learning three-dimensional shapes at the elementary school level. The results of this study are expected to serve as a reference for developing technology-based learning media to improve mathematical conceptual understanding and reduce students' misconceptions. In addition, it is also expected to be useful for teachers as an innovative instructional medium, for schools as a basis for developing digital learning, and for students to support a more concrete and meaningful understanding of three-dimensional shapes.

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RESEARCH METHOD

This study employed a Research and Development (R&D) method aimed at developing an Augmented Reality (AR)-based magazine to reduce students' misconceptions in learning three-dimensional shapes at the elementary school level, as well as to examine the effectiveness of its use in the learning process. According to Sugiyono (2019), Research and Development (R&D) is a method used to produce a particular product and simultaneously test its effectiveness. The development model used in this study was ADDIE, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). This model was selected because it provides a systematic and structured development procedure and allows evaluation to be conducted at each stage. The following figure presents the research design.

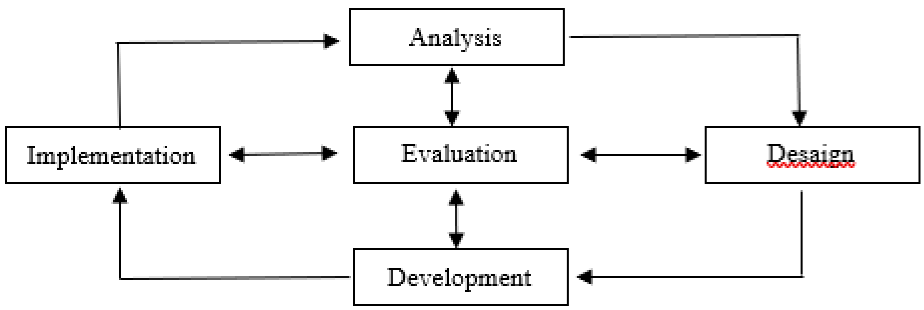

Figure 1. ADDIE Model RnD Research Design Chart ((Branch, 2009)

The research was carried out in October 2025–February 2026. The research population was all fifth-grade elementary school students in Gugus Ki Hajar Dewantara Korwilcam Kalibening, Banjarnegara. The selection of locations and samples was carried out using purposive sampling based on needs analysis, student characteristics, school potential, and readiness to implement augmented reality-based media. The research sample consisted of 41 class V students, namely 20 students at SDN 1 Karanganyar as the control class and 21 students at SDN 3 Sikumpul as the experimental class. Validators consisting of material experts, media experts, and language experts are selected based on suitability of competency and area of expertise. The research was carried out after obtaining permission from the school and maintaining the confidentiality of research participant data.

Research data was collected through expert validation questionnaires, a Certainty of Response Index (CRI)-based misconception diagnostic test, and supporting documentation. Product feasibility analysis was conducted quantitatively using percentages based on a Likert scale (1–5) to assess media, materials, and language aspects. The scores obtained were then converted into percentages using the formula:

$$P = \frac{f}{N} \times 100\%$$

Note: P (percentage of suitability), f (core obtained), N (maximum score). The percentage results were then interpreted to determine the media suitability category. The criteria used were 81%–100% (highly feasible), 61%–80% (feasible), 41%–60% (moderately feasible), 21%–40% (less feasible), and 0%–20% (not feasible). These categories were used to provide an objective overview of product quality based on expert assessments (Mustofa, 2025).

Before use, the research instruments were tested for validity and reliability. Validity was tested using Pearson Product Moment correlation, while reliability was calculated using Cronbach's alpha to determine the instrument's consistency. All data analysis was conducted using IBM SPSS Statistics 26.

The media effectiveness analysis was conducted in several stages. First, the percentage of each CRI category was calculated from the pretest and posttest data to assess changes in students' conceptual understanding. The CRI test classified student responses into four categories: scientific conception, lack of knowledge, error, and misconception.

