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DEVELOPMENT OF AUGMENTED REALITY-BASED WORKSHEETS TO IMPROVE ELEMENTARY SCHOOL STUDENTS' GEOMETRIC THINKING

Kurnia Nabilah Farhah[1], Puri Pramudiani[2]
[1,2,3*]Elementary School Teacher Education, Faculty of Teacher Training and Education, Universitas Muhammadiyah Prof. Dr. HAMKA, Jakarta, Indonesia.

E-mail: kurnianabilah03@gmail.com [1]
puri.pramudiani@uhamka.ac.id [2]

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ABSTRACT
Many fifth-grade students experience difficulties in understanding cubes and rectangular prisms as the use of interactive learning media remains limited. Accordingly, an Augmented Reality (AR)-integrated student worksheet was developed and evaluated in this study by incorporating Van Hiele's geometric thinking framework, emphasizing the visualization, analysis, and degrees of informal deduction to strengthen students' geometric thinking. The development process adopted a Research and Development (R&D) methodology guided by the ADDIE model through five sequential phases: Analysis, Design, Development, Implementation, and Evaluation. The participants included 29 fifth-graders from SD NWS, Bekasi Regency, West Java, Indonesia. Information was gathered using observations, interviews, validation sheets, and pretest–posttest tools. The validation results showed Aiken's V coefficients of 0.90 (very valid) for the material aspect and 0.76 and 0.75 (valid) for the media and language aspects, respectively. The results also indicated a notable enhancement in pupils' geometric thinking skills, with the mean score increasing from 58.86 on the pretest to 86.00 on the posttest. Furthermore, the Wilcoxon Signed Rank Test showed a significance value of $p < 0.05$, showing that the pretest and posttest results differed significantly. The effect size result ($r \approx 0.88$) was categorized as very large, demonstrating a strong effects of the developed educational media on pupils' geometric cognitive abilities. Collectively conclusion show that the AR-based student worksheet is valid and effective in improving students' geometric thinking skills.
Keywords: augmented reality; geometric thinking; mathematics learning; student worksheet.

ABSTRAK
Pemahaman konsep kubus dan balok masih menjadi tantangan bagi murid kelas V sekolah dasar karena terbatasnya penggunaan alat pendidikan yang interaktif. Penelitian ini berfokus pada upaya pengembangan sekaligus evaluasi terhadap Lembar Kerja Peserta Didik yang memanfaatkan teknologi Augmented Reality (AR) yang disusun berdasarkan teori berpikir geometri Van Hiele pada tiga tahap, yakni visualisasi, analisis, dan deduksi informal. Melalui LKPD tersebut, diharapkan terjadi peningkatan terhadap kemampuan berpikir geometri yang dimiliki murid. Studi ini menggunakan pendekatan Research and Development (R&D) dengan model ADDIE yang meliputi tahap Analisis, Perancangan, Pengembangan, Implementasi dan Evaluasi. Partisipan dalam penelitian ini melibatkan 29 murid kelas V SD NWS, Kabupaten Bekasi, Jawa Barat, Indonesia. Instrumen pretest-posttest, wawancara, observasi, dan lembar validasi adalah cara data diperoleh. Hasil validasi menunjukkan koefisien Aiken's V sebesar 0,90 (sangat valid) untuk aspek materi serta 0,76 dan 0,75 (valid) masing-masing untuk aspek media dan bahasa. Hasil penelitian juga menunjukkan peningkatan yang signifikan pada kemampuan berpikir geometri murid, dengan rata-rata nilai meningkat dari 58,86 pada pretest menjadi 86,00 pada posttest. Selain itu, uji Wilcoxon Signed Rank menunjukkan nilai signifikansi $p < 0,05$ yang mengindikasikan adanya perbedaan yang signifikan secara statistik antara nilai pretest dan posttest. Nilai effect size ($r \approx 0,88$) termasuk dalam kategori sangat besar, yang menunjukkan bahwa kemampuan berpikir geometri murid dipengaruhi secara signifikan oleh sumber pembelajaran yang dibuat. Hasil studi menunjukkan bahwa LKPD berbasis AR dapat diterima dan berhasil meningkatkan kemampuan berpikir geometri murid.
Kata kunci: *augmented reality; berpikir geometri; pembelajaran matematika; LKPD.*

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Introduction

Education plays an essential part in cultivating students' abilities and providing them to respond to the social and technological changes of modern society (Mulyati & Junaedi, 2021). The educational system of Indonesia continues to evolve to fulfill the requirements of 21st-century competencies, such as teamwork, communication, and critical thinking. Fitriyani et al. (2023). As a result, learning is increasingly focused on developing skills relevant to global society and real-world contexts rather than merely imparting knowledge.

