



interactive features, AR has increasingly been used in education. In preschool education in particular, AR may be valuable because young children learn more effectively in environments that are concrete, engaging, and responsive to multiple senses (Cabero-Almenara & Vila, 2019; Fan, Antle, & Warren, 2020).

The widespread integration of technological advancements in modern education has established Augmented Reality (AR) as a primary tool for content enrichment across all academic levels (Alkan, 2024). By projecting digital content onto concrete objects, AR facilitates a multisensory learning environment that is particularly effective in preschool education, where it enhances perception through interactive audio, visual, and three-dimensional models (Bingöl, 2018; Fan et al., 2020). The preschool period, children are known to have a natural tendency to explore and learn. For this reason, there is a need to design and implement activities that appeal to all senses in order to foster positive attitudes toward learning in children (Taşkın-Gökçe & Kandır, 2025). Beyond early childhood, research across various application areas indicates that AR technologies yield significantly positive outcomes in core disciplines such as science, mathematics, and language learning, providing students with immersive experiences that bridge the gap between abstract theory and physical space (Aydoğdu & Kelpšiene, 2021; Alfarsi et al., 2021; Dilek Eryiğit, Küçük, & Taşgın, 2025).

The preschool education curriculum adopts a holistic approach to support all developmental domains, with mathematics activities—including skills such as counting, classification, comparison, measurement, spatial awareness, and the recognition of shapes and symbols—playing a vital role in cognitive growth (Flores et al., 2024; Yazlık & Öngören, 2018). To effectively teach these abstract mathematical concepts, AR technology is used to design immersive learning environments that sustain children's curiosity and interest. By integrating physical objects with digital information, AR concretizes abstract visuals and allows children to engage in learning through interactive play (Gecu-Parmaksiz & Delialioğlu, 2020). Ultimately, the ability of AR to provide multisensory stimuli and enriching experiences increases children's motivation and extends their attention spans during these foundational mathematical activities (Yao,

Wang, & Liu, 2024; Zhufeng & Sitthiworachart, 2024).

Attention is a fundamental cognitive process that directs mental resources toward specific stimuli, serving as a prerequisite for effective learning, memory, and problem-solving from early childhood onward (Posner & Snyder, 2024; Weber & Greiff, 2023). In the preschool period, where children naturally possess limited attention spans, the ability to focus on and explore environmental stimuli is critical for developing complex cognitive representations (Gözüm & Kandır, 2019; Öhman, 2021). Integrating Augmented Reality (AR) into this developmental stage offers a strategic advantage by providing rich, multisensory content that effectively captures and sustains child engagement (Hanafi et al., 2021). By stimulating multiple sensory channels simultaneously, AR-enhanced activities are expected to increase both motivation and the duration of focused attention, thereby facilitating more conscious and robust learning outcomes (Gözüm & Kandır, 2020).

Although previous studies have examined the use of augmented reality in preschool education and in areas such as science, language, and mathematics instruction, limited evidence is available on whether AR-supported mathematics activities improve attention skills in preschool children. This issue is important because attention is a foundational component of learning in early childhood, and mathematical concepts at this stage are often abstract and cognitively demanding. In this respect, AR may provide a more engaging and accessible learning environment by making mathematical content more concrete and interactive.

Based on this gap, the present study aimed to examine the effect of mathematics activities conducted through augmented reality applications on the attention skills of children aged 60-72 months. More specifically, the study sought to determine whether AR-supported mathematics activities would lead to higher attention scores than routine classroom activities in preschool settings.

## METHOD

This section presents the research design, study group, data collection instruments, data collection process, and data analysis.

## Research Design

This study employed a pretest-posttest quasi-experimental design with an experimental group and a control group. This design was preferred because the study was conducted in a natural school setting in which full random assignment of children to groups was not feasible. Instead, two existing classrooms were designated as the experimental and control groups. Pretest and posttest measurements were obtained from both groups in order to examine whether augmented reality-supported mathematics activities were associated with changes in children's attention skills over the intervention period.

## Study Group

The study group consisted of 22 children aged 60-72 months attending a preschool institution affiliated with the Ministry of National Education in Gökçebey, Zonguldak, Türkiye, during the 2024-2025 academic year. Convenience sampling was used because the study was conducted in the school where the researcher was working as an administrator. The sample comprised two intact classrooms, one assigned as the experimental group and the other as the control group. Descriptive information on the participants should be presented in a separate table, including group size, gender distribution, mean age in months, and duration of preschool attendance.

