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MODERN VISUALLY EFFECTIVE TOOLS FOR BUILDING QUANTITATIVE CONCEPTS IN KINDERGARTEN CHILDREN

Maria Petrova Temnikova
Faculty of Education, Trakia University, Stara Zagora, Bulgaria
mariya.temnikova@trakia-uni.bg

Abstract

Digitalization and the rapid development of information and communication technologies over the past decades have significantly changed social life and the conditions in which preschool education is carried out. By using different aids for visualization in teaching, the contradiction between the abstract nature of mathematical concepts that children learn in kindergarten and their concrete-active and visual-imaginative thinking is overcome. The modernization of education in mathematics in kindergarten is related not only to the application of innovative technologies and approaches but also to the contemporary tools that are used. The problem of selecting them and using them adequately in methodological work exists and is significant.

The aim of the research work is to analyze and systematize theoretical concepts related to modern visual-active tools and to develop and test methodological options for their application in building quantitative understanding in children in kindergarten. The empirical study was conducted with 128 children from a kindergarten in the town of Stara Zagora. The obtained results show that the use of modern visual-active tools supports the development of children's knowledge and skills regarding the quantitative and ordinal value of numbers up to 10, the

formation and comparison of sets through the relations "as many as," "more," "less," the subtraction or addition of 1 or 2 elements from a given set, and the modeling of numbers up to 10. The new educational paradigm requires the application of modern visual-active tools in preschool education in mathematics, which contributes to improving the level of knowledge and skills of children in the educational Cluster "Quantitative Relations," as well as their interest, activity, and motivation.

Keywords:

Modern Visual-Active Tools, Education in Mathematics, Touchscreen Devices, Interactive Learning, Kindergarten

1. Introduction and Theoretical Framework

The development of modern technologies has brought educational resources, particularly purposefully designed and electronic materials, to the forefront as some of the most influential tools of globalization and social transformation. These resources have a significant impact on the teaching and learning processes in kindergarten, creating new opportunities to enhance pedagogical effectiveness. Technological innovations, encompassing both networked and non-networked, projected and non-projected, as well as visual, auditory, and audiovisual electronic materials, represent key milestones in the development of knowledge transfer mechanisms and provide multimodal support for learners in various educational contexts.

The advancement of information technologies, artificial intelligence, innovations in the digital world, as well as the rapidly changing social and personal needs, determine the necessity for new approaches in education (Nedeva, 2025). These changes require a profound reconsideration of the existing teaching and learning paradigms, especially in the field of early education in mathematics. The traditional transmission model, based on one-way knowledge transfer from teacher to student (Harrell & Bynum, 2018), is increasingly viewed as inadequate for the needs of the modern learner and the context of the globalized information society. Integration of contemporary digital tools and innovative educational practices help to develop key 21st-century competencies such as critical thinking, creativity, digital literacy, and the ability to learn adaptively in a dynamic environment. (Nedeva, 2025)

The educational environment for mathematics in early childhood plays an important role in the child's long-term success (Prusinski et al., 2023). The visual-active tools are part of this environment and are essential for the effectiveness of the education in mathematics. Their selection and application are determined by the abstract nature of the mathematical knowledge that children learn in kindergarten. The significance of visualization as a tool for mathematical thinking and learning has been discussed by Bishop (Bishop, 1973) and Presmeg (Presmeg, 1986).

Arcavi (Arcavi, 2003, p. 217) offers the following definition of visualization: "the process and the product of creating, interpreting, using, and reflecting upon pictures, images, diagrams—whether mentally, on paper, or with technological tools—to depict and communicate information, thinking about and developing previously unknown ideas, and advancing understanding."

Visualization can be carried out in three ways: as graphs or shapes, animations, and computer software programs (Dundar, Gökkurt & Soylu, 2012); (İpek, 2003).

In preschool education, visualization plays an important role in teaching and learning (Van Meter & Garner, 2005). The external visualization during teaching and learning mathematics facilitates the achievement of educational goals such as understanding and solving mathematical tasks, mastering concepts related to numbers and operations with them, and more. In the context of mathematics, J. Schoenherr and St. Schukajlow inductively identify the key characteristics of external visualization. (Schoenherr & Schukajlow, 2024).