At the primary education level, Mathematics contributes significantly to the growth of logical, analytical, and the ability to think methodically (Mulyati & Junaedi, 2021; Widyastuti & Susiana, 2019). Beyond numerical computation, mathematics also supports the growth of analytical, critical thinking, and reasoning skills. According to the National Council of Teachers of Mathematics (2000), mathematics instruction should promote solving problem abilities, logic, communication in mathematics, as well as reflective and creative thinking. Therefore, educators are required to design learning experiences that emphasize deep conceptual understanding through meaningful and contextual activities rather than focusing solely on procedural outcomes (Jumaena et al., 2024; Nurwijaya & Sukaria, 2025).

One important topic of mathematics that contributes to conceptual and spatial reasoning is geometry. Through geometry learning, students are able to recognize object forms, spatial positions, dimensions, and relationships among shapes in space, while simultaneously developing visual-spatial abilities and logical reasoning that are essential in everyday life (Battista et al., 2017). Based on Van Hiele's theory, geometric thinking develops hierarchically from visualization to formal deduction (Romano, 2009). However, empirical studies show that primary school pupils need concrete and visible learning experiences since they are typically at the visualization and analytical levels (Handayani & Permatasari, 2022).

Despite its importance, many elementary school students continue to encounter difficulties in understanding three-dimensional geometry, particularly cubes and rectangular prisms. These difficulties arise from abstract instructional approaches, limited use of visual media, and insufficient interactive learning tools (Dilaines et al. 2024). Furthermore, students often struggle to identify geometric elements such as faces, edges, and vertices (Putri et al, 2024), and demonstrate low spatial ability due to the lack of engaging and contextual instructional materials (Rahmadini & Alim, 2023).

One alternative effort to overcome these learning difficulties is the creation of more interactive and innovative worksheet materials. Worksheet serves as a structured learning guide that facilitates active and independent learning, enabling students to construct knowledge through guided activities (Anita, 2022). However, most existing worksheet remain conventional, focusing primarily on exercises and rote memorization, and fail to provide meaningful learning experiences, particularly in geometry, which requires strong visual and spatial understanding.

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However, previous studies have generally focused only on the application of Augmented Reality (AR) as a tool for visualization in mathematics learning without directly integrating it into activity-based student worksheets that encourage the growth of geometric thinking (Jumaena et al., 2024; Meilindawati et al., 2023). Although AR-based worksheets have been developed, studies specifically addressing cube and rectangular prism topics through learning activities designed according to Van Hiele's geometric thinking theory remain limited (Nurvitasari & Sulisworo, 2023; Ramadhani, 2025). In particular, there is still limited research integrating AR into worksheet activities that guide students through the visualization, analysis, and informal deduction levels of geometric thinking (Handayani & Permatasari, 2022; Romano, 2009). Thus, a research gap remains in the development of AR-based worksheets that not only provide three-dimensional visualization but also systematically support students' geometric thinking development.

The integration of Augmented Reality technology into worksheet presents a promising innovation to enhance learning quality. AR enables real-time visualization of three-dimensional objects, allowing students to observe, manipulate, and explore geometric forms interactively, thereby supporting spatial reasoning and conceptual understanding (Nurwijaya & Sukaria, 2025; Yanuarto & Iqbal, 2022). Prior research has demonstrated that AR-based educational study greatly enhance conceptual understanding, spatial reasoning, and student engagement (Widyastuti & Susiana, 2019). Moreover, AR supports interactive, contextual, and technology-enhanced learning environments aligned with 21st-century educational demands.