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Second, the N-Gain Score was calculated to determine the level of improvement in learning outcomes after using the media using Hake's (1999) formula:

$$g = \frac{Posttest - Pretest}{100 - Pretest}$$

Note: g (ormalized improvement (N-Gain), which indicates the level of improvement in student learning outcomes), Posttest (student's score after using the media), Pretest (student score before using the media), 100 (maximum achievable score). The N-Gain value obtained was then interpreted based on the following criteria: g ≥ 0.70 (high), 0.30 ≤ g < 0.70 (medium), and g < 0.3 (low). This interpretation was used to demonstrate the effectiveness of the learning media in improving student learning outcomes.

Third, a series of analyses were conducted to determine the feasibility and effectiveness of augmented reality-based magazine media in reducing misconceptions in spatial geometry material in elementary schools. The prerequisite test was a normality test (Shapiro–Wilk) with decision-making criteria: if Sig. > 0.05 (normal data) and Sig. ≤ 0.05 (non-normal data). The homogeneity test used Levene's test to determine the similarity of variance between the experimental and control classes, with decision-making criteria of Sig. > 0.05 (homogeneous data) and Sig. ≤ 0.05 (non-homogeneous data). Furthermore, the hypothesis test was conducted using the independent samples t-test, and the effect size was Cohen's d, if the data were normally distributed. If the data does not meet parametric assumptions or is not normal, the non-parametric Mann-Whitney U test is used, and the effect size is calculated using the Z-value r-value:

$$r = \frac{|Z|}{\sqrt{N}}$$

Note: r (effect size), Z (statistical value of the Mann-Whitney test), N (total sample size). Interpretation of the effect size refers to the following criteria Cohen (1988): r = 0.10 (small), r = 0.30 (medium), and r ≥ 0.50 (large). This analysis is used to determine the strength of the influence of media use on changes in learning outcomes, as determined by the Z-value (Field, 2018).

In addition, an analysis of the percentage reduction in misconceptions for each spatial concept was conducted using a comparison of the number of students in the misconception (MC) category in the pre-test and post-test using the formula:

$$P = \frac{\text{MC Pretest} - MC \text{ Postest}}{MC\ Pretest} \times 100\%$$

Note: P (percentage reduction in misconceptions), MC Pretest (misconceptions before learning), MC Posttest (misconceptions after learning). The calculation results were then interpreted based on the following criteria: P ≥ 66% (high reduction in misconceptions), 33% < P < 66% (medium), and P < 33% (low). These criteria are used to provide an overview of the level of effectiveness of learning media in reducing student misconceptions quantitatively, thereby facilitating the interpretation of research results (Mustofa, 2025).

RESULTS AND DISCUSSION

RESULT

Based on a series of development and testing processes that have been carried out through the ADDIE model, this research produces a number of important findings that reflect the quality of the product, the development process, and the effectiveness of the media being developed. Each stage provides interrelated contributions, starting from needs analysis to final evaluation, resulting in an augmented reality-based magazine that is not only theoretically and practically feasible but is also proved to have an impact on students' conceptual understanding. Therefore, the results of this research are presented systematically according to the ADDIE stages to provide a clearer picture of the process, main findings, and changes that occur in each phase of media development and implementation in spatial learning in elementary schools.

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Analysis

The analysis stage was conducted to identify learning needs, students' characteristics, characteristics of three-dimensional shapes material, and the types of misconceptions experienced by students. The results of this analysis served as the basis for developing an Augmented Reality (AR)-based learning media that is aligned with real classroom conditions and students' needs in understanding three-dimensional shape concepts in a more concrete way. The analysis of students' characteristics indicated that fifth-grade students are at the concrete operational stage; therefore, they still require visual learning support to understand abstract concepts. Students tend to understand learning material more easily through pictures, animations, and interactive media. In addition, students' abilities vary, so learning activities need to accommodate these differences.

