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Beyond Flat Screens: The Impact of Augmented Reality-Based Learning Media on Geometric Abilities in Children Aged 4-5 Years

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Abstract

This study aimed to analyze the effect of Augmented Reality (AR)-based learning media on the geometric abilities of children aged 4–5 years at RA Nurul Ula Burai. Geometric ability is an important aspect of children's cognitive development, encompassing the ability to recognize geometric shapes and understand spatial concepts. This study employed a quantitative approach with an experimental method and a One-Group Pretest–Posttest Design. The participants consisted of 30 children aged 4–5 years selected through total sampling. Data were collected through observation using a geometric ability observation instrument and analyzed using descriptive and inferential statistics, including a paired-samples *t*-test. The results showed an improvement in children's geometric abilities following the intervention using AR-basedlearning media. The mean score increased from 49.73 at pretest to 77.37 at posttest, representing an increase of 27.64 points. The paired-samples *t*-test also indicated a statistically significant difference between the pretest and posttest scores ($p < .001$). The improvement was particularly evident in children's ability to recognize geometric shapes and understand spatial concepts. These findings suggest that AR-based learning media can provide a positive and statistically significant contribution to the development of geometric abilities among children aged 4–5 years. AR-based learning may therefore serve as an innovative learning medium for providing more visual, concrete, and interactive geometry learning experiences in early childhood education.

[*Penelitian ini bertujuan untuk menganalisis pengaruh media pembelajaran berbasis Augmented Reality (AR) terhadap kemampuan geometri anak usia 4–5 tahun di RA Nurul Ula Burai. Kemampuan geometri merupakan salah satu aspek penting dalam perkembangan kognitif anak yang mencakup kemampuan mengenali bentuk geometri dan memahami konsep ruang. Penelitian ini menggunakan pendekatan kuantitatif dengan metode eksperimen dan desain One-Group Pretest–Posttest Design. Subjek penelitian terdiri atas 30 anak usia 4–5 tahun yang dipilih menggunakan teknik total sampling. Data dikumpulkan melalui observasi menggunakan instrumen kemampuan geometri anak dan dianalisis menggunakan statistik deskriptif dan*

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inferensial melalui paired-samples t-test. Hasil penelitian menunjukkan adanya peningkatan kemampuan geometri anak setelah diberikan perlakuan menggunakan media pembelajaran berbasis AR. Nilai rata-rata meningkat dari 49,73 pada pretest menjadi 77,37 pada posttest, atau mengalami peningkatan sebesar 27,64 poin. Hasil paired-samples t-test juga menunjukkan adanya perbedaan yang signifikan secara statistik antara skor pretest dan posttest ($p < .001$). Peningkatan terutama terlihat pada kemampuan anak dalam mengenali bentuk geometri dan memahami konsep ruang. Temuan ini menunjukkan bahwa media pembelajaran berbasis AR dapat memberikan kontribusi positif dan signifikan terhadap perkembangan kemampuan geometri anak usia 4–5 tahun. Dengan demikian, pembelajaran berbasis AR dapat menjadi salah satu media pembelajaran inovatif yang memberikan pengalaman belajar geometri yang lebih visual, konkret, dan interaktif dalam pendidikan anak usia dini.]
Keywords: Augmented Reality; Learning Media; Geometric Abilities; Early Childhood.

Introduction

Geometric ability is an important aspect of cognitive development in early childhood because it is associated with children's ability to recognize shapes, understand spatial relationships, perform visualization, and develop reasoning and problem-solving skills (Faoziyah et al., 2026; Hidayah et al., 2025; Miftahurrohmah et al., 2025). At the age of 4–5 years, children begin to develop an understanding of various geometric shapes through observation and concrete experiences in their surrounding environment. Introducing basic shapes such as circles, triangles, and squares not only helps children distinguish the characteristics of objects but also provides a foundation for the development of spatial thinking and readiness to learn mathematical concepts at later stages (Hutabarat et al., 2025). Therefore, geometry learning in early childhood needs to be designed in accordance with children's developmental characteristics, which favor direct experiences, visualization, play, and engaging activities.