Given the context outlined earlier, this research seeks to create and assess an Augmented Reality (AR)-integrated student worksheet aimed at enhancing the geometric thinking skills of fifth-grade students as they learn about cubes and rectangular prisms. The innovation of this research is in the incorporation of AR technology into worksheet exercises that are organized according to Van Hiele's geometric thinking levels: analysis, visualisation, and informal deduction. Unlike earlier studies that predominantly utilized AR for visualization purposes, this research embeds AR within organized worksheet tasks to promote the growth of students' geometric understanding. Thus, AR functions not only as a medium for visualization but also as a learning resource that supports instructional activities tailored to the various levels of students' geometric thinking. It is anticipated that this study will help elementary schools adopt more engaging and participatory mathematics instruction.

Research Methods

Research Design and Objectives

This research utilized a Research and Development (R&D) strategy rooted in the ADDIE framework, consisting of five distinct stages: Analysis, Design, Development, Implementation, and Evaluation. The objective is to create and assess a student worksheet that incorporates Augmented Reality (AR) to enhance geometric reasoning abilities among fifth-grade learners while studying cubes and rectangular prisms. The practical steps of Figure 1 shows the results of the investigation.

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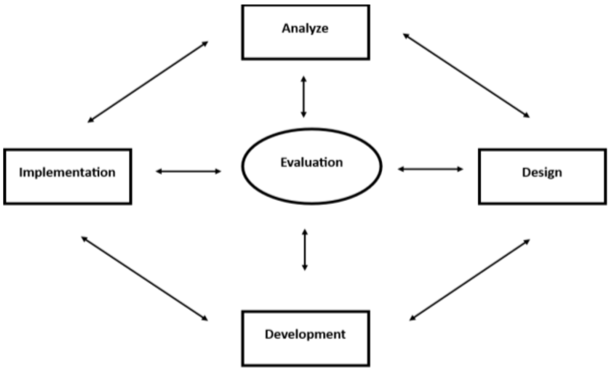

Figure 1. Operational Stages of the ADDIE Model Used in This Study

Research Setting and Participants

The research was carried out at SD NWS, located in Cibitung District, Bekasi Regency, West Java, Indonesia. For ethical and confidentiality reasons, the school's name has been replaced with a pseudonym. The school was selected due to its readiness for technology-based education, as demonstrated by the availability of smartphones and stable internet connectivity. The individuals involved were of 29 fifth-grade students aged 10–11 years. Purposive selection was used to choose the participants sampling because they had studied basic geometry concepts and were involved in learning cube and rectangular prism topics during the research period. In addition, students at this age are often in the stage of concrete operation and require visual support to understand abstract geometric concepts. The research was carried out over six months, from November 2025 to April 2026, covering all ADDIE stages from needs analysis to final evaluation and reporting.

Development Procedure and Instruments

The development procedure followed the ADDIE model. In the analysis stage, data were collected through classroom observations, teacher interviews, and diagnostic tests to identify students' needs and difficulties in geometry learning. The design stage involved developing worksheet structures, AR integration, and research instruments, including validation sheets, observation forms, and geometric thinking tests. During the development stage, the AR-based worksheet was created using Assemblr Edu to produce interactive 3D models of cubes and rectangular prisms, followed by expert validation involving five validators. The validation results were examined using Aiken's V coefficient to ascertain the legitimacy of the developed product. The validation process involved two subject matter experts (a fifth-grade elementary school teacher and a mathematics education lecturer), two media experts from the fields of information technology and educational media, and one language expert specializing in Indonesian language education. The subject matter experts evaluated the precision and suitability of the mathematical content, the media experts assessed the design, usability, and functionality of the AR-based worksheet, while the language expert reviewed the clarity, readability, and suitability of the language for fifth-grade students. The implementation stage involved classroom implementation with 29 fifth-grade students during mathematics learning on cubes and rectangular prisms. Data were collected using observation sheets, questionnaires, interviews, and pretest–posttest instruments.

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All instruments were verified by professional judgment and examined for dependability using the Cronbach's alpha coefficient

Data Analysis and Evaluation Criteria

Both quantitative and qualitative methods were employed to analyze the research data. Qualitative data collected from expert validation, observations, and interviews were analyzed descriptively to assess the feasibility and practicality of the created product. The content validity of the product was determined Utilising the V coefficient of Aiken based on the evaluations provided by material, media, and language experts (Nurjanah et al., 2023). The content validity coefficient was obtained using Equation (1).

$$V = \frac{\sum s}{n(c-1)} \quad (1)$$

Description:
V : Aiken's V coefficient
$s : r - l_0$
r : score assigned by the validator
l_0 : lowest score in the rating scale
n : number of validator
c : number of rating categories

The resulting Aiken's V coefficients were interpreted using the criteria summarized in Table 1.