The analysis of three-dimensional shape content shows that topics such as cubes, cuboids, prisms, cylinders, and cones involve a high level of abstraction because they are related to three-dimensional concepts. The main difficulty experienced by students lies in visualizing spatial forms and identifying parts of shapes that cannot be observed directly, thus requiring media that can support more concrete conceptual visualization. The following table presents a comprehensive analysis used to identify the initial condition of students in conventional learning that is still dominated by lecture-based instruction. The mapping of students' conceptual categories for each item in the three-dimensional shapes test is presented in the following table:

Table 1. Initial Misconception Condition of Students (Pretest)

Three-Dimensional Shape Concept	Group	SC	LOK	E	MC (Misconception)
Number of sides on a cube	Control	3	10	1	6
	Experimental	2	11	0	8
Horizontal cylinder	Control	13	7	0	0
	Experimental	17	4	0	0
Solid cuboid	Control	6	6	0	8
	Experimental	6	8	1	6
Horizontal triangular prism	Control	1	9	1	9
	Experimental	1	6	3	11
Number of vertices on a cone	Control	0	4	0	16
	Experimental	0	1	0	20

Source: Primary research data (2026)
Conception category description:
SC (Scientific Conception): Understanding the concept scientifically.
LOK (Lack of Knowledge): Not having a scientific conception
E (Error): not having a scientific conception.
MC (Misconception): Misconception

The results of misconception identification in table 1 show almost similar difficulty patterns in both classes. The highest misconception was found in the concept of the number of vertices on a cone, while the concept of a horizontal cylinder showed the best level of understanding because no misconceptions were found in students. In addition, several concepts such as the number of sides on a cube, solid cuboid, and a horizontal triangular prism were in the Lack of Knowledge category, which indicates that students do not yet have an adequate basic conceptual understanding of the material. Furthermore, pretest score data were analyzed to compare the initial abilities between the two groups, as presented in the following table

Table 2. Analysis of Pretest Scores

Stage	Group	N	Total Score	Mean	Min	Max
Pretest	Control	20	177	8.85	5	11
	Experimental	21	184	8.76	5	11

Source: Primary research data (2026)

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Based on the pretest analysis, the average score for the experimental class was 8.76, and for the control class, it was 8.85. The very small difference in average scores indicates that both groups had relatively similar initial abilities before being given the treatment. This indicates that the experimental and control classes had comparable initial abilities, making them suitable for use in experimental research.

Design

The design stage involved the preparation of a storyboard for the magazine, development of the media interface, integration of Augmented Reality (AR) technology, and the construction of research instruments in the form of validation sheets and a diagnostic test for identifying misconceptions. This stage focused on designing the learning product to align with students' characteristics and the objective of reducing misconceptions in three-dimensional shape materials.

The storyboard was developed to organize the presentation flow of the "Exploring the World of Three-Dimensional Shapes" content in a systematic and student-friendly manner. It was divided into three main sections: the opening section, which introduces characters and provides AR usage guidelines; the main section, which presents materials on seven types of three-dimensional shapes; and the closing section, which includes summaries, quizzes, learning activities, and an appreciation certificate.

The media interface was designed with an attractive, colorful, and consistent visual appearance across all pages. Each topic includes simplified definitions, tables of shape elements (faces, edges, and vertices), colored 3D illustrations to clarify structural components, and real-life examples to help students better understand abstract concepts. AR technology was integrated as the main visualization tool in the learning process. Each page includes a marker that can be scanned using a mobile device, allowing students to observe three-dimensional objects that can be rotated and viewed from different angles, thereby supporting more concrete conceptual understanding.

In addition, research instruments were developed through a diagnostic test based on a three-tier format consisting of answer choice, confidence level, and reasoning. The results were categorised into SC (*Scientific Conception*), LOK (*Lack of Knowledge*), E (*Error*), and MC (*Misconception*) to identify students' levels of understanding in more detail. Validation sheets were also prepared to assess the feasibility of the media in terms of content, design, and instructional alignment.

