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RESEARCH ARTICLE

Teaching mathematics with mobile devices and the Realistic Mathematical Education (RME) approach in kindergarten

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Abstract: Nowadays, smart mobile devices such as tablets and accompanying applications (apps) are a part of young children's daily lives. In kindergarten education, properly designed digital educational activities can become a potent educational tool for efficient and effective learning. These tools allow children to take advantage of new learning platforms and effectively reach new knowledge through activities related to their immediate interests and real-life scenarios in learning domains, such as mathematics. At the Department of Preschool Education, University of Crete, systematic research was carried out in the last years to investigate whether there are compelling benefits to using tablet-type devices in preschool education to implement teaching reform proposals to implement the Realistic Mathematical Education in kindergarten classrooms. The findings propose mobile devices' integration, running developmentally appropriate apps, in kindergarten classrooms. These apps were based on the three levels of Realistic Mathematics Education (RME), targeting fundamental mathematical concepts for the kindergarten level.

Keywords: preschool education, realistic mathematics, mobile learning, apps

1 Introduction

The introduction of ICT (Information and Communication Technologies) in Preschool Education has been a point of debate and controversy among researchers for an extended period. Due to the highly dynamic introduction of computers in the educational reality among Western society and the influence of related research, a wide variety of ICT tools have become increasingly accepted as developmentally appropriate educational resources for preschool and primary school-age children (Druin & Fast, 2002; Plowman et al., 2010).

Decades of research have revealed that ICT can play an essential role in achieving the kindergarten curriculum goals in all areas and subjects (Hirsh et al., 2015) if the provided developmentally appropriate educational software are embedded in appropriate educational scenarios (Lee, 2009). In the classroom, ICT has been treated as a learning tool (Zaranis & Kalogiannakis, 2011) and a means for children to achieve familiarity with innovative technologies. There is also a tool of investigation, communication, and understanding across the curriculum's full range. Furthermore, due to the rapid technological advances, researchers have expanded the content of the term ICT to deal not only with the desktop and laptop computers but to include mobile technologies embedded in various devices such as e-toys, robotics, intelligent games, and especially smart mobile devices (Gjelaj, 2013).

Nowadays, digital media are a part of day-to-day life for children of all ages, and several researchers have proposed smart mobile devices for learning (Dias & Brito, 2021; Dorouka et al., 2021; Kalogiannakis et al., 2018). As these technologies play an increasingly prominent role in the lives of children worldwide, national ministries, organizations, and stakeholders are experimenting with the use of these devices for a wide range of alternative methods of teaching and learning aims. Since 2011 smart mobile devices such as smartphones and tablets are recognized as among the six new emerging technologies that may significantly impact teaching and learning in the educational sector (Johnson et al., 2011). There are multiple advantages concerning using these devices in the learning process, including stimulus, motivation, ease of use, availability, connectivity, among others (Kim et al., 2021). Smart mobile devices could become the new means of providing educational content to students (Furenes et al., 2021).

In the early years, mathematics education's importance has gained increasing attention worldwide (Lee & Pant, 2017; Moomaw, 2015). Significant changes in mathematics education in pre-kindergarten through first grade are strong predictors of future academic and economic success (Ryoo et al., 2014). Prior studies examining the longitudinal relations between number sense skills (e.g., counting, number knowledge, and number transformation) and later mathematics learning has shown promising results about the effect of these skills on elementary and middle school mathematics achievement (Aubrey & Dahl, 2014; Aunio & Niemivirta, 2010; Aunio et al., 2008).

The main purpose of this paper is to summarize the characteristics and effect of an ICT learning intervention in the context of mathematics in kindergarten education. The study wanted to understand whether computers and especially tablets, when combined with developmentally appropriate software based on Realistic Mathematical Education, could substantially contribute to early childhood students' comprehension of numbers.