Table 1. Interpretation criteria of aiken's v coefficient

Aiken's V Value	**Category**
0.80–1.00	Very Valid
0.60–0.79	Valid
0.40–0.59	Less Valid
< 0.40	Invalid

(Nurjanah et al., 2023)

The interpretation criteria for Aiken's V coefficients are summarized in Table 1. Moreover, the developed product’s efficacy was examined by computing the normalized gain (N-gain) score according to the formula that follows :

$$g = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \quad (2)$$

The calculated N-Gain values were interpreted according to the criteria shown in Table 2.

Table 2. Criteria of N-Gain score

N-Gain Score	**Category**
g ≥ 0.70	High
0.30 ≤ g < 0.70	Medium
g < 0.30	Low

(Sukarelawan et al., 2024)

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The criteria for evaluating the worksheet's efficacy from the perspective of students' learning outcomes are shown in Table 2. To ascertain whether the pretest and posttest results differed significantly, the Wilcoxon Signed Rank Test was employed.

Results and Discussion

1. Analysis

Observations and interviews with the fifth-grade instructor revealed that geometry learning is still predominated by the application of two-dimensional media, including textbooks and worksheets. The teacher also reported that students often experienced difficulties in identifying the properties of geometric solids and relating them to real-world objects. Due to this circumstance, pupils find it challenging to visualize three-dimensional shapes, particularly in understanding the elements of cubes and rectangular prisms, such as faces, edges, and vertices.

In addition, The first test's findings show that pupils' geometric thinking abilities are still at the visualization level, where they were only able to recognize shapes without analysing their properties. This condition highlights the need for learning media that can provide concrete and interactive visualization. Therefore, an Augmented Reality (AR)-based worksheet was developed as a solution to address this problem.

2. Design

At the design stage, the worksheet was developed by integrating Augmented Reality (AR) technology to support interactive visualization of three-dimensional shapes. The design process involved determining learning objectives, organizing learning activities based on Van Hiele's geometric thinking levels, and integrating AR features into the worksheet. The worksheet structure was systematically arranged, comprising a cover, page, introduction table of contents, learning objectives, learning outcomes, and usage guidelines, learning materials, and activity-based worksheets. This design aims to facilitate not only informative learning but also exploratory and student-centered learning. Figure 2 shows the cover of the developed AR-based worksheet.

Figure 2. Cover design of the developed ar-based worksheet

As illustrated in Figure 2, the initial section of the worksheet features an attractive cover design with illustrations of cubes and rectangular prisms to

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introduce the learning topic. This is followed by the preface and table of contents, which help students navigate the worksheet easily. The learning outcomes and objectives are clearly defined to guide the learning process in accordance with the expected competencies. The worksheet's usage guidelines and educational resources are shown in Figure 3.

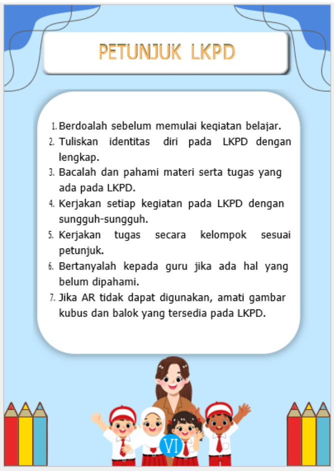

Figure 3. Use Guidelines and educational resources

Figure 3 presents, the instruction section is designed to help understand how to use AR technology, including steps for scanning markers and displaying three-dimensional objects. The learning materials on solid shapes are presented concisely and supported with illustrations of cubes and rectangular prisms to strengthen understanding before engaging in further exploration. Figure 4 illustrates the activity-based design of the developed worksheet.