According to Goldin and Kaput, internal visual representations are mental, cognitive concepts or configurations formed by children, while external visualizations are physically embodied and observable from the outside. In the process of interacting with external visual representations, children engage in complex bidirectional cognitive processes that involve the transfer and integration between internal mental models and external representational forms (Goldin & Kaput, 1996).

In their study, Sambasivarao et al. define the following types of teaching aids and materials: “projected and electronic materials, non-projected materials, and phenomenal and manipulative materials” (Sambasivarao et al., 2023, p. 153).

Many of the modern visual and maniulative tools are touchscreen devices. Some studies by Mattoon et al. (Mattoon et al., 2015), Herodotou (Herodotou, 2018), González-González et al. (González-González et al., 2019), Hsin et al. (Hsin et al., 2014), and others reveal the potential of touchscreen devices to enhance the level of knowledge and skills in education in kindergarten when used appropriately.

The lightweight design and tactile-based digital interface of touchscreen screens enable even very young children to interactively engage with digital content (Plowman et al., 2012).

Touchscreen devices provide unique opportunities for learning through physical experience and/or actions by enabling sensorimotor interactions and physical manipulation of the elements displayed on the screen (Wang et al., 2016).

As the article explores the development of quantitative concepts among kindergarten children, the below presentation focuses on certain aspects of this process.

Laying a solid foundation for mathematical knowledge in kindergarten is crucial for children's mathematical development (Claessens & Engels, 2013); (Garon-Carrier et al., 2018); (Rittle-Johnson et al., 2017). Quantitative knowledge and skills are identified as important factors influencing mathematics achievement in later grades (Chu et al., 2018); (Garon-Carrier et al., 2018); (Hawes et al., 2019).

“Forming mathematical competencies, specifically the development of elementary quantitative understanding in the children, can be defined as a fundamental activity in the process of pedagogical interaction, conditioned by the specifics of preschool education in mathematics in unity with the stimulation and activation of proper speech.” (Angelova, 2023, p. 51)

The numerical competencies and skills in kindergarten consist of knowledge about numbers, relationships between numbers, and operational knowledge (Jordan et al., 2009); (Jordan et al., 2010); (Powell & Fuchs, 2010). Arithmetic operations with numbers include knowledge and skills for addition and subtraction of objects, as well as solving mathematical tasks involving orally described situations and numbers (Jordan et al., 2009); (Jordan et al., 2010).

Regarding the impact on the education in mathematics when touchscreen is used by the children compared to traditional methods, the following skills have been studied: counting and sorting skills (Brown & Harmon, 2013); (Outhwaite et al., 2019), computational skills (Disney et al., 2019), number-object correspondence and quantity comparison (Schacter & Jo, 2016), and addition and subtraction (Outhwaite et al., 2019).

The aim of the research work is to systematize and analyze theoretical concepts related to modern visual-active tools, to build and test a methodological system of work in which they are used for developing quantitative visualizations in children during their education in mathematics in kindergarten.

The object of research is the process of teaching mathematics in grades 1-4 of kindergarten.

The subject of research is the influence of the newly developed methodological system of work, in which modern visual-active tools are applied, on the level of quantitative visualizations of the children in groups 1-4 of the kindergarten.

The first stage of the research work examined what visual and action tools the preschool teachers use to facilitate pedagogical interaction during mathematics classes in kindergarten. For this purpose, a Quetionarre survey was conducted, which found that teachers most often use the following visual aids to develop quantitative understanding: PowerPoint presentations; electronic versions of educational books approved by the Ministry of Education and Science, interactive whiteboards, and traditional media, images of real objects from the surrounding world and substitutive objects - plastic sticks, abacus balls, etc.

2. Methodology

At the second stage, a methodological system of work was developed and applied, in which modern visual and action means of visualization are used for building quantitative ideas in the children from groups 1.- 4. of kindergarten.

The paragraphs below present some aspects of it. In the age group 1 of kindergarten, in addition to the visual-active tools listed above, another modern tool has been used and namely the Wingsys interactive tables, which can also be used for STEAM activities.

For the situation in mathematics, 6 desks are provided for 24 children at a time, divided into teams of 4 children each.