Children's geometric understanding develops gradually. Van Hiele's theory explains that geometric thinking develops through hierarchical levels, beginning with the ability to recognize shapes visually and progressing toward an understanding of the properties and relationships among geometric figures. At the initial level, children primarily recognize shapes based on their overall visual appearance; therefore, visual and manipulative experiences are important in the learning process (Rizkianto et al., 2013; Windasari & Dheasari, 2023). This condition is consistent with the cognitive characteristics of children at the preoperational stage, who generally understand concepts more readily through concrete objects and visual representations than through abstract explanations. Accordingly, geometry learning requires media that can transform abstract concepts into experiences that children can directly observe and explore (Lumbantobing et al., 2024; Pujiastuti et al., 2024).

This problem was identified in geometry learning at RA Nurul Ula Burai. Based on an initial observation of 30 children aged 4–5 years, only 10 children (36%) were able to recognize basic geometric shapes, including circles, triangles, and squares, and accurately describe their characteristics, whereas 18 children (64%) still experienced difficulties. These difficulties included distinguishing shapes and sizes, understanding spatial positions and orientations, and arranging shapes into simple patterns. The difficulties were observed when children participated in activities involving placing shapes on boards, arranging blocks according to patterns, and identifying objects in their surroundings that had geometric forms (Nugroho et al., 2026). These findings indicate that the geometric abilities of most children had not yet developed optimally and required stimulation through learning activities that were more closely aligned with children's learning characteristics.

Interviews with teachers also indicated that geometry learning at RA Nurul Ula Burai primarily relied on conventional media, such as shape cards and building blocks. Although these media helped

children recognize shapes, their use did not fully sustain children's attention and engagement during learning activities. Teachers reported that some children continued to experience difficulties in distinguishing shapes with similar characteristics and understanding basic spatial concepts. Limited variation in learning media resulted in geometry activities that tended to be static, whereas young children require concrete, engaging learning experiences that involve active exploration.

One alternative medium that can be used to address these challenges is Augmented Reality (AR) (Alpariji et al., 2025; Koriah et al., 2025; Riwu et al., 2022; Sumarlin et al., 2026). AR technology combines virtual objects with the real-world environment in an interactive manner, allowing users to observe digital objects as though they were present in the actual environment. In geometry learning, this technology offers the advantage of presenting three-dimensional objects that can be viewed from multiple perspectives. Geometric shapes that were previously presented only through two-dimensional images can be visualized more realistically, helping children connect concepts of shape, size, position, and space with objects that they can observe directly (Nur & Ningrum, 2023). In addition, the interactive nature of AR can increase children's engagement in learning because children do not merely receive information from teachers but also have opportunities to observe and explore objects visually.

The use of AR is also consistent with the characteristics of early childhood learning, which require concrete and enjoyable experiences. Three-dimensional visualization can help reduce children's difficulties in understanding abstract concepts, while interactive elements can create more engaging learning experiences than media that are solely static (Herman et al., 2025; Khairunisa et al., 2026). Thus, AR can function not only as a tool for displaying objects but also as a learning medium that supports the exploration and understanding of geometric concepts. Nevertheless, the use of AR also has limitations, including dependence on technological devices, teachers' readiness to operate the media, and the need for content appropriate to children's developmental levels. Therefore, AR should be positioned as a supplementary learning medium designed in accordance with learning objectives and the developmental characteristics of early childhood (Hafifah et al., 2025).

Several previous studies have demonstrated the potential of AR in early childhood learning. Ulfadhilah et al. (2025), found that the use of AR media improved children's ability to recognize geometric shapes. The strength of this study lies in its direct examination of the use of AR in relation to geometric abilities through a one-group pretest–posttest design. However, the study involved children aged 5–6 years and therefore did not address the effectiveness of AR among 4–5-year-old children, who are at an earlier stage of geometric development.

Nasution et al (2022), developed AR-based learning media for early childhood education using the ADDIE model. The findings indicated that the developed media was feasible and practical and could increase children's interest through the visualization of three-dimensional objects. The strength of this study lies in its systematic media development process, which resulted in a learning medium suitable for early childhood education. However, the study focused primarily on media development and feasibility rather than specifically examining the effect of AR on children's geometric abilities. Therefore, the effectiveness of AR media in changing children's geometric abilities still needs to be examined through experimental research.

Another study was conducted by Nugroho et.al, (2026), on the development of AR-based learning media using card games to introduce three-dimensional geometric figures to young children. The study showed that the developed media was feasible for use and helped children recognize three-dimensional geometric figures through engaging three-dimensional visualization. A strength of this study was the integration of game elements and AR technology, which made learning more engaging. However, the study focused on media development and the recognition of three-dimensional geometric figures, whereas children's geometric abilities encompass broader aspects, including

recognizing shapes, distinguishing their characteristics, understanding spatial position and orientation, and relating shapes to objects in the surrounding environment.

