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«Nimble fingers» electronic application for the development of graphomotor skills in preschoolers: A randomized controlled trial in Kazakhstan

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Abstract

The initial analysis revealed that the main challenge for preschoolers was the lack of graphomotor skills, such as hand coordination when writing and drawing. Consequently, this research aims to investigate the efficacy of the «Nimble Fingers» application as an educational tool to enhance graphomotor abilities. Samples were prepared for a controlled study involving 90 children aged 4-6 years. Participants were randomly assigned to an experimental group (45 children) that completed learning activities using the electronic application, and a control group (45 children) who completed tasks on paper as usual. Before and after a two-week period, the level of graphomotor skills was assessed in both groups using the «Nimble Fingers» software. The results of the experiment indicated that the children in the experimental group demonstrated a significant improvement in graphomotor abilities compared to those in the control group. This suggests that the «Nimble Fingers» program may be an effective tool for enhancing graphomotor skills among preschoolers. The differences arose due to the use of the «Nimble Fingers» electronic application. Overall, the application has been shown to be effective in improving children's graphomotor skills, making it a valuable tool for their development.

Keywords: Development of fine motor skills, graphomotor skills, preschoolers, the «Nimble Fingers» electronic application.

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1. Introduction

In early childhood, the foundations of graphomotor skills are established, which are essential for the successful acquisition of writing, drawing, and other activities that require precise movement coordination. The development of these

abilities plays a crucial role in a child's learning and cognitive growth [1]. Therefore, it is essential for kindergarten educators and curriculum developers to implement strategies that enhance hand motor skills and movement coordination. Neglecting this process may lead to difficulties in later learning, underscoring the importance of effective methods for developing graphomotor abilities.

Graphomotor skills play a significant role in a child's cognitive development [2]. They not only help with hand coordination but also contribute to the development of essential skills such as logical thinking, analytical abilities, concentration, and problem-solving. In today's rapidly changing technological world, the ability to precisely and confidently manipulate one's hands is crucial for successful learning and adapting to new challenges. While knowledge is essential, it is equally important to cultivate ways of thinking that allow children to analyze, creatively approach problems, and make informed decisions [3]. Developing graphomotor skills through hands-on activities helps children lay a solid foundation for future learning and confidently assimilate new concepts.

The latest results of the International Student Assessment Program (PISA) 2024 have shown that Kazakhstan has performed poorly and is among the countries with the lowest educational achievement indicators [4]. Although the tests were conducted among 15-year-old schoolchildren, it can be assumed that their educational level was formed at an earlier age. This suggests that insufficient development of graphomotor skills in preschool may affect later education. Research has confirmed that predictors of academic success identified in preschool can determine academic achievement later on [5].

The initial analysis of kindergarten students revealed an insufficient development of graphomotor skills, which is largely due to ineffective teaching methods [6]. In particular, traditional approaches that involve passive learning of material without the active participation of the child and the use of digital tools give insufficient results. This indicates the need to introduce innovative methods aimed at increasing the motivation and participation of children in the educational process.

In early childhood, development takes place through specific operations; therefore, learning based on direct interaction with real objects, interesting visual materials, and modern technologies is the most effective approach. This method helps to form stable motivation and interest in developing graphomotor skills among children [7]. Children acquire new skills by actively interacting with their environment and using different materials and tools. Electronic applications play an important role in developing fine motor skills and hand coordination. However, their educational potential is often underestimated, and the understanding of their importance as a teaching method among teachers and practitioners in the preschool education system is unclear. This requires further study and the introduction of innovative approaches to the educational process.

The stimulus plays a significant role in the development of fine motor skills in preschool children. Kindergarten teachers need to take into account individual characteristics, cultural diversity, and the needs of different groups of children when designing effective e-learning programs [8]. Educators must be aware that managing the educational process involves multitasking, making quick decisions, and adapting to unexpected changes.

Graphomotor skills require gradual and consistent development, so meaningful learning through electronic applications should be a focus of preschool education. It's important to create an environment where children can naturally improve their hand coordination, fine motor skills, and confidence in graphical exercises.

