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The effect of Zesquare visual attention set on the development of pattern skills in early childhood: A quasi–experimental study

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The purpose of this research is to determine the effect of the Zesquare (Ze^2) Visual Attention Set (VAS) on the development of pattern skills in early childhood. The study utilized a pre-test–post-test control group design. The study group consisted of 38 students (18 females, 20 males) aged 5, attending a preschool in Istanbul. A quasi-experimental pre-test–post-test control group design was employed. These intact groups were then designated as either the experimental or the control group. In the study, the experimental group participated in Ze^2 VAS activities for 30-40 minutes daily over 12 weeks, considering each child's attention and interest level. The control group continued their education following the standard curriculum. Data collection employed the Preschool Pattern Skills Test, which included demographic information. Data analysis was conducted using SPSS v24 and the R package. The study found no significant difference in pre-test pattern skills scores between the experimental and control groups ($p > 0.05$, Cohen's $d = 0.24$). Statistical analysis revealed a significant increase in the post-test scores of the experimental group compared to their pre-test scores, indicating a notable gain in pattern skills favoring the intervention ($p < 0.01$, Cohen's $d = 0.80$). There was no significant difference in pattern skills post-test scores compared to pre-test scores for the control group ($p > 0.05$, Cohen's $d = 0.12$). The findings indicate that children using the Ze^2 VAS app demonstrated improvement in their pattern recognition skills. In summary, the study suggests that Ze^2 VAS contributes positively to children's development.

Introduction

Mathematics education during the preschool period provides a solid foundation for mathematical learning by enabling children to explore mathematical concepts such as numbers, shapes, patterns, and space. This period is considered a critical period in which children develop mathematical thinking skills and these skills form the basis for their future education (Chen, 2025; Kandır & Orçan, 2011; National Association for the Education of Young Children [NAEYC], 2002). Clements and Sarama (2008) explain that learning mathematics in early childhood should be supported by play-based and interactive activities. These activities enable

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children to learn mathematical concepts through concrete experiences and to understand these concepts by relating them to daily life (Björklund, van den Heuvel-Panhuizen, & Kullberg, 2020).

Ginsburg (2006) emphasizes that starting mathematics learning at an early age and including children in programs that develop their mathematical skills from preschool onwards play a critical role in terms of mathematics achievement in later years and that children's mathematical thinking skills can be strengthened through appropriate learning environments provided at an early age. Sophian (2004) examined how mathematical knowledge develops in early childhood and how this process affects cognitive development. In this study, the researcher details how children learn mathematical concepts through natural world interactions and manipulative materials. Existing studies in the literature provide important scientifically grounded information on how mathematics is learned in the preschool period and how children can be supported in this area (Çevikbaş & Kaiser, 2023; Ferres-Forga et al., 2022; Günaydın, Küçük-Demir, & Tutkun, 2023; Hayıroğlu, 2017, etc.). These studies commonly emphasise that using strategies such as play-based learning, the use of manipulative materials, and mathematical practices in real-world contexts to strengthen children's mathematical abilities can help manage this process effectively.

However, developing pattern skills plays a critical role strengthening preschool children’s mathematical thinking skills. According to the National Council of Teachers of Mathematics (NCTM), pattern is considered an important part of mathematical science and occupies an important place in mathematics education. The NCTM's standards (2000) for mathematics instruction include comparing and repeating objects according to their size, number, and different properties, and understanding patterns and relationships between objects. Pattern skills lay the foundation for further mathematics learning, while also strengthening problem-solving and logical thinking skills (Casey et al., 2008). According to Baroody and Dowker (2013), mathematical pattern skills in early childhood facilitate the understanding of numerical operations and mathematical concepts. Children's ability to recognize and use patterns contributes to the development of mathematical expertise and mathematical problem-solving skills. These skills help children develop deeper and more enduring learning habits in mathematics (Baroody, Clements, & Sarama, 2019). Clements and Sarama (2014) point out how interactive learning activities with manipulatives develop children's ability to discover and use patterns. Such learning experiences can strengthen children's mathematical thinking processes and provide a solid foundation for future mathematical achievement (Clements & Sarama, 2014). Casey et al. (2008) argue that playing with blocks as a play material increases children's ability to think spatially and understand mathematical concepts. They also argue that interactive activities help children develop the ability to recognize, analyse, and maintain patterns.