Based on these previous studies, AR demonstrates potential for increasing children's interest in and understanding of concepts that require visual-spatial processing. However, a research gap remains concerning the effect of AR-based learning media on the geometric abilities of children aged 4-5 years, particularly in the context of *Raudhatul Athfal* (RA). Previous studies have predominantly involved children aged 5-6 years or focused on the development and feasibility of learning media. In addition, no study has specifically examined the use of AR media to address geometric ability difficulties among 4-5-year-old children at RA Nurul Ula Burai. This gap provides an important basis for further investigation. Based on these problems and the identified research gap, the main research question is whether the use of Augmented Reality-based learning media affects the geometric abilities of children aged 4–5 years at RA Nurul Ula Burai. AR is considered a promising alternative because it can present geometric objects in three-dimensional, interactive, and more concrete forms, thereby providing learning experiences that are consistent with children's developmental characteristics. Accordingly, this study aims to analyze the effect of Augmented Reality-based learning media on the geometric abilities of children aged 4–5 years at RA Nurul Ula Burai.

Method

This study employed a quantitative approach with an experimental method to determine the effect of using Augmented Reality (AR)-based learning media on the geometric abilities of children aged 4–5 years. A quantitative approach was used because the research data consisted of geometric ability scores obtained before and after the treatment, which were then analyzed using statistical techniques to test the research hypothesis. The research design was pre-experimental, using a One-Group Pretest–Posttest Design. This design involved one group of subjects who were given an initial measurement (pretest), treatment using AR-based learning media, and a final measurement (posttest). The pretest and posttest results were compared to determine changes in the children's geometric abilities after the treatment.

The study was conducted at RA Nurul Ula Burai with children aged 4–5 years as the research subjects. The study population consisted of 30 children, including 18 boys and 12 girls. The sample was selected using purposive sampling, considering the characteristics of the subjects relevant to the research objectives, namely children aged 4–5 years who participated in geometry learning activities at RA Nurul Ula Burai. The independent variable in this study was the use of Augmented Reality (AR)-based learning media, while the dependent variable was the geometric abilities of children aged 4–5 years. The research was conducted in three stages. The first stage was the pretest, which was administered to determine the children's initial abilities in recognizing and understanding geometric shapes before the treatment.

The children participated in activities involving the recognition of basic shapes, such as circles, triangles, and squares, as well as activities requiring them to identify, group, distinguish, and arrange geometric shapes. The second stage was the treatment, which involved learning activities using AR-based media. The children were introduced to geometric shapes through interactive three-dimensional visualizations. They were guided to observe the shapes, name them, identify the appropriate shapes, distinguish between shapes, group similar shapes, and arrange several shapes into simple patterns. The third stage was the posttest, which was administered after all treatment sessions had been completed to determine the children's geometric abilities following the use of AR media. The posttest results were then compared with the pretest results to determine changes in the children's geometric abilities after the treatment.

Data were collected through observation, testing, and documentation. Observation was used to examine the children's activities, responses, and engagement during the learning process using AR media. The test was used as the primary instrument to measure the children's geometric abilities through activities involving the recognition, naming, identification, grouping, differentiation, and arrangement of geometric shapes. Documentation was used as supporting data in the form of photographs and videos of the learning activities, as well as documentation of the pretest, treatment, and posttest implementation. The research instrument was developed based on indicators of geometric abilities for children aged 4–5 years and was validated before being used for data collection. The children's abilities were assessed using a four-point scale: 1 for Not Yet Developed (BB), 2 for Beginning to Develop (MB), 3 for Developing as Expected (BSH), and 4 for Developing Very Well (BSB).

The indicators of geometric abilities assessed in this study included the ability to recognize basic geometric shapes, identify shapes, group shapes based on similarities, compare and distinguish between shapes, and arrange shapes into simple patterns. These indicators were consistently used in both the pretest and posttest measurements so that changes in scores could be used to describe changes in the children's geometric abilities following the treatment using AR media. The research data were analyzed quantitatively using the Statistical Package for the Social Sciences (SPSS). Before hypothesis testing was conducted, the research instrument was first tested for validity and reliability to ensure its suitability for measuring the children's geometric abilities. A Shapiro–Wilk normality test was then conducted to determine the distribution of the data. Because the study involved the same subjects measured before and after the treatment, hypothesis testing was conducted using a paired-samples *t*-test when the data met the normality assumption. The decision was based on a significance level of 0.05. If the Sig. (2-tailed) value was < 0.05, there was a statistically significant difference between the children's geometric abilities before and after the use of AR media, indicating that AR-based learning media had an effect on the children's geometric abilities. Conversely, if the Sig. (2-tailed) value was > 0.05, there was no statistically significant difference between the pretest and posttest results.