In this case, educators should maintain a professional attitude, avoiding letting personal emotions influence the educational process. When working with young children, patience and understanding are essential, especially when planning and implementing playful learning activities. It's important not only to track children's progress but also to continuously improve our teaching skills, serving as role models for our students.

Traditional tasks on paper have significant benefits for the development of motor skills in children, but their use in modern education is decreasing due to the increasing popularity of digital learning apps. These apps may not be accessible to children in rural areas, who may lack access to technology [9].

However, traditional paper-based activities remain a valuable tool as they are easy to do and do not require any special technical equipment [10]. These activities, such as tracing, shading, connecting dots, and drawing patterns, help to develop hand coordination and fine motor skills, which are essential for developing basic graphomotor abilities needed for later writing skills [11].

Several recent studies have shown that learning through electronic applications can help develop graphomotor skills and increase children's motivation. Digital learning tools can make learning more fun and engaging by incorporating game elements and interactive activities that stimulate children's interest in reading [12].

In this study, we use the «Nimble Fingers» electronic application instead of traditional paper-based tasks. This application is designed to help develop hand coordination and fine motor skills in children. Accordingly, the most effective teaching methods for kindergarteners are game-based technologies that combine different approaches, materials, and methods to stimulate the child's senses.

The main purpose of this research is to investigate the effectiveness of the «Nimble Fingers» electronic application as an educational tool for developing graphomotor skills in preschool children. This method could also serve as an alternative approach to developing the basic skills necessary for mastering writing later on.

2. Literature Review

Educational electronic applications are considered to be a learning tool designed specifically for the development of children and the achievement of learning goals [13]. Research suggests that a learning game is any material or technology used in a game with educational value [14].

Electronic learning applications have several features that make them suitable for preschoolers. They are designed to support children's development, and can be used in different ways. These applications are safe and cater to the specific needs of young children, while also helping to achieve educational goals.

The «Nimble Fingers» app is an educational tool designed to help children develop their graphomotor skills. The app offers interactive exercises that focus on improving hand coordination and fine motor skills, as well as preparing children for writing. This makes it a valuable alternative to traditional pen and paper activities.

Teaching graphomotor skills in kindergarten helps to develop fine motor skills and coordination of movements, as well as readiness for writing by learning with electronic tools. Children learn new skills more effectively when they interact directly with objects, rather than just listening to explanations [15].

The «Nimble Fingers» electronic application was developed based on the principles of active learning. In this approach, children actively participate in the learning process through interactive tasks that require precision in finger and hand movements. Research by Sinvani et al. [16] has shown that the use of digital technologies can significantly enhance children's cognitive and motor skills.

It can be assumed that the «Nimble Fingers» app is an effective tool for developing fine motor skills in preschool children. The app provides exercises aimed at strengthening arm muscles and improving eye-hand coordination, as well as preparing children for writing. Therefore, educators should consider incorporating this modern digital learning tool into their curriculum, creating a variety of stimulating environments for children to develop their fine motor skills.

Teacher-student interaction is essential for the development of graphomotor skills in young children [17]. During the learning process, it is crucial to use materials that are accessible and easy to manipulate, as they promote the development of fine motor skills and hand coordination.

Digital technologies play a significant role in the development of young children. According to Akanova et al. [18], early learning should be based on active engagement with the environment and the use of available tools. Modern technology provides new opportunities for children's growth, making learning more interactive and engaging.

Chen Yiyi and Zihe Ding emphasize the importance of using digital tools in the comprehensive development of children, including cognitive, social, and emotional aspects [19]. These interactive applications, educational games, and multimedia resources help children learn new knowledge in a natural and spontaneous way.

The development of graphomotor skills can be enhanced through the use of digital tools. Applications that allow children to draw and perform movement coordination tasks can help them develop these skills. This combination of traditional methods and modern technologies can contribute to effective learning and prepare children for future educational challenges.

One of the most significant principles of brain functioning is to facilitate meaningful learning through practical activities, immersion in the real world, and active engagement with the environment [20]. Therefore, the ideal approach to teaching children is through hands-on experiences that engage their senses and promote deep learning.