Development

The development stage was carried out by transforming the previously designed blueprint into a tangible product in the form of an augmented reality (AR)-based educational magazine entitled "Jelajah Dunia Bangun Ruang" This product was developed as a learning medium for students aged 8–12 years by integrating text, images, and AR technology accessible through marker scanning using digital devices. The material covers seven types of three-dimensional shapes, including complete 3D visualisations, geometric elements (faces, edges, and vertices), and real-world object examples found in the students' environment.

The magazine prototype consists of 17 systematically arranged pages, starting from the opening section (pages 1–6), which includes the cover, character introduction, table of contents, foreword, AR usage guide, and basic concepts of three-dimensional shapes; the main section (pages 7–13), which presents the seven types of three-dimensional shapes; and the closing section (pages 14–17), which includes a summary, quizzes, activity sheets, and an appreciation certificate.

Technically, this media combines printed material with AR technology that can be operated using either laptops or smartphones. The AR feature works by scanning markers using a device camera, after which interactive 3D objects of geometric shapes appear and can be observed from multiple angles. These media are considered practical, stable, and easy to use in classroom learning. The following section presents the magazine display.

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Figure 2. Augmented Reality (AR)-Based Educational Magazine

The feasibility test was conducted through validation by media, content, and language experts to determine the level of suitability of the Augmented Reality (AR)-based magazine before its implementation in learning. Based on the validation results, the developed media was categorised as highly feasible for use, with several notes for revision and improvement. The results are presented in the following table:

Table 3. Expert Validation Results for Media, Content, and Language

No	Validator	Number of Assessment Aspects	Obtained Score	Maximum Score	Percentage	Category
1	Media Expert	13	61	65	93.84%	Highly Feasible
2	Content Expert	14	67	70	95.71%	Highly Feasible
3	Language Expert	9	43	45	95.56%	Highly Feasible

Source: Primary research data (2026)

Based on the validation results, the media expert assessment obtained a percentage of 93.84%, which indicates that the appearance, design, interactivity, and technical aspects of the use of AR-based magazines have met the eligibility criteria. The material expert validation obtained a percentage of 95.71%, which indicates that the content of the spatial structure material, the accuracy of the concept, the presentation, and the relevance of the material to the learning objectives are appropriate. The results of the language expert validation obtained a percentage of 95.56%, which indicates that the use of language, readability, clarity of sentences, and the suitability of the language to the characteristics of students are very good. Overall, AR-based magazine is in the category of highly feasible for use as a learning media.

Implementation

The implementation stage was conducted as a trial phase to examine the effectiveness of the Augmented Reality (AR)-based magazine in reducing students' misconceptions in learning three-dimensional shapes. This study employed a quasi-experimental design using a pretest–posttest control group design involving two groups: a control class (20 students) who received conventional instruction and an experimental class (21 students) who learned using the AR-based magazine "Jelajah Dunia Bangun Ruang" which enables students to visualize three-dimensional concepts interactively, including faces, edges, and vertices. The posttest results of both groups are presented in the following table.

Table 4. Analysis of Posttest Scores

Stage	Group	N	Total Score	Mean	Min	Max
Posttest	Control	20	238	11.90	8	14
	Experimental	21	291	13.86	11	15

Source: Primary research data (2026)

Based on table 4, both groups showed improvement after the intervention. However, the experimental group demonstrated a higher increase compared to the control group. This indicates that the use of augmented reality (AR)-based learning media contributed more effectively to improving students' understanding of three-dimensional shape concepts than conventional instruction.

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Furthermore, to examine changes in students' conceptual understanding in more detail before and after the treatment, an analysis was conducted based on conceptual categories for each topic of three-dimensional shapes. The results are presented in the following table.