Result and Discussion

Children's Geometric Abilities at Pretest

The initial measurement (pretest) showed that the geometric abilities of children aged 4–5 years at RA Nurul Ula Burai were not yet optimally developed before the implementation of Augmented Reality (AR)-based learning media. Based on the assessment of the children's geometric abilities, the mean pretest score was 49.73. This score represents the initial condition of the children's geometric abilities before they experienced learning activities using AR media. The assessment of geometric abilities in this study covered several indicators, including the ability to recognize and point to geometric shapes, name shapes, distinguish between shapes, and group shapes based on similar characteristics. The observations showed that some children still experienced difficulties in recognizing basic geometric shapes, such as circles, triangles, squares, and rectangles. Difficulties were also observed when the children were asked to name shapes, distinguish between two different shapes, and group objects according to their geometric characteristics. In several activities, the children still required assistance and guidance from the teacher to complete the assigned tasks.

These findings indicate that the children's geometric abilities before the treatment still required more concrete and engaging learning experiences. Learning activities using conventional media, such as pictures in books, shape cards, and whiteboards, provided relatively limited visual experiences. Consequently, the children had limited opportunities to explore the characteristics of geometric shapes in greater depth. At this developmental stage, children need not only to memorize the names of shapes but also to engage in learning experiences that allow them to observe, compare, identify, and group

shapes based on their characteristics. The mean pretest score of 49.73 therefore provides an empirical representation of the children's initial geometric abilities. This finding served as the baseline for comparison with the posttest results after the children received the intervention through AR-based learning activities. The comparison between the two measurements was important for examining changes in the children's geometric abilities following exposure to a learning medium that differed from the conventional media previously used.

The initial condition also provided a rationale for implementing AR-based learning media as the intervention. AR media can integrate virtual objects, including three-dimensional objects, into the real environment in an interactive manner. Through this medium, geometric shapes can be presented in a more concrete and visually accessible form, allowing children to observe shapes from different perspectives, identify their characteristics, name the shapes, distinguish between shapes, and group objects based on similarities in shape. These features may provide children with more visual and interactive learning experiences and, consequently, support the development of geometric abilities among children aged 4–5 years.

Children's Geometric Abilities After the Use of Augmented Reality-Based Learning Media

After receiving the treatment using Augmented Reality (AR)-based learning media, the geometric abilities of children aged 4–5 years at RA Nurul Ula Burai showed improvement compared with their condition before the treatment. The posttest results showed that the mean score of the children's geometric abilities increased to 77.37, compared with the mean pretest score of 49.73. Thus, there was an increase of 27.64 points in the mean score after the children participated in learning activities using AR-based media. The improvement was observed across several indicators of geometric abilities, namely the ability to recognize and point to geometric shapes, name shapes, distinguish between shapes, and group shapes based on similar characteristics. After receiving the treatment, the children appeared to be better able to recognize basic shapes such as circles, triangles, squares, and rectangles. The children also found it easier to follow the teacher's instructions to identify specific shapes and name the shapes displayed through the AR media.

In terms of distinguishing between shapes, the children demonstrated better responses when presented with several geometric objects. They began to identify differences between one shape and another based on the visual characteristics they observed. Similarly, in shape-grouping activities, the children were better able to place objects with the same shape into the appropriate groups. These changes indicate that the use of AR media provided visual experiences that helped children identify and compare various geometric shapes. Changes in the children's abilities were also observed during the learning process. The children demonstrated greater attention when geometric objects were presented through AR media. They became more active in responding to the teacher's questions, pointing to the requested objects, naming shapes, and participating in grouping activities. This condition indicates that AR media not only contributed to changes in the measured outcomes of geometric abilities but also supported children's engagement during the learning process.