It has been emphasized in many studies that mathematics performance at early ages is directly related to later educational success and that supporting children's mathematical skills at an early age can positively affect their later academic success (Bierman, 2008; Duncan, 2007; Casey, 2012). It is thought that studies on pattern skills, which “are” an important mathematical skill set / studies on pattern skills, which constitute an important mathematical skill. Pattern skill is the ability to identify the predictable regularity among the elements that make up a sequence (Rittle-Johnson, Zippert, & Boice, 2019). In other words, pattern skill is a cognitive ability that involves identifying the rule governing the elements in a sequence and applying that rule to subsequent sequences. This skill is a fundamental cognitive process that enables children to analyse the relationships between objects, numbers, or events (Atıcı, Çamlıbel Çakmak, &

Yurtsever Kılıçgün, 2025; Hayıroğlu, 2017; Hayıroğlu & Ulus, 2017; Papic, 2015). Measuring and striving to develop mathematical pattern skills in preschool children is critical for monitoring and supporting their mathematical development (Duncan, 2007; Casey, 2012). These skills help children understand basic mathematical concepts such as number association, sorting, and categorization. Developing basic skills such as pattern recognition and construction in preschool can lay the foundation for advanced mathematical skills and help children understand more complex mathematical concepts (Ginsburg, 2006; Jordan & Levine, 2009). The ability to recognize and analyse patterns plays a critical role in the development of mathematical thinking and problem-solving skills. Pattern recognition is particularly important in mathematical subfields such as geometry, algebra, and number theory (Rittle-Johnson, Zippert, & Boice, 2019). Chen, Chao, and Hou (2023) state that pattern recognition improves students' abstract thinking skills and problem-solving processes in mathematics education. The ability to analyse patterns allows students to understand concepts in mathematics more deeply and make meaningful connections. The preschool period is considered a critical time for children to acquire mathematical pattern skills (Clements & Sarama, 2008; Gelman & Brenneman, 2004). Developing pattern skills through different methods is important. The ability to recognize, analyse, and construct mathematical patterns allows students to deepen their mathematical thinking processes (Schoenfeld, 1985; Small, 2017). Therefore, supporting mathematical pattern skills in the preschool period is critical for strengthening children's mathematical development and ensuring their future educational success.

Educational and environmental support provided to children to enhance their mathematical skills is crucial. One such element of this support is high-quality educational play materials (Rittle-Johnson et al., 2017). Incorporating high-quality educational play materials into a child's home and school life will create opportunities for the child to learn through play-based activities. High-quality educational play materials eliminate the boundary between play and learning by providing children with a discovery-focused environment (Hirsh-Pasek et al., 2009). These materials will also enable the child to progress within their zone of proximal development with the help of adults who build scaffolding (Rittle-Johnson, Zippert, & Boice, 2019; Vygotsky, 1978). At the same time, high-quality educational materials can contribute to ensuring equal opportunities in education by providing educational support, especially for children who do not have access to preschool education (OECD, 2018). Therefore, studies investigating the different developmental and educational contributions of educational materials to children are important and will contribute to the literature. In the literature review conducted by the researchers, no study was found that investigated the effect of educational materials on pattern skills in preschool children.

This study employed an experimental approach to investigate the effect of using the educational play material named Zesquare (Ze^2) Visual Attention Set (VAS) on the development of pattern skills in preschool children, is expected to contribute to the literature on early childhood education and mathematics education. Based on these points, this study focused on the pattern skills of preschool children. In this context, the general aim of the study is to determine the effect of Ze^2 VAS on the development of pattern skills in preschool children. In line with this, the following research questions (RQs) were addressed in the study.

- RQ1: Is there a significant difference between the groups in the mean pattern skill scores of the children in the experimental and control groups based on the pre-test results?