A counting application (game), "How many hazelnuts are there?" is installed. Audio and visual effects are provided - animations of 3 moving squirrels and 3 falling hazelnuts. They maintain attention, stimulate positive emotions, and through **multisensory perception, multimodal learning** is realized simultaneously through hearing, vision, and touch. The children are motivated to work through a theatrical sketch about forest animals preparing for hibernation. The discussion method is applied in the methodological work where a task for counting squirrels is solved and children found that the number is 3.

Also, the teacher uses the interactive whiteboard and applies the set-theoretic approach, the demonstration and observation methods, and updates the children's knowledge and skills about the techniques of imposition and application, through which objects are broken down into two sets and consequently compared. The board depicts 3 bears and 3 pears. Under the guidance of the teacher, the children form 2 symmetrically arranged columns from the 2 sets by sliding their elements. First, the imposition technique is applied, and again, by sliding on the whiteboard, the pears are moved and placed in the paws of the bears. Next, the application technique is used, whereby the apples are slid and placed next to the bears. To form children's ideas about the number 3, the Wingsys interactive table as modern visual and manipulative tool is used. Four children work on each board, performing a practical activity to compare two equal sets using the techniques of imposition and application, moving the hazelnuts and establishing that the number of squirrels is equal to the number of hazelnuts.

In group 2 of kindergarten, an interactive wall is used in the methodological system to build quantitative concepts in the children. The interactive wall uses animation to compare unequal sets – one with 4 objects (pears) and the other with 5 objects (bunnies). The children find out that there are more bunnies than pears, and there are fewer carrots than bunnies. The modeling method is applied, and the children are tasked to touch the numerical picture that

shows the number of elements in each of the sets. Children practically work at the interactive tables and solve similar tasks.

The methodological system of work in group 3 of kindergarten includes a task that requires the use of an interactive whiteboard. The purpose of this task is to demonstrate the techniques of subtraction and addition for equalizing the elements in two unequal sets. The children are divided into teams of 2 children, with the practical activity taking place on tablets. First, the children shall form two sets by classifying them according to one characteristic and then compare the number of their elements. They determine that 6 deer are more than 5 does. The children equalize their number first by applying the subtraction technique and by dragging, moving, and subtracting 1 deer from the set of deer. Then they apply the addition technique and by dragging, they add 1 doe into the set of does. The conversation method is applied, and it is established that deer and roe deer are equal.

In group 4, the children perceive addition as adding or as a union of two non-intersecting sets. In the methodological system of work, the teacher applies the set-theoretic approach and the methods of demonstration, observation, modeling, and discussion.

On the interactive wall depicting a forest clearing, 4 foxes are shown. By moving across the clearing,1 more fox is placed. The situation shall be discussed, and as a result, it will be determined how many foxes in total we have in the meadow as a result. Next, the children work with the tablets. Then the children shall be tasked to determine the number of eagles that have landed on the rock and to touch the digit that indicates their number. They shall add 1 more eagle and shall determine how many eagles have become in total. Finally, the children shall touch the digit that shows their total number.

3. Analysis of the Results

The empirical study involved 128 children from grades 1-4 of two kindergartens in the city of Stara Zagora, Republic of Bulgaria. Of these, 64 children were from the referent group and 64 children were from the control group. During the education in mathematics for the children from the experimental group, a methodological system of work was applied, in which modern visual-active tools have been used in combination with traditional ones for the purposes of forming an understanding of quantity. Such methodology system of work has not been applied on the children from the referent group such.

At the beginning of the empirical study, an entry diagnosis of the knowledge and the skills from the educational Cluster "Quantitative Relations" of the children from both groups was conducted. It was found that the number of representations created by the children from

both groups was approximately the same and there was no significant difference. All expected results for the children from group 3 have been achieved and the children can: count to ten in straight order; determine the order of an object in a row of five objects; determine the number of objects up to 5 and connect them with the corresponding digit of the number; arrange two sets depending on the number of objects in them (up to ten objects) and arrange the row of numbers up to 5.

At the end of the 2025 academic year, an exit assessment was conducted with the Group 4 children from both the experimental and control groups. The results are presented in the below chart.