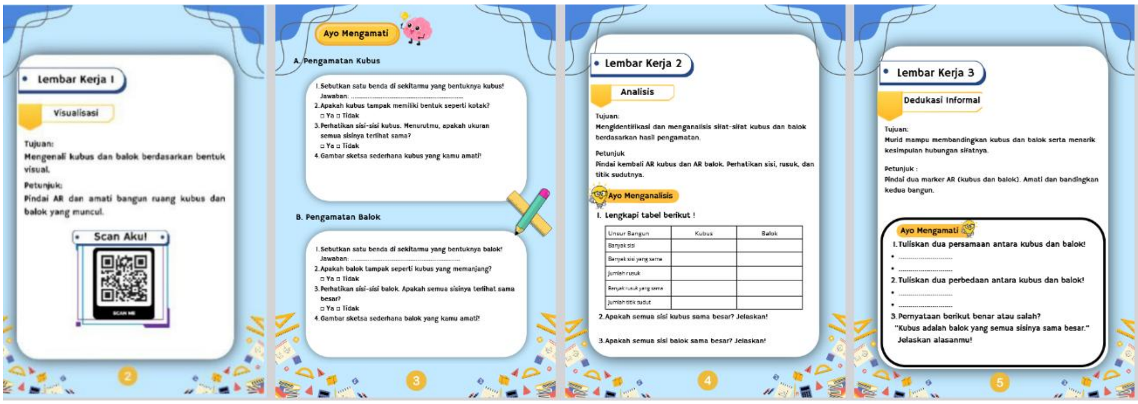

Figure 4. Activity-based worksheet design

As illustrated in Figure 4, the worksheet activities were designed according to Van Hiele's levels of geometric thinking appropriate for elementary school students, namely visualization, analysis, and informal deduction. At the visualization stage, students were asked to observe three-dimensional models of cubes and rectangular prisms through the AR feature and identify similar objects in their surroundings. At the analysis stage, students explored the AR-based models and identified the properties of the shapes through observation tables. Finally, at the informal

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deduction stage, students compared the characteristics of cubes and rectangular prisms and drew conclusions based on their findings.

3. Development

The development phase focused on producing an AR-based worksheet with the Assemblr Edu application. Following product development, feasibility was assessed through evaluations conducted by material, media, and language experts. A detailed summary of table 3 displays the validation findings.

Table 3. Expert Validation Results

Aspect	Aiken's V	Category
Material	0.90	Very Valid
Media	0.76	Valid
Language	0.75	Valid

As shown in Table 3, the material component acquired an Aiken's V coefficient of 0.90, which was classified as very valid. These results show the developed AR-based worksheet satisfied the required validity criteria and was suitable for implementation in classroom learning. During the validation process, the experts suggested improving the worksheet layout, clarifying several learning instructions, and refining the presentation of the learning materials. Based on these suggestions, revisions were made to enhance the visual appearance, improve the clarity of instructions, and ensure the accuracy and readability of the learning content before the product was implemented in the field trial.

4. *Implementation*

The implementation stage was conducted with 29 fifth-grade students during mathematics learning on cube and rectangular prism materials. Students used smartphones to scan AR markers in the worksheet and observe three-dimensional geometric objects interactively. The implementation process showed that students were actively involved during learning activities. Figure 5 depicts students using the AR-based worksheet during classroom activities.

Figure 5. Students using the AR-based worksheet during classroom learning

As seen in Figure 5, the execution of the AR-based worksheet enabled students to interact directly with three-dimensional representations of cubes and rectangular prisms. The AR features facilitated students' understanding of geometric properties by allowing them to observe and explore geometric objects more concretely. These observations indicate that the developed worksheet was

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useful and supported a more interactive educational experience in mathematics classrooms.

5. Evaluation

The assessment phase that was devoted to evaluating how well the worksheet enhanced students' skills in geometric thinking. Characteristic statistics for both the pretest and posttest of the students can be found in Table 4.

Table 4. Descriptive statistics of pretest and posttest scores

Variable	**N**	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**
Pretest	29	58.86	10.19	46	86
Posttest	29	86.00	6.87	73	100

Table 4 illustrates that students' scores improved considerably following the use of the AR-integrated LKPD. The mean score improved from 58.86 (pretest) to 86.00 (posttest), indicating an increase of 27.14 points. Furthermore, the decrease in standard deviation from 10.19 to 6.87 suggests that performance became more homogeneous after the intervention. To further examine the An N-Gain analysis was carried out to see whether pupils' geometric reasoning abilities had improved. Table 5 presents the computed N-Gain values.