As a cognitive theorist, Piaget believed that active interaction with the environment is crucial for children's cognitive development. Digital technologies can be a powerful tool to stimulate cognitive growth, as interactive educational platforms and applications allow children to explore, experiment, and learn through hands-on activities [21].

Modern preschool educational programs aim to develop children through technology by creating conditions for active learning, experimentation, and immersion in a cognitive environment. Research shows that using digital educational tools helps children become more active and develop cognitively. Additionally, repeated practice in a digital setting, such as through educational games and interactive activities, contributes to the development of sustainable skills and knowledge.

The use of digital technologies in kindergartens for the effective learning and development of children should be considered an important pedagogical practice, as they help children assimilate and reinforce new experiences.

Vygotsky's theory emphasizes the importance of tools in the learning process. The use of digital educational technologies in early childhood has a direct impact on children's cognitive abilities and academic achievement. Interactive apps, multimedia resources, and digital platforms become essential parts of the educational process, promoting active engagement and the development of cognitive skills in children.

3. Materials and Methods

The formation of primary graphomotor skills is essential, as it will form the basis for the future development of writing, drawing, and other fine motor skills. By developing these skills through hands-on activities in an engaging digital environment, children's interest in learning can be enhanced. The main aspects of learning graphomotor skills at preschool age include hand and finger coordination, mastering basic lines and shapes, controlling pressure and pencil direction, and developing hand-eye coordination. These elements should be tailored to the individual child's age and integrated into the digital learning process.

Important graphomotor skills in children begin to develop through their interaction with real-life objects of different shapes, sizes, and textures. By using drawing and writing tools like pencils, markers, and chalk, children learn to control their hand movements, develop hand-eye coordination, and learn the basics of writing.

According to Piaget, every child can successfully develop graphomotor skills if the activities they engage in arouse their interest and are appropriate for their age. These skills form the basis for experience, sensory perception, social interaction, and writing, which require a significant amount of time to master. Mastering graphomotor skills involves more than simply completing tasks on paper. Through practical exercises such as drawing, hatching, modeling, designing, and cutting, children develop these skills in a meaningful and exciting way. These activities make the learning process more engaging and help children better understand the importance of the skills they are acquiring.

The term "graphomotor skills" refers to basic skills related to hand and finger coordination necessary for activities such as drawing, writing, and other fine motor tasks. These skills involve movement control, pressure strength, line smoothness, shadowing, the ability to compete, and eye-hand coordination. The basic concepts of these skills are presented in Table 1.

Table 1.
Development of Early Graphomotor Skills in Children.

4-5 years	Developing hand coordination, the ability to hold a pencil correctly, drawing simple lines and shapes (circles, squares), and the beginning of hatching and shading.
5-6 years	Confident use of a pencil, drawing more complex shapes, connecting dots, hatching, trying to write letters and numbers, and developing smoothness of movement while writing.

To determine the level of graphomotor skills development, this study divides graphomotor skills into four main components that characterize the development of fine motor skills in children aged 4 to 6 years.

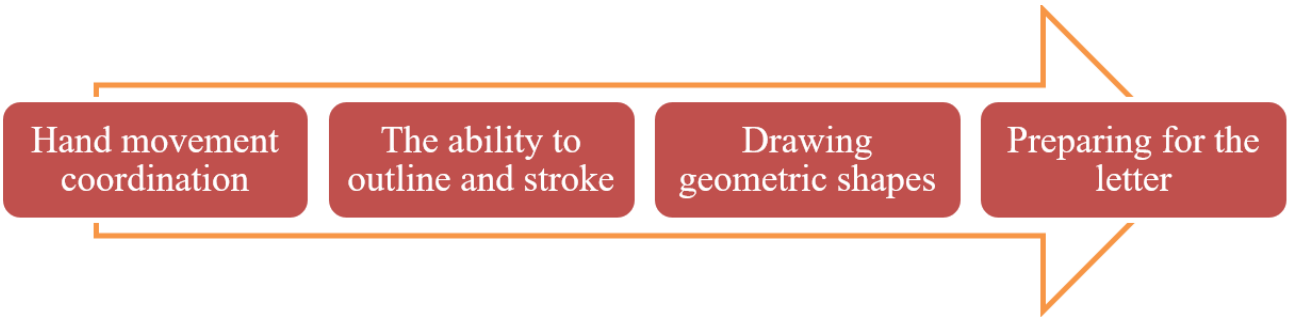

Figure 1.
Main components of graphomotor skills.