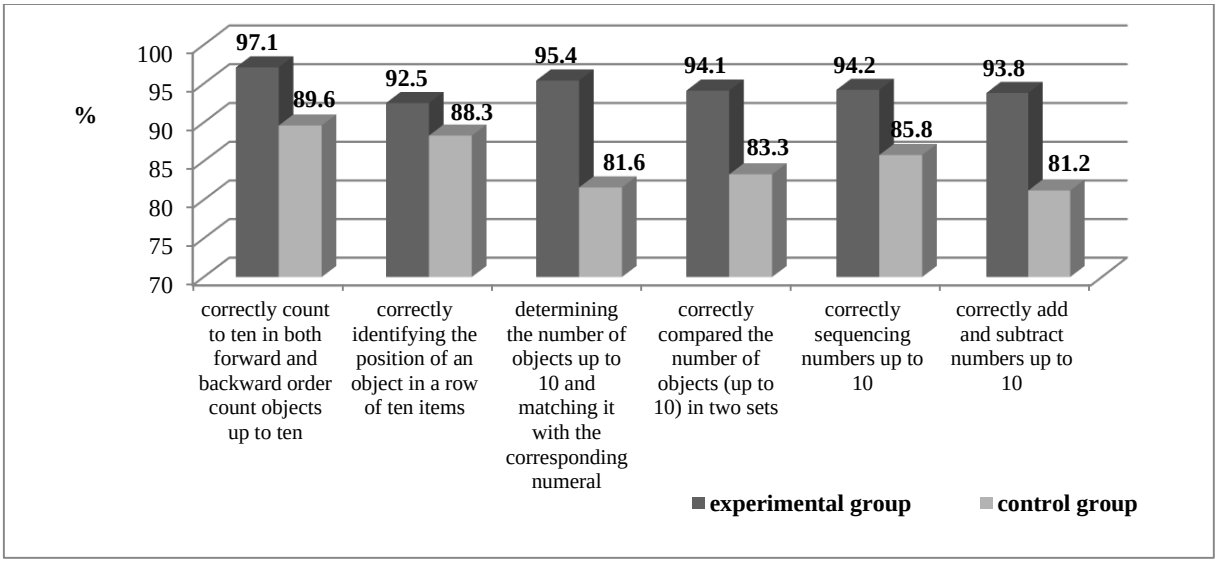

Figure 1: *Results regarding the quantitative concepts in children in Group 4 of kindergarten*

Data showed that 97.1% of the children in the experimental group could correctly count to ten in both forward and backward order and count objects up to ten, compared to 89.6% in the control group. The most common mistakes occurred during backward counting. Correctly identifying the position of an object in a row of ten items was achieved by 92.5% of the children in the experimental group and 88.3% in the control group. When determining the number of objects up to 10 and matching it with the corresponding numeral, 95.4% of the children in the experimental group and 81.6% in the control group performed correctly. 94.1% of the children in the experimental class correctly compared the number of objects (up to 10) in two sets, compared to 83.3% in the control group. Correctly sequencing numbers up to 10 was achieved by 94.2% of the children in the experimental class and 85.8% in the control group. Additionally, 93.8% of the children in the experimental group were able to correctly add and subtract numbers up to 10, while in the control group, this was achieved by 81.2%.

4. Conclusions

Based on the experimental study and the obtained results, the following conclusions can be drawn:

- The level of mathematical knowledge and skills in the children from the experimental group is higher compared to those from the control group, showing that the use of modern visual and manipulative tools helps to achieve higher outcomes.
- The use of modern visual-manipulative tools contributes to the creation of an educational environment that is aligned with the ongoing changes in education and the new learning paradigm.
- The application of contemporary visual-manipulative tools supports the development of quantitative concepts in children and increases their interest, motivation, and engagement in mathematics activities.
- At the present stage, visual aids (pictures, models, diagrams, maps, charts, projected images, animations, videos, PowerPoint presentations, slides, real objects, etc.) support children's understanding and memory, and stimulate their attention in mathematics activities in kindergarten by engaging additional senses.

5. Limitations and Recommendations for Future Research

A potential area for future research is the examination of the application of modern visual and hands-on aids in the pedagogical interaction in kindergarten, aimed at developing children's spatial and temporal concepts as well as their understanding of geometric figures.

Another aspect that should be explored is how these aids can be used to design creative and productive tasks for children in groups 1.-4. of kindergarten.

The limitations concern the organization of such studies in the first age group, due to the early age and the still undeveloped skills of 3–4-year-old children to work with information and communication technologies.

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