Table 5. N-Gain analysis results

N	**Mean N-Gain**	**Category**	**Interpretation**
29	0.68	Moderate	Effective

Based on Table 5, the mean N-Gain score was 0.68, it is classified as moderate. This result indicates that the AR-based worksheet worked well in improving students' geometric thinking skills. Before conducting hypothesis testing, the test for normality was performed to ascertain whether the information satisfied the presumption of normal distribution. The test for normalcy test results are summarized in Table 6.

Table 6. Normality test result

Variable	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Pretest Geometric Thinking Ability	.269	29	.000	.847	29	.001
Posttest Geometric Thinking Ability	.259	29	.000	.905	29	.013

According to Table 6, the importance values for both the pretest and posttest data are less than 0.05 in the Shapiro–Wilk test (0.001 and 0.013, respectively). Similarly, the Kolmogorov–Smirnov test also indicates significance values below 0.05. These findings show that the information do not adhere to a typical distribution. The Shapiro–Wilk test is considered more appropriate for small sample sizes (n < 50), thus it is used as the primary reference in this study. One non-parametric statistical test is the Wilcoxon Signed Rank Test, was used in the following step since the data did not satisfy the normaly assumption.

Hypothesis Testing

The Wilcoxon Signed Rank Test was employed to investigate the variations between the scores from the pretest and the posttest. This specific test is suitable for dependent data that fails to satisfy the requirement of normal distribution, since it evaluates the median differences of two associated samples. The findings from the Wilcoxon Signed Rank Test can be found in Table 7.

Table 7. Wilcoxon signed rank test results

Category	**N**
Statistic	**Value**
Z	-4.739
Asymp. Sig. (2-tailed)	0.000

As shown in Table 7, all 29 demonstrated an increase in their scores after the implementation of the AR-based worksheet, as indicated by the presence of 29 positive ranks and the absence of both negative ranks and ties. This result suggests that the improvement in geometric thinking ability was consistent across all participants, with no student experiencing a decline or stagnation in performance.

Students' geometric thinking abilities increased after utilizing the AR-based worksheet, according to the Wilcoxon signed-rank test, which showed a statistically significant difference between the pretest and posttest scores (Z = -4.739, p <.001). These results imply that students' geometric thinking abilities were successfully improved by the AR-based worksheet. In addition to statistical importance, the size of the effect was also examined using effect size analysis. The effect size was calculated using the formula:

$$r = \frac{Z}{\sqrt{N}} \quad (3)$$

The computations showed that the effect size was roughly r = 0.88, which is categorized as a very large effect (r > 0.5). Both statistically and in terms of its useful advantages for classroom instruction, the improvement was noteworthy. These results imply that students' geometric reasoning skills were significantly impacted by the augmented reality worksheet.

The results demonstrate that integrating augmented reality technology into worksheet activities significantly enhances students' geometric reasoning abilities. This enhancement is shown in the statistically notable distinction between the scores from the pretest and posttest, along with a significant impact size. These results show that the created educational media enhances pupils' learning in addition to outcomes but also deepen their understanding of geometric concepts.

In the present study, the AR-based worksheet facilitated students' progression from the visualization level to the analysis level by providing concrete and interactive learning experiences. Through AR technology, students were able to observe and manipulate three-dimensional representations of cubes and rectangular prisms, enabling them to identify geometric properties such as faces, edges, and vertices more effectively. Consequently, students moved beyond merely

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recognizing geometric shapes visually and began analyzing their properties. For example, before the intervention, some students recognized cubes and rectangular prisms only by their appearance. After using the AR-based worksheet, they were able to identify and explain geometric properties such as faces, edges, and vertices, indicating progression from the visualization level to the analysis level. This finding is consistent with Ramadhani (2025), who reported that AR-based learning supports students' progression through Van Hiele's levels.