2 Literature review

2.1 Children as "iLearners."

Two decades ago, Hertzog & Klein (2005) defined a distinct line between children and their parents' current generation. They very aptly reported that children do not need to adapt to the new technological society because they were born in it, unlike their parents, who have acquired their technological knowledge as somewhat of a foreign language at an advanced age. Young children have described as "digital natives" since they grow up in the digital world (Prensky, 2001) or "iLearners" as digital devices such as smartphones and tablet computers dominate their daily lives in Western societies from the age of 6 months (Prensky, 2010). Since 2012, Lavidas et al. (2012) pointed out that children surpass adults in their modern technological knowledge before attending kindergarten.

Since the era of computers, several studies have reported that digital media could introduce children to abstract concepts previously considered too advanced for their age (Lieberman et al., 2009a). In her research, Yelland (2005) had shown that activities entailing digital media within the school environment facilitate collaborative learning for young children and develop logical thinking while reinforcing their ability to solve problems. Additionally, in a study comparing learning at home and in the kindergarten classroom, Plowman et al. (2010) had reported that ICT promotes three main learning areas:

- The extension of knowledge about the world (cognitive objects).
- The acquisition of functional skills (such as the operation of the mouse).
- The development of the propensity for learning (by strengthening a range of emotional, social, and cognitive functions of learning).

Mobile devices fit perfectly in the lifestyle of young children as they do not need to sit at a table or an office to use the device, they do not need to manage a mouse, while the interface offered with a single touch on the touchscreen is irresistible (Papadakis & Kalogiannakis, 2017). Since the release of the iPad in 2010, Couse & Chen had stated the advantages of mobile devices with touch screens compared to typical computer applications controlled by a mouse (Couse & Chen, 2010). Children now use this technology at a younger age than ever (Papadakis et al., 2019).

2.2 Learning via mobile devices in kindergarten education

Sharples et al. (2007) define mobile learning as any learning in learning environments and areas that consider the mobility of technology, the mobility of learners, and the mobility of learning. Tablets can offer mobile applications' benefits in a broader context in all education levels, not only as an affordable solution for one-to-one learning but also as a feature-rich tool for work inside and outside the classroom. With their large and high-resolution screens and their advanced connectivity, tablets allow tablet users to easily share static and dynamic content such as images and videos. Most tablets have no phone features, making them ideal education tools since disruptive elements for the learners' attention, such as incoming text messages or unwanted calls present in phones and smartphones alike, are absent.

Technological analysts characterize the tablet as an ideal tool for all education levels. Since the first interventions with tablets in the classroom, researchers reported students' enthusiastic reactions to these new media. Students were eager to participate in learning activities due to the medium's novelty, visual characteristics, and ease of use. In all educational levels' tablets can be used to create text, audio, or even video notes, while learning can be achieved through students' active participation and interactive activities and animations. Additionally, the working environment's attractive appearance and the innovative touch interface are considered key learning facilitators for young children and students with learning disabilities. The characteristics of tablets, including lightweight, portability, touch screen, large icons, speakers, voice commands, zoom features, and cognitive simplicity, are some of the key advantages that make them an affordable and more than an efficient tool for the education of young children (Liu & Hwang, 2020).

Egan & Hengst (2012) showed that, even though educational software has been available for almost 30 years now, the educational community of kindergarten education initially resisted using computers to teach young children. Many educators, inspired by Piaget's theory of children's developmental stages, considered that young children need only physical activity and the ability to handle tangible objects to understand the various abstract concepts. However, since the mid-1990s, researchers found that virtual manipulations which are facilitated by computer software are similar to physical manipulations, and therefore, the use of ICT could effectively support the learning process, particularly in mathematics, and the educational development of children as a whole (Yelland (1998); Clements, 2000).

In the last decade, the use of ICT in young children's education and the development of educational software and relevant activities in preschool education had spread in many educational systems (Liu & Hwang, 2020). Research results point out the potential of ICT as a teaching tool and as a cognitive tool (Tavernier & Hu, 2020). Such results formulate an ordinary agreement on the educational policy and school practices that promote the rational integration of ICT in early childhood education (Nikolopoulou, 2020).