Table 5. Analysis of Conceptual Changes from Posttest

Three-Dimensional Shape Concept	Stage	Group	SC	LOK	E	MC (Misconception)
Number of sides on a cube	Posttest	Control	10	8	0	2
		Experimental	15	5	0	1
Horizontal cylinder	Posttest	Control	16	4	0	0
		Experimental	21	0	0	0
Solid cuboid	Posttest	Control	10	6	0	4
		Experimental	15	6	0	0
Horizontal triangular prism	Posttest	Control	9	8	0	3
		Experimental	16	4	0	1
Number of vertices on a cone	Posttest	Control	10	2	0	8
		Experimental	17	3	0	1

Source: Primary research data (2026)
Conception category description:
SC (Scientific Conception): Understanding the concept scientifically
LOK (Lack of Knowledge): Not having a scientific conception
E (Error): not having a scientific conception
MC (Misconception): Misconception

Based on the results in table 5, it can be seen that after the treatment, there was a significant increase in the Scientific Conception (SC) category in both groups, but the increase in the experimental class was more pronounced than in the control class. Furthermore, the number of misconceptions (MC) in the experimental class decreased more drastically, even for certain concepts, such as solid cuboid, where misconceptions were no longer found after the learning process. These findings indicate that augmented reality (AR)-based learning contributes more effectively to improving students' conceptual understanding and reducing misconceptions in the material on spatial shapes. Overall, these findings indicate that the use of Augmented Reality (AR)-based media is more effective in reducing student misconceptions than conventional learning.

N-Gain Analysis

N-Gain analysis was used to measure the level of improvement in student learning outcomes before and after the implementation of Augmented Reality-based magazine media by comparing the difference in pretest and posttest scores with the maximum possible score. The results of this N-Gain calculation were used to determine the effectiveness of learning in the experimental and control classes. The results of the analysis are presented in the following table:

Table 6. N-Gain Analysis Results

Stage	Pretest	Posttest	N-Gain (g)
Control	8,85	11,90	0,50
Experimental	8,76	13,86	0,82

Lilliefors Significance Correction
Source: Primary data processed using IBM SPSS Statistics 26

Based on the N-Gain analysis results in table 6, there was a difference in learning outcomes between the experimental and control classes. The experimental class achieved an N-Gain score of 0.82, which is in the high category. Meanwhile, the control class achieved an N-Gain score of 0.50, which is in the medium category.

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This difference indicates that student learning outcomes in the experimental class were more optimal than in the control class. The class using augmented reality-based learning media experienced a more significant increase in conceptual understanding after the treatment. In contrast, the control class using conventional learning only showed a moderate increase. Thus, augmented reality-based magazine media provides a more effective contribution to improving student learning outcomes than learning without such media.

Next, to determine the significance of the differences in learning outcomes between the two groups, prerequisite analysis tests were conducted, including a normality test using the Shapiro-Wilk test and a homogeneity test using the Levene test. These tests aimed to determine the type of hypothesis testing to be used in the next stage.

Normality Test

The normality test uses the Shapiro-Wilk test to determine whether the N-Gain data is normally distributed or not. This can be used as a basis for determining the type of statistical test to be used in the hypothesis testing stage, whether using a parametric or nonparametric test. The results of the normality test are presented in table below:

Table 7. Normality Test Results

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Stage	Group	Statistic	df	Sig.	Statistic	df	Sig.
Pretes	Control	0.237	20	0.004	0.902	20	0.045
	Experimen	0.229	21	0.005	0.893	21	0.025
Postes	Control	0.270	20	0.000	0.828	20	0.002
	Experimen	0.262	21	0.001	0.809	21	0.001

Lilliefors Significance Correction
Source: Primary data processed using IBM SPSS Statistics 26

Based on the results in table 7, all pretest and posttest data in both the control and experimental classes had a significance value <0.05. This indicates that the data were not normally distributed, so the hypothesis test was conducted using the nonparametric Mann–Whitney U Test. The use of the Mann–Whitney U test was chosen because it is appropriate for comparing two independent groups when the data does not meet the assumption of normality.

Homogeneity Test

The homogeneity test used Levene's test to determine the equality of variances between the experimental and control classes. The results of the homogeneity test are presented in the following table.