This result is also consistent with the constructivist perspective, It highlights the significance of learning occurs by direct interaction with learning materials. As explained by Lestari & Lidinillah (2022), students develop understanding by actively constructing knowledge through meaningful learning experiences. In this study, the AR-based worksheet created an interactive learning environment in which students actively explored geometric objects rather than passively receiving information. Such active engagement likely contributed to the notable enhancement of learning results.

The present findings further reinforce previous research on the role of technology in mathematics education. Destiana et al. (2026) reported that technology-based worksheets enhance students' engagement, understanding, and learning motivation. Similarly, Meilindawati et al. (2023) discovered that pupils' enthusiasm and engagement are increased by AR-based media in mathematics learning. Yanuarto & Iqbal (2022) also reported that AR improves students' spatial reasoning ability, a critical component of geometric thinking. This evidence is further supported by Nurwijaya & Sukaria (2025), who demonstrated that AR-based learning significantly improves students' spatial reasoning skills. In line withBattista (2017), spatial reasoning plays a fundamental role in understanding geometric measurement and relationships, suggesting that the improvement observed in this study is closely associated with enhanced spatial cognition facilitated by AR.

The findings also address common challenges in elementary geometry learning. Previous studies have shown that students often struggle with abstract geometric concepts due to limited visualization and the use of two-dimensional representations. For example, Rahmadini & Alim, (2023) reported that elementary students have difficulty identifying the properties of geometric shapes, while Putri et al. (2024) found that students struggle to understand cube structures because of limited interactive learning media. The AR-based worksheet developed in this study addresses these challenges by providing interactive 3D visualization that allows students to observe and explore geometric objects directly.

The effectiveness of the developed worksheet can also be attributed to the systematic implementation of the ADDIE model. According to Rahayu (2025), the Research and Development (R&D) approach, particularly through the ADDIE model, supports the systematic development of educational products through the stages of Analysis, Design, Development, Implementation, and Evaluation (Hidayat & Nizar, 2021; Mdodana-Zide, 2024). This structured process enables continuous refinement of the learning media to ensure its alignment with students' needs and learning objectives. Likewise, Adeoye et al., (2024), argued that the ADDIE model improves instructional effectiveness by integrating learning strategies, media, and evaluation.

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Furthermore, the findings support the view that instructional design should be adaptive to learners' characteristics. Nuari et al. (2025) emphasized the importance of adaptive learning models that address differences in students' abilities. Consistent with this perspective, all students in the present study demonstrated improved learning outcomes, suggesting that the AR-based worksheet effectively supports learners with different levels of prior knowledge.

Another important aspect highlighted in this study is the role of digital innovation in 21st-century education. Sole & Anggraeni (2018) state that integrating technology into learning is essential to address the challenges of modern education. AR-based learning represents a form of digital innovation that enhances interactivity and engagement. This is further supported by Nurvitasari & Sulisworo (2023), who found that AR-based worksheets both conceptual understanding and learning motivation.

Additionally, the reduction in score variability observed in this study indicates that AR-based worksheet contributes to more equitable learning outcomes. This aligns with the findings of Handayani & Permatasari (2022), who emphasize that students' performance in geometry is often influenced by factors such as anxiety and cognitive readiness. By providing interactive and engaging learning experiences, AR-based media may help reduce anxiety and improve students' confidence in learning geometry. One advantage of the developed AR-based worksheet is its ability to provide interactive three-dimensional visualizations, enabling students to explore geometric objects more concretely than with conventional two-dimensional learning media. During the implementation, some students initially experienced difficulties in scanning the AR markers and operating the application; however, these challenges were overcome through teacher guidance and demonstrations.

Conclusion and Suggestion

Overall, this study demonstrates that the developed AR-based worksheet is a useful, useful, and efficient instructional medium for improving fifth-grade students' geometric thinking skills on cubes and rectangular prisms. The significant improvement in pretest and posttest performance suggests that embedding AR technology into worksheet activities enhances students' conceptual understanding of three-dimensional geometry while fostering geometric thinking in accordance with Van Hiele's theory.

This study used a relatively small sample size, was conducted in a single school, and focused only on the topics of cubes and rectangular prisms. Thus, it is advised that future research use larger and more varied sample sizes, apply AR-based worksheets to other mathematics topics, and employ comparative experimental designs to provide stronger evidence regarding the effectiveness of AR-supported learning media.

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