As shown in Table 1, the participants consist of 22 preschool children distributed equally into experimental and control groups. The groups are perfectly matched regarding their mean age (70 months) and their prior preschool experience (2.7 years), ensuring that any observed differences in post-test results can be more accurately attributed to the experimental variables rather than developmental or educational discrepancies.

## Data Collection Instruments

In the study, a Personal Information Form and the Attention Factor of the Early Learning Behaviors Scale (Akpınar Afşin & Kandır, 2025) were used.

The Personal Information Form consisted of information on the child's name and surname (or initials, optionally), gender, date of birth, duration of

attendance in a preschool education institution, and birth order.

The Early Learning Behaviors Scale was developed to evaluate the learning behaviors of children aged 48-72 months. It consists of 188 items and is divided into 26 subdimensions under 7 factors, namely Planning, Attention, Entrepreneurship, Competence, Emotion Management, Motivation, and Participation. The factors of the scale can be used separately, and the scale can be completed through observations made at different times. Considering the number of items, both the overall scale score and the factor scores can be calculated separately. Within the scope of the validity studies, it was examined through exploratory factor analysis whether each factor demonstrated a unidimensional structure. After principal components analysis provided evidence that the 7 factors were indicators of the Early Learning Behaviors Scale, confirmatory factor analysis provided evidence for the model fit of the scale. Within the scope of the reliability studies, Cronbach's alpha values above 0.70 for all factors indicated that the scores obtained from the factors were reliable. As a result of the validity and reliability studies, the Early Learning Behaviors Scale was shown to be a valid and reliable assessment instrument. Each item in the scale was prepared in a 5-point Likert format and ranked as "Always," "Most of the Time," "Sometimes," "Rarely," and "Never." Within the scope of the present study, the Attention Factor, consisting of 26 items, was used. In the present study, the Attention Factor was completed by the classroom teacher for each child at both pretest and posttest. Because the ratings were teacher-reported, the possibility of rater expectancy bias should be considered when interpreting the findings.

In the original scale development study, the Attention Factor was also found to have acceptable validity and reliability. Since the present study used only the 26-item Attention Factor, its psychometric adequacy was taken into consideration. The Cronbach's alpha coefficient for the Attention Factor was reported as 0.97.

## Procedure

Prior to the implementation, parental informed consent was obtained for all participating children.

The researcher provided preparatory training on the augmented reality applications and the intervention activities. The intervention lasted five weeks, with one mathematics activity implemented per week for approximately one hour. The experimental group participated in AR-supported mathematics activities, whereas the control group received routine mathematics activities aligned with the daily preschool plan. The same attention measure was administered before and after the intervention period. The activities were implemented by the classroom teacher under the guidance of the researcher. To reduce instructional variation, the same teacher delivered the activities in both groups. The AR activities were conducted individually / in small groups / as whole-class guided activities. A smartphone/mobile device was used to display the AR content during the activities. To ensure consistency across sessions, the activities were implemented according to pre-prepared activity plans.

### **Week 1: Demonstrates number awareness and counting skills**

The first topic of the study, numbers, was presented to the children in both the experimental and control groups by the teacher using the same expressions to explain the concept of number and counting skills.

*Activity process for the experimental group:* The activity was conducted using the relevant worksheet in the Quiver application. The teacher explained the topic to the children through direct instruction based on the visual on the Quiver worksheet. After the topic had been explained, the children colored the relevant worksheet, and the teacher then animated each child's worksheet in three dimensions on a phone using the Quiver augmented reality application. Rhythmic counting activities were then carried out using the animated numbers.

*Activity process for the control group:* The teacher presented the topic by showing number visuals prepared in advance and using the same verbal expressions as those used in the experimental group. The children were then asked to color the number visuals. The teacher placed on a table the same number of objects as the number written on the page and asked the children to place the colored

numbers next to the objects. Rhythmic counting was carried out after the activity.

### **Week 2: Performing simple addition using objects**

The second topic of the study, performing simple addition, was presented to the children in both the experimental and control groups by the teacher using the same expressions.

*Activity process for the experimental group:* The activity was conducted using the ARLOOPA application. Through ARLOOPA, the teacher displayed different objects selected by the children on the same plane on the screen. After the preliminary setup, the children were given instructions related to addition skills. The instructions given for the animated objects were as follows:

“There were 2 dogs, and I added 1 more dog. How many dogs are there now?”