Table 8. Homogeneity Test Result

		Levene Statistic	df1	df2	Sig.
Pretes	Based on Mean	0.014	1	39	0.907
	Based on Median	0.027	1	39	0.870
	Based on Median and with adjusted df	0.027	1	38.930	0.870
	Based on trimmed mean	0.007	1	39	0.935
Postes	Based on Mean	0.012	1	39	0.914
	Based on Median	0.001	1	39	0.975
	Based on Median and with adjusted df	0.001	1	37.651	0.975
	Based on trimmed mean	0.010	1	39	0.921

Lilliefors Significance Correction
Source: Primary data processed using IBM SPSS Statistics 26

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Based on the results of the homogeneity test using the Levene test, the significance value obtained for all pretest and posttest calculations was > 0.05. This indicates that the data variance between the control and experimental classes is homogeneous, or the level of data distribution is relatively the same. This condition indicates that both classes have comparable data characteristics, making it suitable for further comparative analysis in the study. Although the data is homogeneous, because it is not normally distributed, the analysis was continued using the nonparametric Mann–Whitney U test.

Hypothesis Testing and Effect Size (Mann–Whitney U Test)

Hypothesis testing was conducted to determine the differences in learning outcomes between the experimental and control classes before and after treatment. Based on the results of the prerequisite test, the data were found to be non-normally distributed, so the analysis was continued using the nonparametric Mann–Whitney U Test to compare the two independent groups. In addition, to determine the magnitude of the treatment effect, the effect size was also calculated based on the Z value obtained from the Mann–Whitney test, the results of which are presented in the following table.

Table 9. Results of Hypothesis Testing and Effect Size (Mann–Whitney U Test)

	Pretes	Postes
Mann-Whitney U	201.000	59.000
Wilcoxon W	432.000	269.000
Z	-0.242	-4.030
Asymp. Sig. (2-tailed)	0.809	0.000
N Total	41	41
Effect Size r	0.04	0.63

Grouping Variable: Group
Source: Primary data processed using IBM SPSS Statistics 26

Based on table 10, the results of the Mann–Whitney U test on the pretest data show an Asymp. Sig. (2-tailed) value of 0.809 (> 0.05) with a Z value of -0.242. In addition, the effect size r is 0.04, which is categorized as small. This indicates that before the treatment was applied, there was no significant difference between the experimental and control classes; thus, both groups had relatively similar initial abilities.

Furthermore, in the posttest data, the Asymp. Sig. (2-tailed) value was 0.000 (< 0.05) with a Z value of -4.030. The effect size result shows an r value of 0.63, which is categorized as large. This indicates a significant difference between the experimental and control classes after the treatment was applied, with higher learning outcomes observed in the experimental class. It can be concluded that the use of augmented reality (AR)-based media had a significant effect on improving students' learning outcomes in geometry material.

In addition, an analysis of the percentage reduction in misconceptions for each geometry concept was conducted by comparing the number of students categorized as Misconception (MC) in the pretest and posttest. The results are presented in the following table:

Table 10. Percentage Reduction of Misconceptions in the Control and Experimental Classes

Three-Dimensional Shape Concept	MC Pretest (Control)	MC Posttest (Control)	Reduction Control (%)	MC Pretest (Experimental)	MC Posttest (Experimental)	Reduction Experimental (%)
Number of sides on a cube	6	2	66,7	8	1	87,5
Horizontal cylinder	0	0	–	0	0	–
Solid cuboid	8	4	50,0	6	0	100
Horizontal triangular prism	9	3	66,7	11	1	90,9
Number of vertices on a cone	16	8	50,0	20	1	95,0

Source: Primary research data (2026)

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Based on the results of the analysis presented in Table 10, it can be observed that both groups experienced a reduction in misconceptions for each geometry concept after the learning process. In the control class, the reduction in misconceptions ranged from 50.0% to 66.7% across most concepts, with the highest reduction occurring in the concept of the number of faces of a cube at 66.7%. The experimental class showed a higherreduction in misconceptions across all measured concepts. The highest reduction occurred in the solid cube concept at 100%, followed by the vertex points of a cone at 95.0%, the horizontal triangular prism at 90.9%, and the number of faces of a cube at 87.5%.