- RQ2: Is there a statistically significant difference between the groups in the mean pattern skill scores of the children in the experimental and control groups according to the post-test measurement results?
- RQ3: Is there a significant difference between the mean pre-test and post-test scores of the children in the experimental group?
- RQ4: Is there a significant difference between the mean pre-test and post-test scores of the children in the control group?
- RQ5: When pre-test scores are used as a covariate, does the Ze^2 VAS application lead to a significant difference in the pattern skills of the experimental and control groups?

Method

Research Design

In this study, in line with the study's overall aim and research questions, "pre-test–post-test control group quasi-experimental model" was used. In a pre-test–post-test control group quasi-experimental design, pre-existing groups are used instead of random assignment. In this study, one of two pre-existing preschool classes was assigned as the experimental group and the other as the control group. In this model, to ensure internal validity, the same measurement procedures are applied to both the experimental and control groups during the pre-test and post-test phases (Karasar, 2020). The independent variable in this study was the Ze^2 VAS application prepared for preschool children, and the dependent variable was preschool children's pattern skills.

Study Group

The study group consisted of 38 children attending a kindergarten in the Üsküdar district of Istanbul, affiliated with the Ministry of National Education (MoNE). A quasi-experimental design was employed, in which two pre-existing classes were selected via convenience sampling. These intact groups were then designated as either the experimental or the control group. To determine whether the groups were initially comparable, the pre-test scores were analysed using an independent samples t-test. Inclusion criteria were established for participant selection. The inclusion criteria included normal developmental status, no chronic health problems, no disabilities, and native Turkish speakers. In this study, there were 19 children in each of the experimental and control groups and all of the children were five years old. Regarding gender distribution, there were 9 females and 10 males in the experimental group and 9 females and 10 males in the control group.

Instruments

In this study, a demographic information form prepared by the researcher was used to obtain descriptive information (gender and age) about preschool children, and the Preschool Pattern Skills Test was used to evaluate pattern skills.

Preschool Pattern Skills Test

The Preschool Pattern Skills Test was a test developed by Güven et al. (2019) to determine children's pattern skills. The test comprises two forms, a long form with 26 questions and a short form with 17 questions. In this study, the 17-item short form was administered. The assessment tool evaluates seven core patterning competencies: pattern copying, finding the missing unit, identifying the core unit, pattern transformation, pattern extension, pattern expansion, and pattern generation. Pattern copying refers to a child's ability, to an individual's ability to replicate a given pattern exactly, without disrupting its structure, sequence, or relationships. Identifying the missing unit depends on analysing the structural order of the pattern. Identifying the core unit involves the ability to distinguish and define the smallest repeating structural unit that forms the pattern. Pattern transformation skill involves the ability to convert an existing pattern into a different form of representation according to a specific rule. Pattern extension skill refers to the ability to continue a pattern accurately by recognizing the underlying rule. Pattern expansion refers to developing a pattern to include more complex or multiple relationships while maintaining its fundamental rule. Pattern generation skill refers to the ability to design an original and consistent pattern based on a specific rule. Patterns are ordered from simple to complex. The test consists of 17 items, with a dichotomous scoring system where correct answers receive 1 point and incorrect answers receive 0 points (Total score range: 0-17). Children's answers are scored as correct or incorrect. In the study conducted by Güven et al. (2019), the reliability coefficient of the test calculated using KR-20 reliability analysis was 0.86. In this study, the KR-20 reliability coefficient of the test was calculated as 0.83, and the values obtained indicate that the test is a reliable measurement instrument in the evaluation of preschool children's pattern skills.

Data Collection Process

Permissions were obtained from the Ordu University Social and Human Sciences Ethics Committee, Istanbul Provincial Directorate of National Education, the scale developer and the publishing house of Ze^2 VAS for the implementation of the study. After the permissions were obtained, students and parents were informed before the applications, and brief information about the study was. The families of the children were informed about the study through the Parental Consent Form. Children whose families signed the consent form participated in the study in a quiet area or room at their schools. The scales were administered to the children for approximately 20 minutes in a single session during pre-test and post-test applications. Before data collection, a short conversation was held with the children to establish rapport with the children between the practitioner and the children. During the implementation period, the children's attention spans were taken into consideration. The collected data were coded in such a way that the identity information of the children could not be identified.