Similar instructions were given by changing the numbers. At the end of the activity, the children were asked to draw a picture related to the activity they had completed.

*Activity process for the control group:* The teacher showed a worksheet containing addition operations prepared in advance and presented the topic using the same verbal expressions as those used in the experimental group. The children were then asked to perform the operations. An abacus, as an addition material, was used to enable the children to carry out the operations written on the page. At the end of the activity, the children were asked to draw a picture related to the activity they had completed.

### **Week 3: Measuring objects and entities**

The third topic of the study, measuring objects and entities, was presented to the children in both the experimental and control groups by the teacher using the same expressions.

*Activity process for the experimental group:* The activity was conducted using the Measure application. By using the Measure application, the teacher carried out activities such as measuring the length of each object in the classroom and measuring the children's height with the animated measuring tool. The lengths of the measured objects and entities were expressed verbally.

*Activity process for the control group:* The teacher introduced a measuring tape brought in

advance and carried out activities such as measuring objects in the classroom and measuring the children's height. The lengths of the measured objects were expressed verbally.

#### **Week 4: Following directions related to place, direction, and position**

The fourth topic of the study, following directions related to place, direction, and position, was presented to the children in both the experimental and control groups by the teacher using the same expressions.

*Activity process for the experimental group:* Using the LeoArCamera application, the children transformed a visual found in their surroundings into a three-dimensional image on a phone and positioned it in accordance with the given instructions. The activity continued through animated and audio-supported representations by giving different directions related to place, direction, and position. At the end of the activity, the children were asked to draw a picture related to the topic for evaluation purposes.

*Activity process for the control group:* The teacher explained the concepts related to direction and position. The children were then asked, one by one, to take an object from the classroom and position it in line with the given directions related to place, direction, and position. At the end of the activity, the children were asked to draw a picture related to the topic for evaluation purposes.

#### **Week 5: Recognizing geometric shapes**

The fifth topic of the study, recognizing geometric shapes, was presented to the children in both the experimental and control groups by the researcher using the same expressions.

*Activity process for the experimental group:* The activity was conducted using the relevant worksheet in the Quiver application. The teacher explained the topic to the children through direct instruction based on the visual on the Quiver worksheet. After the topic had been explained, the children colored the worksheet containing geometric shapes, and the teacher then animated each child's coloring in three dimensions on a phone using the Quiver augmented

reality application. An analogy activity was then carried out using the animated shapes by relating them to objects in the children's surroundings.

*Activity process for the control group:* The teacher showed geometric shapes prepared in advance and presented the topic by using the same verbal expressions as those used in the experimental group. The children were then asked to color the shapes. After coloring the geometric shapes on the page, the children were asked to draw an object from their surroundings that had the same shape.

#### **Follow-up measurement**

To examine whether the effects of the intervention were maintained over time, a follow-up measurement was conducted four weeks after the posttest. The follow-up assessment was administered to the experimental group using the same Attention Factor of the Early Learning Behaviors Scale. The scale was completed by the teacher under the same rating procedure used at pretest and posttest. No additional AR-supported mathematics activities were implemented during the follow-up interval.

#### **Data Analysis**

The data were analyzed using SPSS. First, descriptive statistics and normality values were examined for the pretest, posttest, and follow-up scores. Given the small sample size and the group structure of the study, non-parametric tests were preferred for both within-group and between-group comparisons. The Wilcoxon signed-ranks test was used to compare the pretest, posttest, and follow-up scores within the experimental and control groups, and the Mann-Whitney U test was used to compare the experimental and control groups at pretest and posttest. Statistical significance was evaluated at the .05 level.

#### **Ethical approval**

The ethical approval was obtained from the Ethics Committee of Bartın University (dated March 12, 2025; decision no. 2025-SBB-0109).

#### **FINDINGS**

The results of the study are presented under descriptive statistics, reliability analysis, normality

assessment, between-group comparisons, and within-group pretest-posttest comparisons.

In Table 2, the mean scores obtained from the attention measure are presented together with skewness, kurtosis, and normality values. For samples smaller than 50, normality is commonly evaluated based on the Shapiro-Wilk test (Aldrich, 2018). However, given the small sample size and the group structure of the study, non-parametric tests were preferred for subsequent analyses (Field, 2013; Wilcox, 2012).