The evaluation of each component was carried out according to the following criteria, as presented in Table 2:

Table 2.
The following criteria of each component

Line-keeping accuracy	**It is estimated by the extent to which the line extends beyond the boundaries.**
Deviation from the set trajectory	The degree of deviation of the line from the specified path.
Number of lines (repeated attempts)	The number of times it takes to hit the trajectory.
The evenness of the lines	The smoothness and absence of sudden movements are evaluated.
Directional control (stability of movement)	The ability to keep a direction without frequent changes.
Smoothness of movements	The absence of sudden and shaky movements is assessed.
Screen/paper pressure monitoring	Stable pressing without sudden fluctuations.
Hand-eye coordination	The ability of the hand to follow a given direction.
Task completion rate	The time required to complete the task.
Holding the stylus/pencil	Correct grip and stable hand position.
Completion of the task	The degree of performance of work.
Writing letters	The clarity and recognizability of written characters.
Attention stability	The child's ability to maintain focus on performing graphomotor tasks without frequent distractions.

Based on Tables 1 and 2, graphomotor skills were divided into four main components and 13 criteria for their assessment. This study aims to examine the basic graphomotor skills of children aged 4-6 in relation to hand movement coordination, geometric shape drawing, and preparation for writing.

To evaluate graphomotor skills, the «Nimble Fingers» electronic application was used as a learning tool. The tasks included performing simple graphic elements (lines, shapes, letters) on the screen of the device and on a piece of paper during the study.

4. Results

The study was conducted among kindergarten students in Astana, Republic of Kazakhstan, with an average age of 4-6 years. Two groups of 90 students participated in this study (45 in the experimental group and 45 in the control group). These groups were divided into two conditions: an experimental group and a control group. Under the terms of the experimental condition, the children performed their learning activities on paper. In the control condition, children used the «Nimble Fingers» electronic application to perform their tasks.

This study defines the concept of graphomotor skills as the ability of children to perform precise and smooth hand movements during writing, drawing, and other graphic tasks. These skills include directional control, movement coordination, attention stability, and writing preparation. The development of these skills is especially important for children aged 4-6 years, since at this age the basic prerequisites for mastering writing are formed.

The graphomotor skills assessment included an evaluation of tasks where the children's skills were assessed using a number of criteria, such as line accuracy, smoothness of movement, pressure control, and hand-eye coordination. To assess the results, a 5-point scale heading was used for each criterion (see Table 2).

The same graphomotor indicators were used in preliminary and subsequent testing in the experimental and control groups, which made it possible to determine the effectiveness of the «Nimble Fingers» electronic learning application in developing skills for each age group.

The study included three stages: before testing, after implementation, and after testing. Before testing, the initial level of graphomotor skills was assessed in 90 children, divided into two groups of 45 each. The assessment was conducted separately by three educators and two researchers. During the implementation phase, participants were divided into a control and an experimental group. Children in the control group completed graphomotor tasks on paper under the supervision of a teacher, while those in the experimental group used «Nimble Fingers» as a learning tool. This lasted two weeks. One week after the intervention ended, post-testing took place to assess the effectiveness of the use of the electronic application in developing graphomotor skills.

Graphomotor skills were assessed using a 5-point scale based on 13 criteria. Statistical analysis was performed using Startech V. 4.8.0, and the normal distribution of the quantitative data was verified using the Shapiro-Wilk test.

Numerical indicators whose sample distributions corresponded to a normal distribution were characterized by arithmetic means (M) and standard deviations (SD), and for the mean values, confidence intervals were shown as representative measures.