Process

After obtaining all necessary approvals for the study, one of the two classes at the same school was designated as the experimental group and the other as the control group. The researcher administered the Preschool Pattern Recognition Skills Test to the children in both groups as a pre-test. Subsequently, the activities included in the Ze^2 VAS were implemented under the guidance of the researchers for the children in the experimental group over a 12-week period, five days a week, for 30–40 minutes per session, depending on the children's level of interest and attention. The activities were conducted in a manner similar to the Montessori method, where each child worked individually, self-corrected their errors, and progressed at their own pace. Meanwhile, the children in the control group continued their education with their regular teachers in accordance with the MoNE 2013 Preschool Education Curriculum throughout this period, with no additional activities to support pattern skills were implemented. Upon completion of the intervention by the researcher, the Preschool Pattern Skills Test was administered again to both groups as a final assessment.

Zesquare (ZE²) Visual Attention Set (VAS)

Ze^2 VAS is an educational play material. This educational material consists of 10 different booklets and one eight-stone matching panel. Each child can work with the material individually. This educational material contains various exercises designed to develop children's visual perception skills and logical and mathematical reasoning skills. It has five different forms addressing different developmental and difficulty levels: ages 2–4, 5, 6, 6–9, and 9–12. The patterns on the front surface of the stones in the matching panel in sets prepared for different age groups different age groups were selected in accordance with the target age group. In this study, the children in the experimental group continued their studies with the Ze^2 VAS 5 age group set. The exercises in the 5-year-old set are solved with an 8-stone matching panel.

One of the most important educational features of the Ze^2 VAS is that it includes a device that allows children to self-check the work they have done within the set. This approach is also compatible with the error control principle of the Montessori method (Altan & Ulutaş, 2024), a contemporary international preschool education approach. The control mechanism in this educational material provides the child with the opportunity to self-monitor their work through colourful patterns that emerge according to the child's answers. This creates an independent working environment for children.

Ze^2 VAS offers child opportunities to learn through play. The play-based nature of the educational material, which allows for self-control, can be considered pedagogically beneficial in line with the Self-Determination Theory's principles of autonomy and competence, as well as the view that play-based materials enhance children's motivation to learn (Wang et al., 2024). The set is appropriately designed for the required difficulty level, with activities progressing from simple to complex. This structured progression from easy to difficult may support children in reaching their developmental potential by providing scaffolding from adults within the Zone of Proximal Development (ZPD), consistent with Vygotsky's sociocultural approach.

Data Analysis

The data were evaluated using IBM SPSS Statistics Standard Concurrent User Version 24 and the R package. Due to the small group sample size ($n = 19$, <30), the assumption of normal distribution was evaluated using the Shapiro-Wilk test statistic, skewness and kurtosis values. Skewness and kurtosis values in the range of -1.5 and +1.5 (Tabachnick, Fidell, & Ullman, 2013) were accepted as an indicator that the data were normally distributed. The results of the analyses conducted to assess normality assumption of normal distribution showed that the data were normally distributed. The following statistical tests were used to test the sub-hypotheses. An independent samples t-test was used to compare the mean scores of the experimental and control groups. A paired samples t-test was used to compare pre-test and post-test scores within each group. An independent samples t-test was used to compare the post-test mean scores of the experimental and control groups. When the pre-test mean scores of the experimental and control groups were controlled for, an analysis of covariance (ANCOVA) was used to determine whether there was a difference between their post-test mean scores.

ANCOVA and it is primarily used to eliminate the difference in mean scores between the experimental and control groups before the intervention. All assumptions required for this analytical method were examined and presented in detail in the relevant sections of the study. The level of statistical significance for the results obtained in all analyses was set at $p < .05$. The criteria proposed by Jacob Cohen (1988) were used to interpret Cohen's d effect sizes (d =

0.20: small; d = 0.50: moderate; d = 0.80 and above). Cohen's (1988) criteria were also used to interpret the level of partial eta-squared effect (small = 0.01, medium = 0.06, large = 0.14).

Findings

In this section of the study, the findings obtained as a result of examining the effect of Ze^2 VAS on preschool children's pattern skills are presented. For the first research question of the study, the differences between the averages of the pre-test scores of the students randomly assigned to the experimental and control groups in equal numbers (n = 19) were determined using independent samples t-test and the results of the analysis are presented in Table 1.