This comparison indicates that although both groups showed improvement in conceptual understanding, the experimental class using augmented reality-based media demonstrated a greater reduction in misconceptions than the control class. This suggests that interactive three-dimensional visualization helps students understand geometric concepts more concretely, thereby reducing conceptual errors more effectively. It can be concluded that the use of augmented reality-based media has a stronger impact on reducing students' misconceptions compared to conventional learning.

Evaluation Stage

The evaluation phase is conducted continuously at each stage of the development process to assess the quality of the product and the effectiveness of the resulting media. Formative evaluation is carried out during the analysis, design, development, and implementation stages. At this stage, evaluation is used to identify learning needs, refine the media design, follow up expert validation results (covering media, content, and language aspects), and improve the product based on findings from limited classroom trials. The results of the formative evaluation serve as the basis for revisions to ensure that the developed product aligns with students' characteristics and learning objectives.

Furthermore, summative evaluation is conducted at the end of the study to assess the effectiveness of the Augmented Reality (AR)-based magazine entitled "Jelajah Dunia Bangun Ruang." This evaluation is carried out by analyzing student learning outcomes through comparisons of pretest and posttest scores, N-Gain calculations, and changes in students' conceptual categories, as well as hypothesis testing using the Mann–Whitney U test and effect size analysis.

The evaluation results indicate that the developed media is categorized as highly feasible based on expert validation in media, content, and language aspects. In addition, the implementation of the media shows higher learning outcomes in the experimental class compared to the control class, as well as a more significant reduction in misconceptions in each geometry concept. These findings are supported by statistical test results showing a significant difference between the experimental and control classes ($p < 0.05$), with the effect size categorized as large. Therefore, the AR-based magazine "Jelajah Dunia Bangun Ruang" meets the criteria of feasibility, practicality, and effectiveness and is therefore appropriate to be used as a learning medium to help students understand geometry concepts more concretely and reduce misconceptions in elementary mathematics learning.

DISCUSSION

The development of the Augmented Reality (AR)-based magazine "Jelajah Dunia Bangun Ruang" integrated with the diagnostic approach of the Certainty of Response Index (CRI), has a positive impact on improving students' conceptual understanding as well as reducing misconceptions in geometry learning at the elementary school level. This effectiveness is indicated by the difference in posttest results between the experimental group ($M = 13.86$) and the control group ($M = 11.90$), which shows a more optimal improvement in the experimental class. These findings are supported by the results of the Mann–Whitney U Test, which revealed a significant difference between the two groups ($p < 0.05$), as well as an effect size value of $r = 0.63$, which is categorized as large. This confirms that the impact of the media is not only statistically significant but also has a strong practical effect in improving students' learning outcomes.

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The reduction of misconceptions in the experimental class indicates that the influence of AR is not limited to learning outcomes but also extends to the quality of conceptual understanding. The greater reduction in misconceptions across various geometry concepts, including up to 100% in the concept of a solid rectangular prism and 95.0% in the vertex points of a cone, demonstrates that three-dimensional visualization helps students connect geometric objects with the mathematical concepts being learned. In contrast to conventional learning based on two-dimensional images, which may lead to misinterpretations, AR enables students to observe objects more concretely and from multiple perspectives. This process helps students correct previously inaccurate conceptual representations, thereby reducing misconceptions more effectively.

The findings are consistent with the study by Al-Ansi et al. (2023), which states that AR can enhance the quality of learning through interactive visualisation. The results of this study strengthen those findings, as the use of AR in the form of a digital magazine helps students understand geometry concepts more concretely, thereby minimising misconceptions. However, the previous study emphasised the general benefits of AR in education, whereas this study highlights a more specific mechanism, namely how AR visualisation contributes to conceptual change that can be measured through the reduction of misconceptions using a diagnostic instrument based on the Certainty of Response Index (CRI). In other words, this study not only demonstrates that AR makes learning more engaging but also shows that AR can transform how students construct geometric concepts.