In the absence of a normal distribution, quantitative data are characterized by the median (Me), lower and upper quartiles (Q1 - Q3).

When comparing normally distributed quantitative indicators calculated for two related samples, the paired t-test was used.

When comparing quantitative indicators that differ from normal distribution, the Wilcoxon test was used on two related groups. Differences were considered statistically significant if $p < 0.05$

Table 3.
Descriptive statistics of quantitative variables.

Control group (4-5 years) on a piece of paper, M ± SD	33.12 ± 8.19	29.74 – 36.50	25	16.00	46.00
Experimental group (4-5 years) on the «Nimble Fingers» electronic application, M ± SD	41.08 ± 7,54	37.97 – 44.19	25	29.00	54.00
Control group (5-6 years) on a piece of paper, Me	37.00	29.00 – 42,00	20	15.00	45.00
Experimental group (5-6 years) on the «Nimble Fingers» electronic application, M ± SD	39.85 ± 7.88	36.16 – 43.54	20	25.00	49.00

The dynamics of the 4–5-year-old group was analyzed.

Table 4.
Analysis of the Dynamics of the 4–5-year-old group.

Control group (4-5 years) on a piece of paper		**Experimental group (4-5 years) on the «Nimble Fingers» electronic application**		
M ± SD	95% CI	M ± SD	95% CI	
33.12 ± 8.19 (n=25)	29.74 – 36,50	41.08 ± 7.54 (n=25)	37.97 – 44.19	< 0.001*

Note: * – differences in indicators are statistically significant ($p < 0.05$)

During the analysis, a statistically significant change ($p < 0.001$) was observed in the 4–5-year-old group (paired Student t-test method used).

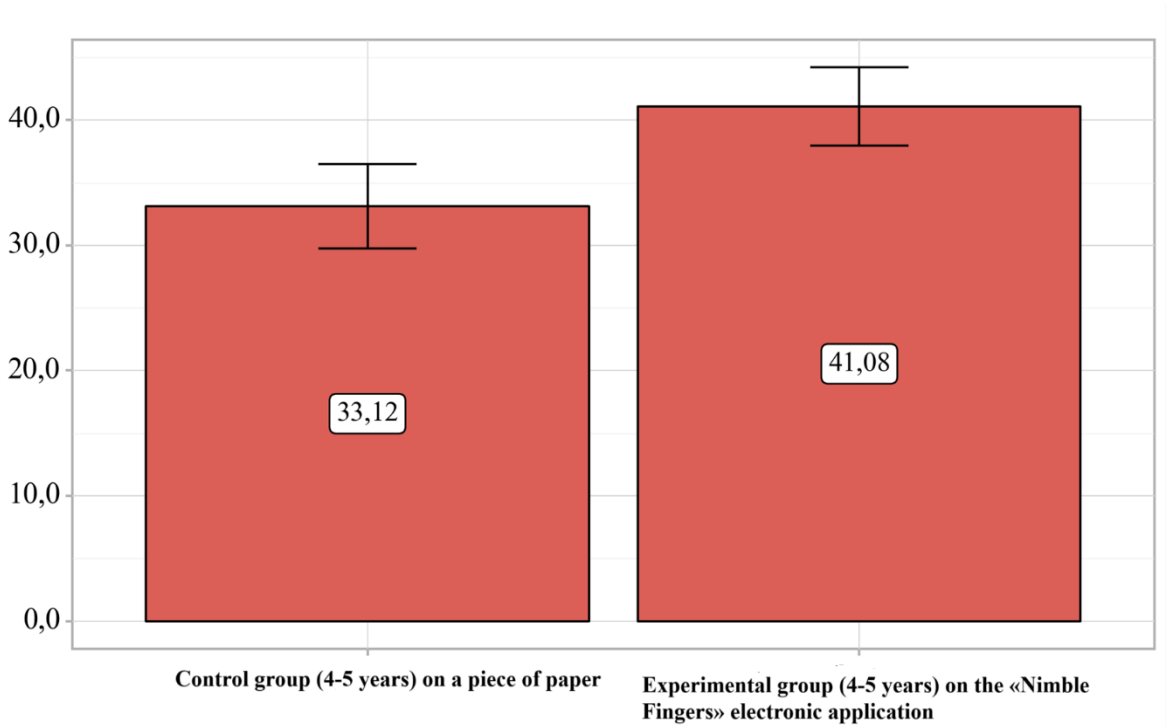

Figure 2.
Analysis of the dynamics over 4-5 years.