Table 1. Comparison of the Pre-test Mean Scores of the Experimental and Control Group Children in Pattern Skills

Group	X	Sd	t	p	Cohen's d
Control	6.16	2.34	-0.73	0.47	0.24
Experimental	6.89	3.75			

Note: Sd = Standard deviation, t = Independent samples t-test statistic value, Cohen's d = Effect size, p = significance level

Table 1 shows that, no statistically significant difference was observed between the experimental and control groups in the averages of the total scores of the *Preschool Pattern Skills Test,* which was administered as a pre-test in the first phase of the study (t = -0.73, p > 0.05, Cohen's d = 0.24, small effect size).

The second research question of the study, the differences between the averages of the post-test scores of the students in the experimental and control groups were determined using independent sample t-test and the results of the analysis are presented in Table 2.

Table 2. Comparison of the Post-Test Mean Scores of Children in the Experimental and Control Groups in Pattern Skills

Group	Mean	Sd	t	p	Cohen's d
Control	6.42	1.92	-3.99^{w}	0.00	1.29
Experimental	9.79	3.14			

Note: Sd = Standard deviation, t = Independent samples t-test statistic value, Cohen's d = Effect size, p = significance level, w=Welch's t test

When the results of the post-test total mean scores of the children in the experimental and control groups of the study in Table 2 are analysed, it was determined that the mean post-test score of the students in the control group (6.42 ± 1.92) was statistically significant and lower than the mean score of the students in the experimental group (9.79 ± 3.14) (t = -3.99, p < 0.01, Cohen's d = 1.29, large effect size).

Within the scope of the third research question of the study, the differences in the pre-test and post-test total mean scores of the students in the experimental groups obtained from the *Preschool Pattern Skills Test* were evaluated with paired samples t-test statistics, and the results obtained are presented in Table 3.

Table 3. Paired Samples t-test Results of the Experimental Group Students' Pre-test and Post-test Total Mean Scores

Time	Mean	Sd	t	p	rho	Cohen's d
Pre-test	6.89	3.75	-6.50	0.00	0.86	0.80
Post-test	9.79	3.14				

Note: Sd = Standard deviation, t = Paired samples t-test statistic value, Cohen's d = Effect size, rho = pre-test-post-test correlation coefficient

When Table 3 is examined, it can be seen that mean post-test score of the students in the experimental group was 9.79 ($Sd = 3.14$) and the mean pre-test score was 6.89 ($Sd = 3.75$). The comparison results of the pre-test and post-test mean scores of the experimental group revealed that the post-test scores were statistically significant and higher ($t = -6.50$, $p < 0.01$, Cohen's $d = 0.80$, large effect size).

Fourth research question of the study, the differences in the pre-test and post-test total mean scores of the students in the control group obtained from the *Preschool Pattern Skills Test* were evaluated with paired samples t-test statistics, and the results are presented in Table 4.

Table 4. Paired Samples t-test Results for Control Group Students' Pre-test and Post-Test Total Mean Scores

Time	Mean	Sd	t	p	rho	Cohen's d
Pre-test	6.16	2.34	-0.61	0.55	0.63	0.12
Post-test	6.42	1.92				

Note: Sd = Standard deviation, t = Paired samples t-test statistic value, Cohen's d = Effect size, rho = pre-test-post-test correlation coefficient

When the pre-test and post-test total mean scores of the preschool children in the control group in Table 4 are examined, it was that the post-test mean score is 6.42 ($Sd = 1.92$) and the pre-test mean score is 6.16 ($Sd = 2.34$). No statistically significant difference was observed based on the results of the comparison between the pre-test and post-test mean scores of the children in the control group ($t = -0.61$, $p > 0.05$, Cohen's $d = 0.12$, negligible effect size).

Within the scope of the fifth research question of the study, in order to examine the effect of Ze^2 VAS on the pattern skills of preschool children, the difference of post-test scores on the basis of groups (control and experimental) was examined by treating the students' pre-test scores as a covariate. In other words, while controlling for pre-test scores, the post-test scores of the experimental group—subjected to the Ze^2 VAS—were compared with those of the control group to determine the relative effectiveness of the intervention. In this context, first, descriptive statistics of the covariate-adjusted post-test mean pattern scores of the children in the experimental and control groups are presented in Table 5.