Based on the earlier research, mobile devices' integration into the preschool curricula aims to strengthen young learners' interest and enhance their participation and cooperation with their classmates and teachers (Rocha & Nunes, 2020). According to Lindahl & Folkesson (2012), this learning type attracts young students' interest and is considered an enjoyable experience and an attractive learning environment. Children learn more easily in positive and encouraging learning environments (Bourbour, 2020) that enhance student expression while helping children learn at their own pace. Smart learning environments can provide differentiated teaching to young learners, allowing them to be actively responsible for their learning while stimulating their brain's various areas, resulting in better intellectual development (Sysoev et al., 2017). Furthermore, tablets portability allows kindergarteners and their teachers to use various classroom locations, enabling the creativity and collaboration of small groups of students. Additionally, tablets' sophisticated user interface allows both individual interaction and, often, mutual interaction, depending on the application at hand, between two or more children (Wakefield & Smith, 2012).

Since the first tablet type device's first release in 2010, research findings correlate learning effectiveness through educational content delivery based on touch screen technology. Sandvik et al. (2012) point out that learning with tablets can occur in various everyday activities in the kindergarten, in a formal and informal context, inside and outside the classroom. McManis & Gunnewig (2012) reported that smart mobile devices and their accompanying applications could offer kindergarten children unique opportunities to participate in useful and targeted activities, individually or collectively, with their peers and kindergarten teachers. Chiong & Shuler (2010) study in the United States involving iPod touch devices and audiovisual material properly configured for children ages three to seven years old showed that children drew remarkable vocabulary gains phonological awareness. Bebell et al. (2012) study on kindergarten students selected randomly to use tablets for literacy study showed that infants who used tablets recorded remarkably strong performance in their phonological awareness and their ability to represent sounds with letters concerning other children that did not.

2.3 Digital mathematics activities and children

The research into using digital technologies in developmentally appropriate mathematics education methods is not new (Larkin & Calder, 2016). For over three decades, digital technologies have been part of mathematics educators' repertoire of tools, knowledge, and processes to enhance engagement and understanding in learning and teaching (Calder, 2015). Research that focuses on best practice in the incorporation of technology in Early Childhood Education (ECE) has shown the use of Information and Communication Technologies (ICT) can result in improvements to student engagement, motivation, persistence, curiosity, and attention even with preschoolers with concurrent risk for mathematics difficulties (Larkin, 2013; Moore et al., 2015; Orlando & Attard, 2016).

Digital technologies may transform the way mathematics could be taught and learned with the assimilation of the technologies to existing classroom practices. Although technologies open the possibility for meaningful mathematics, still, in many cases, technologies are used to substitute paper-and-pencil calculations or supplement graphing skills (Olive et al., 2010). The link between mathematical practices and mathematical knowledge is strengthened in didactical situations that involve effective uses of technology with the use of developmentally appropriate software. It has been suggested that within an appropriate pedagogical framework, the use of mobile technologies can make mathematics more meaningful, practical, and engaging (Bray & Tangney, 2016) as they provide children with an opportunity to learn and practice skills in an engaging and interactive environment (Chmiliar, 2017).

Digital activities are particularly effective when designed to examine a specific problem or teach a specific skill, encouraging learning in the thematic areas of the curriculum such as mathematics, natural sciences, and language where the specific goals can be determined and selectively developed within a context relevant to the learning activity and the specific target (Johnson et al., 2011). For children aged three to five years old, digital educational activities often focus on readiness skills for the kindergarten, including reading (letter recognition, letter formation, correlation of sounds and letters, simple spelling), mathematics (recognition of numbers, formation of numbers, counting, grouping), thinking and reasoning skills, perceptual skills, daily life skills (hygiene), social skills, creativity, and self –expression; as well as the understanding of concepts such as family relations, emotions, professions (Lieberman et al., 2009b). Lieberman et al. (2009b) distinguish the quality of digital learning activities in the following categories:

- Well-designed activities provide powerful interactive experiences that can enhance young children's learning, foster skills development, and promote healthy development.
- Poorly designed activities - simple, sedentary activities that contribute little to children's learning, skills development, or healthy development while potentially associated with obesity and poor physical condition.
- Very poorly designed activities - can potentially cause considerable damage to children either through strengthening the aggressive or antisocial behavior, approbating ethnic or transgender stereotypes, and promoting bad eating standards.