Next, the dynamics of the 5-6-year-old group were analyzed.

Table 5.
Analysis of the dynamics over 5-6 years

Control group (5-6 years) on a piece of paper		**Experimental group (5-6 years) on the «Nimble Fingers» electronic application**		
Me	$Q_1 – Q_3$	Me	$Q_1 – Q_3$	
37.00 (n=20)	29.00 – 42.00	42.00 (n=20)	33.75 – 46.50	< 0.001*

Note: * – differences in indicators are statistically significant (p <0.05).

The analysis showed that the 5-6-year-old group showed statistically significant changes ($p < 0.001$). (Method used: Wilcoxon test).

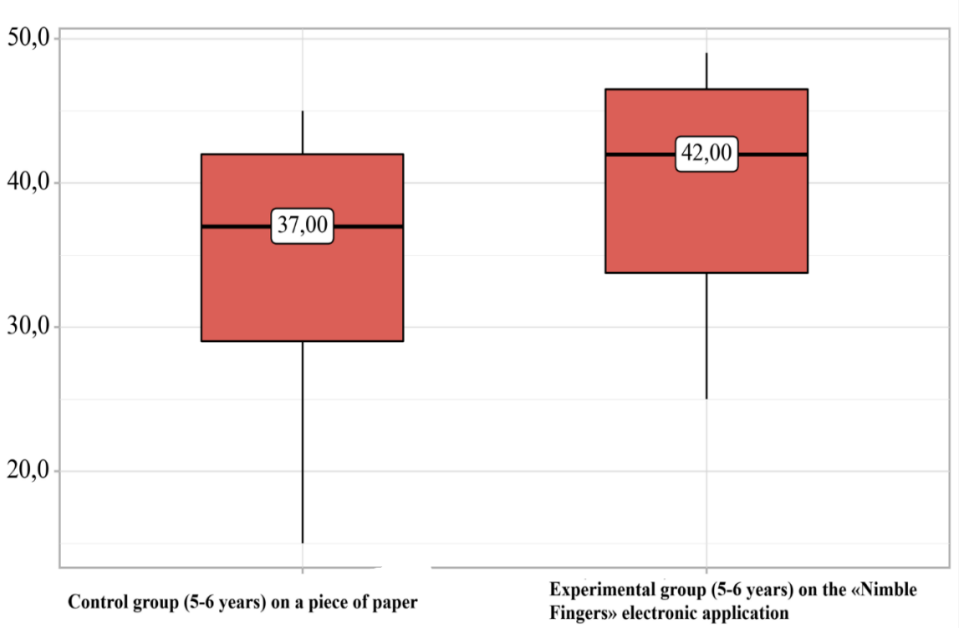

Figure 3.
Analysis of the dynamics of the 5–6-year group.

The results of the statistical analysis confirmed a significant improvement in graphomotor skills in children who used the «Nimble Fingers» electronic application compared to the traditional method of writing on paper. In both age groups (4-5 years and 5-6 years), there was increased line accuracy, smoothness of movement, control of pressure, and hand-eye coordination.

5. Discussion

The results of the study showed that there were no statistically significant differences in graphomotor skills between the control and experimental groups at the preliminary testing stage. However, analysis of data obtained during testing revealed a significant improvement in graphomotor abilities in children from the experimental group compared to those from the control group. This improvement is attributed to the use of «Nimble Fingers», an electronic application that contributes to the development of fine motor skills and hand-eye coordination.