Table 5. Mean Scores of Experimental and Control Group Children in the Post-test with Covariate Control After the Educational Intervention

Group	Mean	Se	95% CIs
Experiment (n=19)	9.55	0.37	8.79-10.30
Control (n=19)	6.66	0.37	5.91-7.42

Note: Se: Standard error, 95% CIs = Lower Limit and Upper Limit at 95% Confidence Interval (LLCI-ULCI)

When Table 5 is examined, it is seen that the mean pattern skills score of the preschool children who received the Ze^2 VAS after the training intervention was 9.55 ($Se = 0.37$), while the mean pattern skills score of the control group preschool children was 6.66 ($Se = 0.37$).

Within the scope of the fifth research question of the study, secondly, the effect of Ze^2 VAS implementation on students' pattern skills was tried to be determined using ANCOVA. However, in an experimental study, some specific assumptions must first be met in order to conduct ANCOVA model-based analysis. The ANCOVA assumptions tested in this study are as follows.

- Assumption of normality of standard residuals: It was tested using the Shapiro-Wilk test ($p > .05$). Relevant results are presented in the methodology section of the study.
- The assumption of homogeneity of variances between groups was tested using Levene's test. The obtained values $F_{(1.36)} = 0.00$, $p = 0.99$ (the results are presented in a table in the methodology section of the study) indicate the homogeneity of variances.
- The assumption of equality of regression slopes was tested. The results of the Interaction ANCOVA Model ($F_{(1,34)} = 2.85$, $p = .30$) for testing this assumption revealed that the data were suitable for ANCOVA analysis.

After meeting the ANCOVA assumptions in the study, the ANCOVA model evaluating the post-test scores controlled by the pre-test scores across groups is presented in Table 6.

Table 6. ANCOVA Model for the Evaluation of Post-test Scores Controlled by Pre-test Scores across Groups

Sources of Variation	Sum of Squares	df	Mean Squares	F	p	η_p^2
Pre-test score	153.19	1	153.19	59.18	0.00	0.63
Groups	77.80	1	77.80	30.05	0.00	0.46
Error	90.60	35	2.59			

Note: $R^2 = .742$ (Adjusted $R^2 = .728$), η_p^2 : Partial Eta Squared (effect size); df : Degrees of Freedom

When Table 6 is examined, statistically significant differences were observed between the groups in terms of the post-test mean scores obtained by the students, with their pre-test pattern skill scores controlled. Accordingly, the post-test score average of the students in the experimental group ($X = 9.55$, $Se = 0.37$) was found to be statistically significantly higher than the average of the students in the control group ($X = 6.66$, $Se = 0.37$) ($F_{(1,35)} = 30.05$, $p < 0.01$). When the effectiveness of the Ze^2 VAS applied to the experimental group was examined in terms of partial eta squared, 46% of the variance observed in the students' mean scores was associated with the attention set applied ($\eta_p^2 = 0.46$, large effect size).

Discussion

The study provides a comprehensive examination of the functionality of the Ze^2 VAS in teaching pattern skills to preschool children. The statistical analysis results related to the comparison of pre-test scores between the experimental and control groups in the first research question of the research indicate that the pattern skill scores of the experimental and control groups were similar before the implementation of the Ze^2 VAS. This result can be considered as the absence of a bias in the initial assignment of students to the experimental and control groups. In pre-test and post-test experimental studies with control groups, it is generally expected that there is no significant difference between the pre-test score averages of the experimental and control groups, suggesting that both groups have similar characteristics regarding the dependent variable prior to the intervention (Kaptan, 1998). Based on the findings obtained from the analyses conducted within the scope of the first research question of this study, it can be stated that the pattern skills of preschool children in both the experimental and control groups were similar before the application of the Ze^2 VAS.