As shown in Table 3, there was no significant difference between the experimental and control groups in pretest attention scores ( $U = 53.500$ ,  $z = -.461$ ,  $p = .645$ ). This result indicates that the two groups were comparable in terms of attention scores before the intervention.

As shown in Table 4, a significant difference was found between the experimental and control groups in posttest attention scores ( $U = 22.000$ ,  $z =$

$-2.533$ ,  $p = .011$ ). The mean rank of the experimental group (15.00) was higher than that of the control group (8.00), indicating that the experimental group obtained higher posttest attention scores following the intervention.

As shown in Table 5, there was a significant difference between the pretest and posttest attention scores of the experimental group ( $z = -2.524$ ,  $p = .012$ ). Considering the rank distribution, this difference was in favor of the posttest scores. This finding suggests that the AR-supported mathematics activities had a positive effect on the attention scores of the children in the experimental group.

As shown in Table 6, no significant difference was found between the pretest and posttest attention scores of the control group ( $z = -.665$ ,  $p = .506$ ). This result indicates that routine classroom activities did not produce a statistically significant change in the attention scores of the children in the control group during the study period.

**Table 2: Descriptive Statistics for the Pretest and Posttest Attention Skill Scores of Children in the Experimental and Control Groups**

Group	n	Skewness	Kurtosis	Kolmogorov-Smirnov	Shapiro-Wilk	M	SD
Experimental Group Pretest	11	-.075	-1.667	.200	.129	3.26	.628
Experimental Group Posttest	11	-.901	.657	.200	.189	3.59	.386
Control Group Pretest	11	-1.003	-.87	.200	.127	3.11	.691
Control Group Posttest	11	-1.025	-.234	.200	.181	3.14	.737

Note. For samples smaller than 50, normality should be interpreted based on the Shapiro-Wilk value (Aldrich, 2018).

**Table 3: Mann-Whitney U Test Results for the Difference Between the Experimental and Control Groups in Pretest Attention Scores**

Group	n	Mean Rank	Sum of Ranks	U	Z	p
Experimental Group	11	12.14	133.50	53.500	-.461	.645
Control Group	11	10.86	119.50			

Note.  $N = 22$ .

**Table 4: Mann-Whitney U Test Results for the Difference Between the Experimental and Control Groups in Posttest Attention Scores**

Group	n	Mean Rank	Sum of Ranks	U	Z	p
Experimental Group	11	15.00	165.00	22.000	-2.533	.011
Control Group	11	8.00	88.00			

Note.  $N = 22$ .  $p < .05$ .

**Table 5: Wilcoxon Signed-Ranks Test Results for the Pretest and Posttest Attention Skill Scores of the Experimental Group**

Pretest-Posttest	n	Mean Rank	Sum of Ranks	Z	p
Negative Ranks	0	0	0	-2.524	.012
Positive Ranks	8	4.50	36.00		
Ties	3				
Total	11				

**Table 6. Wilcoxon Signed-Ranks Test Results for the Pretest and Posttest Attention Skill Scores of the Control Group**

Pretest-Posttest	n	Mean Rank	Sum of Ranks	Z	p
Negative Ranks	8	9.20	73.60	-.665	.506
Positive Ranks	1	1.80	1.80		
Ties	2				
Total	11				

**Table 7: Wilcoxon Signed-Ranks Test Results for the Posttest and Follow-up Attention Scores of the Experimental Group**

Posttest- Follow-up	n	Mean Rank	Sum of Ranks	Z	p
Negative Ranks	0	0	0	-2.524	0.012
Positive Ranks	8	4.50	36.00		
Ties	3				
Total	11				

A follow-up analysis was conducted to examine whether the attention gains observed after the intervention were maintained over time in the experimental group. As shown in Table 7, no significant difference was found between the posttest and follow-up attention scores of the experimental group ( $z = -2.524$ ,  $p = 0.012$ ). This result suggests that the attention gains observed after the intervention were maintained over the follow-up period.

## DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

In this study, the effect of mathematics activities conducted through augmented reality applications on the attention skills of children aged 60-72 months was examined. The results showed that AR-supported mathematics activities were associated with improved attention scores in the experimental

group, whereas no statistically significant change was observed in the control group, which continued with routine classroom activities. These findings suggest that integrating augmented reality into preschool mathematics activities may help sustain children's attention during cognitively demanding tasks. In early childhood, mathematical concepts such as number awareness, spatial relations, and shape recognition may place considerable demands on children's attention. In this respect, AR-supported activities may provide a more engaging and accessible learning environment by making abstract content more concrete and interactive. Similar findings in the literature have also suggested that AR applications can support children's learning and classroom engagement in early educational settings (Cesur, 2024; Çevik et al., 2017; Alfarsi et al., 2021; Alyousify & Mstafa, 2022; Alzahrani, 2025).