According to the literature review, the development of graphomotor skills in preschool children is closely related to cognitive processes such as movement control, concentration, and visual coordination. The use of interactive learning applications improves the quality of motor control, increases the accuracy of hand movements, and reduces errors in the performance of graphomotor tasks. Digital tools provide rapid feedback, which promotes effective learning and the development of motor skills.

The use of interactive technologies has a significant impact on children's involvement and motivation, creating a digital educational environment that promotes the development of sustained attention, smooth movements, and coordination. As a result, knowledge and skills acquired through «Nimble Fingers» are better absorbed and retained over time, increasing the effectiveness of graphomotor skill formation in preschoolers.

In this context, the present study is consistent with international studies that show the importance of the active involvement of children in the educational process as a key factor in developing effective pedagogical methods for developing graphomotor skills in preschoolers. The results confirm previous studies that found that graphomotor exercises improve hand coordination, line accuracy, and attention stability when interactive and motivational elements are included. Using digital learning tools such as the «Nimble Fingers» app allows children to more effectively develop fine motor skills, as well as improve smoothness of movement and hand-eye coordination through various stimuli and interactive tasks.

Although the children in the control group showed only a slight improvement in graphomotor skills, the use of digital technologies in education played a key role in the development of fine motor skills and coordination of movements in children in the experimental group. Digital technologies are becoming an integral part of the learning process and contribute to creating an accessible and stimulating environment. Various forms of digital educational resources, including interactive apps, tablets, and touch technologies, have a significant impact on the development of writing, drawing, and spatial coordination skills in preschoolers. In modern conditions, education provides equal opportunities for mastering basic skills through both traditional and interactive approaches. The use of the «Nimble Fingers» electronic application in the study showed that digital technologies not only increase motivation to learn but also increase the stability of attention necessary for performing tasks related to movement control and drawing smooth lines. The use of interactive learning tools contributes to the more effective development of graphomotor skills, which is supported by modern research on digital learning.

In addition, this study showed that teachers' knowledge and understanding of graphomotor skills development has a significant impact on their teaching experience. Teachers with a deep knowledge of the importance of graphomotor development develop and apply more effective methodological approaches, adapt educational technologies, and use innovative tools such as «Nimble Fingers», an electronic application, to improve the quality of learning. Insufficient knowledge about the significance of graphomotor abilities can lead to decreased effectiveness in teaching. This finding confirms research that teacher education and attitudes directly affect teachers' ability to organize educational processes.

The results showed that the impact of the «Nimble Fingers» electronic app on the development of graphomotor skills in children was significant. Previous research has found that digital educational technology can be an effective tool for improving fine motor skills and hand-eye coordination.

Modern research also shows that the use of interactive tools stimulates natural learning mechanisms, helping children master the basics of writing and drawing using digital interfaces. Lai also argued that traditional (non-digital) methods can promote the development of cognitive skills in preschoolers. However, unlike analog methods, digital educational games such as «Nimble Fingers» provide interactive feedback, task adaptation, and the possibility of multiple actions, making the learning process more flexible and efficient.

6. Conclusion

In conclusion, the study showed that the use of the «Nimble Fingers» electronic application has significant potential and contributes to the development of graphomotor skills in preschool children (4-6 years old). The digital approach can be an innovative method that improves hand-eye coordination, motor skills, and spatial perception, which in turn has a positive effect on learning writing and other cognitive skills. Future research may require examining the impact of e-learning on the development of other key skills such as hand-eye coordination and tactile perception.

The study confirmed the importance of teachers' knowledge and pedagogical approach to the successful implementation of digital learning technologies. Teachers with a deep knowledge of graphomotor development and methods for its improvement demonstrate a high-quality approach to teaching by developing adapted educational strategies. The use of modern digital tools, such as «Nimble Fingers», not only enhances the learning experience but also increases the interest and motivation of children.

In addition, the study emphasizes the importance of a teacher's creative approach to using digital technologies. Preschool children are at a stage of clear thinking, so learning tools should be visual, interactive, and as accessible as possible. Electronic educational resources developed with age characteristics in mind can harmoniously integrate into the learning process and create an effective learning environment that promotes graphomotor skill development and prepares children for future education.

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