The findings obtained within the scope of the second research question of the study indicate that the post-test pattern skill scores of the children in the experimental group were higher than those of the children in the control group, and this difference in score averages was found to be significant. According to the effect size corresponding to this difference, the score of a randomly selected student in the experimental group was higher than the score of any student in the control group by d = 1.29 standard deviations. Based on this finding, it may be suggested that the educational materials provided to children during free playtime while implementing the MoNE 2013 preschool program may be more effective in supporting the development of preschool children's pattern skills compared to the implementation of only the MoNE 2013 preschool education program. Similarly, several studies in the literature have reported findings consistent with this study, suggesting that programs incorporating enriched activities such as music, games, and drama in addition to the MoNE program may be effective in supporting pattern skills. For instance, in the study conducted by Günaydın et al. (2023), it was found that the use of music, games, and drama methods yielded more positive outcomes in teaching mathematical skills to preschool children compared to traditional instruction. Similarly, the study by Küsmüş (2023) reported that drama-based learning activities were associated with improvements in children's reversing skills. Additionally, Hayıroğlu's (2017) study suggested that play-based activities may be effective in supporting pattern skills. These findings in the literature appear to be consistent with the results of the present study.

Within the scope of the third research question of the study, the effect of the Ze^2 VAS on the pattern skills of children in the experimental group was examined by comparing the pattern skill scores of the children before (pre-test) and after (post-test) the application of the Ze^2 VAS. The results indicated that the pattern skill scores of the experimental group increased significantly after the application of the Ze^2 VAS. The effect size analysis revealed a substantial increase from pre- to post-test scores within the experimental group (d = 0.80). This finding suggests that the Ze^2 VAS may have a positive effect on children's pattern skills. There are studies in the literature examining the effects of different educational programs on the pattern skills of preschool children. In a study conducted by Hayıroğlu (2017), the impact of the play method on teaching pattern skills to children attending preschool education institutions was investigated. The study was conducted with 43 children, including 21 in the experimental group and 23 in the control group. The children in the experimental group participated in a play-based pattern skills program for three days a week over seven weeks. The research results indicated a significant increase in the second dimension of pattern skills, "completing the missing object in a pattern," and the third dimension, "creating an original pattern with objects," among the children in the experimental group compared to those in the control group. Considering that the Ze^2 VAS applied in the present study is also an educational material with play-based content, the findings of this study appear to be consistent with those reported by Hayıroğlu (2017).

The analyses conducted within the scope of the fourth research question of our study revealed that while there was a slight increase in the pattern skill scores of the students in the control group who continued their education in the routine MoNE Preschool Education Program without the application of the Ze^2 VAS, this increase was not statistically significant according to the comparison of the pre-test and post-test scores. The lack of a significant difference between the pre-test and post-test score averages for the pattern skills of the children in the control group suggests that the MoNE Preschool Education Program could potentially be further supported by additional applications to further promote children's pattern skills.

Within the scope of the fifth research question of the study, the pre-test scores of the experimental and control groups were checked, and the post-test scores were compared to determine the extent to which the increase observed in the post-test of the experimental group could be attributed to the application of the Ze^2 VAS. The effectiveness of the Ze^2 VAS applied to the experimental group was examined using the partial eta squared value, and it was found that 46% of the variance observed in the students' score averages was associated with the applied Ze^2 VAS. This finding suggests that the Ze^2 VAS may have significant effects on the development of pattern skills in preschool children. The positive change in pattern skills associated with the Ze^2 VAS is thought to possibly stem from its developmental content, its play-based structure that incorporates attention training, the presence of error control mechanisms, and the opportunity for students to work independently and progress at their own pace. To create patterns, it is believed that children must first possess skills such as matching, classifying, comparing, and ordering (Yıldırım-Hacıibrahimoğlu, 2019). Furthermore, it is believed that the Ze^2 VAS—designed as a material that incorporates real-time feedback capabilities and error-correction mechanisms—may have supported these positive changes by fostering metacognitive awareness and, through its structure that promotes active learning, providing opportunities for hands-on learning. It is assumed that Ze^2 VAS's potential success in developing pattern recognition skills aligns significantly with the "Algebra Standards" defined by the NCTM (2000) and that it can contribute to supporting key objectives outlined in the standards, such as analysing patterns, making generalizations, and understanding mathematical relationships. In this context, it can be said that Ze^2 VAS offers a notable opportunity for the development of early algebraic thinking skills—as emphasized in international standards—through the structured framework it provides to children.