Before the intervention, the pretest results indicated that the difference between the experimental and control groups was limited. After the implementation of the AR-supported mathematics activities, the attention scores of the experimental group increased, and the gap between the two groups became more visible. This pattern suggests that AR-supported activities may have contributed positively to children's attention during mathematics tasks. One possible explanation is that AR provides visual and interactive support while children are working with mathematical content, thereby helping them remain engaged in the activity. Previous studies have similarly reported that AR can increase learners' motivation, curiosity, and task-focused engagement (Radu, 2014; Yuen et al., 2011). In this respect, the findings of the present study are consistent with the view that AR may function as a supportive instructional tool in early childhood mathematics education.

The higher posttest mean rank observed in the experimental group suggests that the AR-supported mathematics activities were more effective than routine classroom activities in supporting attention during the intervention period. Although a small degree of change may also occur naturally in preschool children due to ongoing developmental processes, the stronger improvement in the experimental group indicates that the intervention itself may have played an important role. This interpretation is also supported by earlier studies showing that AR-based activities can positively influence motivation, engagement, and learning-related behaviors (Çakır, Solak, & Tan, 2015; Huang & Yang, 2020). Taken together, the findings suggest that AR-supported mathematics activities may offer a more attention-supportive classroom environment for preschool children than traditional activity formats alone.

The fact that skills are maintained or continue to improve in follow-up tests indicates that the attention skills acquired through AR are not limited to the moment of application but have become a cognitive schema. Dunleavy et al. (2009) argue that the highly interactive environment created by AR is effective in transferring information from short-term to long-term memory and in making cognitive processes permanent. Other studies supporting this finding indicate that AR-based activities in the preschool

period help maintain children's curiosity and sense of discovery, which in turn enhances the retention of learned skills—that is, improves performance on follow-up tests (Demirtaş, 2023; Okatan, 2024).

The follow-up findings further suggest that the improvement observed in the experimental group was maintained over time. Since no significant difference was found between the posttest and follow-up scores, the results may indicate that the attention gains associated with the AR-supported mathematics activities were sustained during the follow-up period. This finding should be interpreted cautiously; however, it is still consistent with previous work suggesting that interactive and engaging AR environments may help support continued task engagement after the intervention period (Demirtaş, 2023; Okatan, 2024).

Overall, the findings of the study indicate that AR-supported mathematics activities may contribute positively to the attention scores of preschool children aged 60-72 months. Compared with routine classroom activities, the AR-supported intervention was associated with stronger posttest performance in the experimental group. These results suggest that augmented reality may be used as a supportive instructional tool in preschool mathematics education, particularly when the aim is to make abstract concepts more concrete and to support children's attention during structured learning activities.

This study has several limitations that should be considered when interpreting the findings. First, the sample size was small and limited to a single preschool setting. Second, the study used convenience sampling and intact classrooms, which limits the generalizability of the results. Third, the attention measure was completed by the teacher, and teacher-reported ratings may involve expectancy bias. Finally, although a follow-up measurement was included, the duration of the intervention and the study context were limited. Future studies with larger samples, multiple settings, and additional assessment methods are needed to strengthen the evidence base.

### *Implications for practice*

The findings suggest that augmented reality may be integrated into preschool mathematics activities as a structured instructional support rather than as a

purely technological novelty. Teachers may use short, guided, and age-appropriate AR-supported tasks to help children engage more actively with abstract mathematical concepts such as number awareness, shapes, measurement, and spatial relations. However, successful classroom use may depend on teacher preparation, device availability, and careful activity planning.

Based on the results of the study, the following suggestions may be offered for future research:

- Future studies may examine whether AR-supported mathematics activities have a similar effect on the attention skills of children aged 48-60 months.
- Further research may investigate the effects of AR-supported mathematics activities on other learning-related outcomes, such as problem-solving skills, motivation, or engagement.
- The effects of augmented reality applications in other preschool activity domains may also be explored.
- Comparative studies may examine whether different AR applications, such as Numbers 4D, Arloon Geometry, or Osmo, produce different outcomes in preschool mathematics activities.

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