A finding of several studies in children three to six years old correlates the benefits of using digital activities in different sectors such as:

- Learning - Digital activities can provide multiple educational services to children. Comparative studies have suggested that well-designed educational activities potentially provide more motivation and encourage learning than traditional teaching methods (Swing & Anderson, 2008).
- Cognitive skills - Using digital activities, children learn cognitive skills through repetition, as relevant studies have found improvements in operating memory, spatial ability, visual attention (Thorell et al., 2009).
- Social interaction - In preschool education, young children often engage in cooperative social interaction when playing digital activities (Christie & Johnson, 2009).

Suppose materials for play and learning (including digital activities) are designed to indulge the interests and abilities of children, as well as their instinct to learn. In that case, students are more likely to develop and strengthen their initiative, attention, industriousness, and love for learning (Kalogiannakis & Papadakis, 2020). However, not all digital activities are developmentally appropriate or meticulously designed to enhance the procedure according to which young children play and learn (Hirsh et al., 2015).

While much of the available literature on digital technologies in ECE focuses on the role and use of computers by young children (Nikolopoulou & Gialamas, 2013), during the past few years, there has been an increase in research and descriptive literature about the use of other kinds of ICT focusing on the rising popularity of smart mobile technologies and mobile applications (apps) (Papadakis, 2020a).

The intuitive nature of mobile touch screen tablet devices reduces the mental and spatial demands needed to use and navigate the device (Papadakis & Kalogiannakis, 2017). These devices allow incredibly young children to interactively engage intuitively with actions as simple as touching, swiping, and pinching (Lovato & Waxman, 2016). The iPad and other tablets are viewed as tools that increase student learning and achievement due to their multi-sensor properties and various accompanying applications (Dittert et al., 2021). The touch and swipe actions needed for touchscreen tablets remove the complex spatial knowledge required to associate actions with the mouse or keyboard to the screen's actions. These reduced cognitive demands should increase attention to content and promote greater and more immediate learning with mobile tablet devices than desktop computers. There are five specific affordances or benefits associated with the use of tablets, such as portability, affordable and ubiquitous access, situated just-in-time learning opportunities, connection, and convergence, individualized and personalized experiences (Kalogiannakis & Papadakis, 2020).

3 Realistic mathematics

The foundations of children's mathematical thinking derive in the early years of their life. They gradually acquire their first experiences with time and space, then with basic mathematical processes (measurement, calculation, sorting, and comparison) (Gadzichowski, 2012). Research findings prove logical principles for counting from the age of three years old children (Gelman & Meck, 1983). Other researchers indicate that numbers and numerical phenomena spark children's intense interest from an early age. Mathematics in preschool education is approached as a foundation that will help children learn about the world around them and adapt to this world (Tzekaki, 2007). Egan & Hengst (2012) report that a large body of research shows that kindergarten time is crucial for children to develop fundamental numeric skills. In their research on the development of mathematical concepts in kindergarten, (Clements & Sarama, 2007) concluded that children's numerical abilities developing before they enter the first grade of primary school are the best predictors of their subsequent mathematical progress, more than other skills. When watching 200 students from kindergarten up to the third grade, Jordan et al., 2009 concluded that the conquest of mathematical concepts in kindergarten is positively correlated with high mathematical achievement performance at the end of the third grade.

Consequently, the teaching of mathematical concepts in kindergarten has a huge significance, as it aids children to acquire the necessary mental condition and the necessary cognitive foundation for the systematic learning of "real" mathematical concepts, later on, in primary school. Kindergarten aims to teach mathematics and initiate children thinking that characterizes mathematical science while providing a parallel realization of their social dimension.