The activities included in the Ze^2 VAS involve intensive matching, classifying, comparing, and ordering. Furthermore, in a study conducted by Yıldız and Akman (2022) on the methods used by preschool teachers to support pattern skills, it was found that teachers predominantly included large group activities in their planning and relied solely on repeating types of patterns in the process of teaching pattern skills. In contrast, the Ze^2 VAS applied to children in this study is an educational material designed for individual work, containing activities that encompass various aspects of pattern skills. It is considered that the opportunity for individual work and the diverse pattern content provided by the Ze^2 VAS might have contributed to the positive changes observed in pattern skills. Additionally, Sophian (2004) argues that children learn mathematical concepts more effectively by using manipulative materials. The fact that the Ze^2 VAS is an educational material that allows children to manipulate, play, and learn may have contributed to the positive development observed in pattern skills.

This study, which examines the effect of the Ze^2 VAS, an educational material designed to support pattern recognition skills in preschool children, should be evaluated in light of certain limitations. First, a primary consideration is that the experimental and control groups consisted of a limited number of participants (n=19). This sample size may limit the generalizability of the findings to broader preschool population. Future studies could utilize larger samples to further enhance the external validity of the results. Second, the children in the control group were attending the 2013 preschool education program. Given that the updated Early Childhood Education (ECE) and Maarif Model preschool education programs began to be implemented in Turkey in 2024, it would be beneficial for new studies to examine the effectiveness of the Ze^2 VAS in the context of these recent curriculum changes. Third, the study's findings are specific to children attending preschool education in Istanbul. This might suggest a need for caution when generalizing the results to children living in areas with different geographical and cultural characteristics.

Conclusion

The findings of the study are as follows. There is no significant difference in the pre-test comparisons of pattern skill scores the children in the experimental and control groups. This result suggests that both the experimental and control groups had similar characteristics in terms of pattern skills prior to the application of the Ze^2 VAS. The post-test scores of the children in the experimental group who received the Ze^2 VAS were significantly higher than their pre-test scores. This finding indicates that the Ze^2 VAS may be effective in the development of pattern skills in preschool children. Furthermore, post-test mean scores of the children in the experimental group were significantly higher than the post-test averages of the children in the control group. This finding suggests that the improvement in pattern skills among the children in the experimental group may be associated with the application of the Ze^2 VAS. No significant differences were found between the pre-test and post-test scores of the children in the control group. This finding suggests that there may be a need for additional support programs to supplement the MoNE preschool education program for the enhancement of pattern skills in preschool children. Comparisons of the post-test mean scores after controlling for the pre-test scores of the experimental and control groups indicate that the increase observed in the post-test of the experimental group may be related to the application of the Ze^2 VAS. Overall, the findings from the study suggest that the Ze^2 VAS may be effective in improving the pattern skills of preschool children.

Based on the research findings, several recommendations have been proposed. Programs with different content may be developed to support the development of pattern skills in preschool children, and their effectiveness may be examined. Longitudinal follow-up studies involving children from the experimental and control groups in the current study may be conducted to explore the potential long-term effects of the Ze^2 VAS. The effectiveness of the Ze^2 VAS may also be examined in disadvantaged groups. Similarly, its effectiveness may be evaluated within samples from private school settings. The potential impact of the Ze^2 VAS on various cognitive skills of preschool children may be investigated. Further research may be designed to compare the effectiveness of the Ze^2 VAS when applied at home by parents and when implemented at home by parents and in the classroom by teacher. In addition, in-service training programmes, face-to-face workshops, or online seminars may be provided to preschool teachers to enhance their knowledge of strategies to support pattern skills.

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Conflict of Interest: *The authors declare that they have no competing interests. Furthermore, there is no financial or personal relationship between the developers and sellers of the Ze^2 VAS and the authors.*

Informed Consent: *Informed consent was obtained from the legal guardians (parents) of all child participants included in the study. Furthermore, the necessary permissions were obtained from the institutions where the study was conducted, and verbal consent was obtained from the children.*

Data availability: *The data that support the findings of this study are available from the first author upon reasonable request.*
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