The increase in the mean score from 49.73 at pretest to 77.37 at posttest indicates that, after experiencing learning activities using AR, the children demonstrated better abilities in recognizing and understanding geometric shapes. AR media allowed geometric objects to be presented in a more visual and interactive manner than the conventional media previously used. The children could observe shapes more clearly, enabling concepts that had previously been presented primarily through pictures or teacher explanations to be learned through more concrete visual experiences. These findings are consistent with the cognitive characteristics of children aged 4–5 years, who are generally in the preoperational stage of cognitive development. At this stage, children tend to understand concepts more easily through representations that can be directly observed. The visualization of geometric

objects through AR provided opportunities for children to engage in more concrete learning experiences, even though the objects presented were virtual. This helped children connect visual representations with the geometric concepts being learned.

The findings are also consistent with the study by Hermita, Solfiah, and Nurlita, which reported an improvement in children's ability to recognize geometric shapes after the use of Augmented Reality media. The consistency between these findings suggests that the visual and interactive characteristics of AR have the potential to support geometry learning in early childhood. However, the present study focuses specifically on children aged 4–5 years at RA Nurul Ula Burai, thereby extending the application of AR to a younger age group.

The Effect of Augmented Reality-Based Learning Media on the Geometric Abilities of Children Aged 4–5 Years at RA Nurul Ula Burai

Normality Test

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.098	30	.200*	.966	30	.430
Posttest	.096	30	.200*	.963	30	.377

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on the normality test output, the significance (Sig.) values for the pretest and posttest data were 0.430 and 0.377, respectively. Both values were greater than 0.05. Therefore, it can be concluded that the pretest and posttest data were normally distributed.

Homogeneity Test

Test of Homogeneity of Variances

45

Levene Statistic	df1	df2	Sig.
1.972	1	57	.166

Based on the results of the homogeneity test, the significance value was 0.166, which was greater than the significance level of 0.05. This result indicates that there was no statistically significant difference in variance between the pretest and posttest data. Therefore, the pretest and posttest data can be considered to have homogeneous variances. The fulfillment of this assumption supports the suitability of the data for further statistical analysis. Accordingly, the analysis was continued with hypothesis testing to determine whether there was a statistically significant difference between the

children's geometric ability scores before and after the implementation of Augmented Reality-based learning media.

Paired-Samples t-Test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Pretest - Posttest	-27.633	.964	.176	-27.993	-27.273	-156.956	29	.000

Based on the results of the paired-samples *t*-test, the significance value (Sig. 2-tailed) was 0.000. Because this value was less than 0.05, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted. This indicates that there was a statistically significant difference between the pretest and posttest scores. Therefore, the results indicate that the use of Augmented Reality-based learning media had a statistically significant effect on the geometric abilities of children at RA Nurul Ula Burai. The significant difference between the pretest and posttest results, together with the increase in the mean score from 49.73 to 77.37, indicates an improvement in children's geometric abilities following the intervention.

The findings provide empirical support for the use of AR-based learning media in early childhood geometry learning. The interactive visualization offered by AR may facilitate children's understanding of geometric shapes by providing opportunities to observe, identify, compare, and classify objects through direct visual experiences. This is particularly relevant to early childhood learning, in which concrete and visually accessible learning experiences can facilitate the development of conceptual understanding.

Conclusion

This study highlights the role of Augmented Reality (AR)-based learning media in supporting the development of geometric abilities among children aged 4–5 years at RA Nurul Ula Burai. The use of AR provided a more interactive and engaging learning experience for children in recognizing, naming, distinguishing, and grouping basic geometric shapes. The results showed that the children's geometric abilities improved after the implementation of AR-based learning. This finding was supported by the hypothesis test, which yielded a statistically significant difference between the pretest and posttest results. The results therefore indicate that the use of Augmented Reality-based learning media had a significant effect on the geometric abilities of children aged 4–5 years at RA Nurul Ula Burai.

The findings suggest that AR can serve as an innovative learning medium that helps transform geometric concepts into more concrete, visual, and interactive learning experiences that are consistent with the characteristics of early childhood development. Therefore, schools are encouraged to provide adequate technological facilities and infrastructure to support the use of innovative learning media, while teachers are encouraged to integrate AR creatively into learning activities that are appropriate for children's developmental stages. Parents can also reinforce children's understanding of geometry through simple activities involving geometric shapes found in the home environment. For future researchers, these findings may serve as a reference for examining the use of AR in other aspects of early childhood development, including cognitive abilities, creativity, spatial reasoning, and problem-solving skills.

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