For many years, the central theme for scientific debate was developing a comprehensive mathematical theory towards interpreting phenomena related to mathematics teaching and learning. Such a theory aimed to provide educators with the ability to help students understand mathematics as a subject and as a tool for solving everyday problems. Over the last few years and in the context of the above considerations, various reform proposals for mathematics teaching have been developed internationally, posing their focus on the problem-solving procedure. One of these proposals is the Realistic Mathematical Education (RME) developed in the Netherlands and supported the view that the same phenomena through which the mathematical concepts get content should be used as a basis for a teaching process that aims to impart these concepts (Freudenthal, 1983).

According to Freudenthal (1983), mathematics is a human activity, and therefore it must be a human value, close to reality, close to children, and have a relationship with society. The central idea of Realistic Mathematical Education is when saying, "I know math" really means "I know how to do math" (Streefland, 1991). The student can easily manage the mathematical language and solve and construct problems and recognize mathematical concepts within specific situations. The term "Realistic Mathematics" refers to mathematics, which relates to problems of the real world as well as to phenomena, which appear in our daily life (De Lange, 1996). This form of mathematical education is characterized as "realistic" because it relates to the real world, and special emphasis is given in situations where the students can envisage their imagination.

Digital learning media can contribute to the learning of mathematical concepts by young children. Aspects of early informal learning of mathematical concepts, such as enumeration, arithmetic problem solving, and spatial syllogism, along with general geometrical knowledge, are developed dramatically during the preschool age. Through the years, digital technologies and accompanying software that teach early learning of mathematical concepts have received considerable attention from the scientific community (Lieberman et al., 2009a). In the last decades, mathematics-related software in preschool children's leisure activities enhanced children's mathematical knowledge (Starkey et al., 2004). Jordan et al. (2009) reported in their study that young children could develop mathematical skills and relevant reasoning and thinking skills while using developmentally appropriate mathematical software.

4 Teaching realistic mathematics through mobile devices

In the Faculty of Education, Department of Preschool Education, University of Crete, systematic research investigated whether there are benefits to using tablet-type devices in preschool education to implement teaching reform proposals, such as Realistic Mathematical Education (RME). The research was carried out by creating developmentally appropriate educational applications (apps). These applications were intended to help preschoolers learn mathematics by following the principles of RME, focusing primarily on the existence of rich thematic frameworks associated with a child's experiences. For this reason, the digital applications were combined with group and individual activities without using a tablet, including board games, dice, activities with hidden objects. This digital application form was chosen because studies have shown that digital educational activities are appealing to the students' interest and are also considered a pleasurable pastime while establishing a new and attractive learning environment. Today's students are more likely to enjoy a learning experience embedded with digital activities because these games are based on the primordial form of learning, "play and learn," from which they derive their benefits as an educational tool (Papadakis & Kalogiannakis, 2020).

According to Van Den Heuvel-Panhuizen (2008), the knowledge of formal mathematical concepts may differ considerably from child to child when entering into kindergarten. To elaborate, some of these children are quite familiar with simple counting while other children are not. Likewise, the extent to which they can distinguish between the different meanings of numbers may vary. The understanding of resultative counting children has developed upon entering kindergarten differs significantly too. The somewhat unstable initial situation in which the children's different initial mathematical knowledge levels began at kindergarten could be described as the ground level. In general, an elementary numerical sense develops before and during preschool education in four general levels (Figure 1).

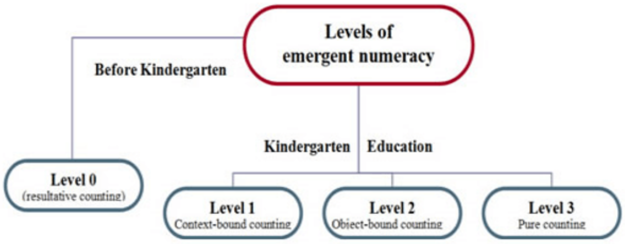

Figure 1 Levels of Realistic Education in kindergarten education

In addition to the pre-existing ground level, the three general levels that are developed during kindergarten education are as follows:

- First level - the level of context-bound counting and calculating simple addition and subtraction.
- Second level - the level of object-bound counting and calculating simple addition and subtraction problems where the objects are displayed and then hidden.
- Third level - the level of pure counting and calculating addition and subtraction using a missing variable.