In line with this, Arena et al. (2022) explain that AR is capable of presenting three-dimensional representations that facilitate the understanding of abstract concepts. This is reflected in the significant improvement in posttest scores in the experimental class. However, the difference lies in the fact that previous studies focused on general learning outcomes or academic performance, whereas this study offers a stronger contribution by not only focusing on learning outcomes but also systematically analysing misconceptions through the categories of Scientific Conception (SC), Lack of Knowledge (LOK), Error (E), and Misconception (MC), allowing students' conceptual changes to be identified in greater depth.

This study is also in line with Demitriadou et al. (2020), who found that AR is more effective than conventional media in mathematics learning. This is evidenced by the differences between the experimental and control groups. However, this study provides an additional contribution by incorporating misconception analysis as a central focus, thereby not only assessing learning effectiveness but also examining the quality of students' conceptual change.

Next, the study by Çevik & Gök (2026) shows that AR can reduce mathematics misconceptions among elementary school students. This finding supports the results of the present study, which indicate a significant reduction in misconceptions in the experimental class. However, this study has a different characteristic, as it integrates an AR-based magazine media with the Certainty of Response Index (CRI) diagnostic approach. The use of CRI provides additional information regarding students' level of confidence in their answers, allowing conceptual changes to be observed more accurately. Thus, the effectiveness of the media is not only indicated by correct answers but also by the reduction of confidence in incorrect concepts.

In addition, Fatma & Anwar (2025) found that AR can improve students' spatial abilities in geometry topics. This is also reflected in the present study, where students experienced an improvement in geometric understanding after using AR-based media. However, the difference lies in the fact that the previous study emphasized the development of visual-spatial skills, whereas this study shows that improved visual ability alone is not sufficient without identifying students' conceptual understanding. The integration of AR with CRI in this study extends the function of the media from merely a visualization tool to both a diagnostic and intervention tool for correcting misconceptions.

Overall, this study demonstrates that the development of an Augmented Reality (AR)-based magazine is effective in improving conceptual understanding as well as reducing students' misconceptions in geometry learning at the elementary school level. Unlike previous studies that focused solely on improving learning outcomes or spatial abilities, this study emphasizes both the identification and reduction of misconceptions through a diagnostic approach based on the Certainty of Response Index (CRI).

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The use of CRI categories Scientific Conception (SC), Lack of Knowledge (LOK), Error (E), and Misconception (MC) allow for a more in-depth analysis, as it not only assesses answer correctness but also measures students' confidence in their responses, making the identification of misconceptions more accurate and structured. Therefore, the contribution of this study goes beyond producing an innovative AR-based learning medium; the AR-based magazine "Jelajah Dunia Bangun Ruang" also serves as a practical solution for detecting and reducing misconceptions more systematically in elementary geometry learning in a more meaningful and sustainable way.

CONCLUSION

The development of an Augmented Reality (AR)-based magazine is effective in reducing students' misconceptions in geometry learning at the elementary school level. The use of this media helps students overcome conceptual errors through more concrete and interactive three-dimensional visualisation, thereby enabling students to develop more accurate understanding aligned with scientific geometric concepts. Thus, this AR-based media is proven to be feasible and effective as a learning innovation to reduce the occurrence of misconceptions in geometry topics at the elementary school level.

Theoretically, AR supports constructivist learning theory by helping students transform abstract concepts into more concrete understanding, which in turn can reduce misconceptions in geometry learning. Practically, AR-based media can serve as an innovative alternative in teaching geometry in grade V of elementary school. Teachers can use it to facilitate the delivery of concepts, schools may begin integrating it with adequate technological support, and instructional developers can use it as a foundation to expand its application to other mathematics topics so that the learning process becomes more interactive and effective.

Nevertheless, this study is still limited to two classes with a focus on geometry material; therefore, the generalisability of the findings should be interpreted with caution. Future research is recommended to examine the effectiveness of this media in other mathematics topics and involve larger samples with stronger experimental designs so that the results obtained are more comprehensive and can be generalised more broadly.

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