The first level consists of context-bound situations in which pupils are instructed to count up to ten, organize numbers in the proper order, and make reasonable estimations or comparisons of numbers through concepts of more than, less than, or equal. Basic addition and subtraction problems are introduced at this level.

The relevant object-bound counting and calculating of the second level, which occurs in problem situations, focus directly on the quantitative aspect. In contrast to the first level, questions asking that the students count and say the number of given objects in a given scenario is presented and understood in the second level. This applies, however, only if the questions asked are associated with specific objects involving natural numbers. The second level also consists of activities in which pupils can choose a proper strategy for solving simple addition and subtraction problems in which the objects at hand are displayed for a brief period before they are hidden. The following are examples of level two questions: "How many pieces of candy are in the box? How many chairs are there? How many people are waiting in line? Which box has the most sweets? How many of the seven candles will remain lit if the wind blows out three?"

Finally, the third level consists of pure counting and calculating, questions using real numbers rather than objects, focusing on the aspect of a missing variable. For instance, "What will remain if you subtract three from seven?" By previously hiding objects after a brief period (second level), children were obliged to use their fingers or other representations for more complex tasks as the visual objects were being removed from the equation. This way, the enumeration is no longer dependent on the objects themselves and is instead put into perspective using physical or mental representations of these objects. These representations can occupy different abstract problems, including problems with addition and subtraction of real numbers and a missing variable.

As Van Den Heuvel-Panhuizen (2008) claims, this can occur by using a "birthday hat," but other possibilities, such as the kindergarten teacher asking the children to describe their age without using words. At the third level, children can represent the numbers one to ten using their fingers and using lines and dots. They are then able to use these skills for addition and subtraction activities. The use of numbers and the execution of the arithmetic operations used in the third level are not generally one of the kindergarten curriculum's targeted objectives, but there are usually children who can work at this level (Figure 2).

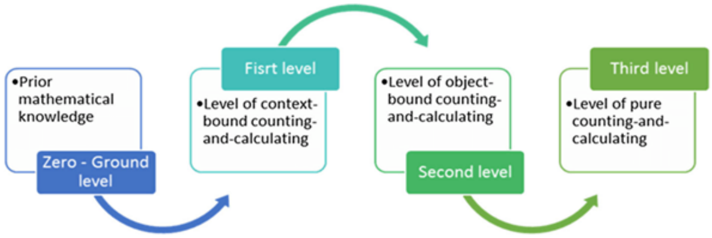

Figure 2 The four levels of basic number sense (Van den Heuvel-Panhuizen, 2008)

At the ground or zero level, students are instructed to use various portable applications. For example, in one of the applications, they have to place a certain number of chicks in their nest or count the number of animals that appear on the screen (Figure 3). Variables are randomized numbers from one to ten for each round.

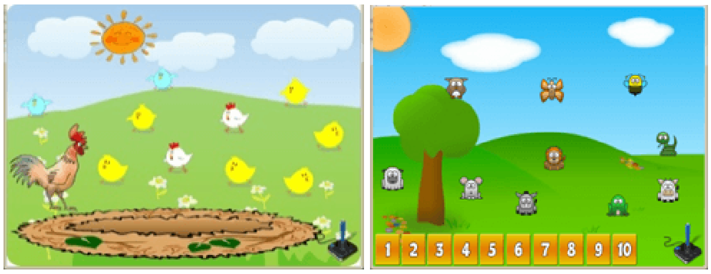

Figure 3 Examples of ground-level apps

The other tasks at hand are to help a climber pass over mountains, count each mountain on the way, and help a monkey down a ladder, counting each rung as it descends (Figure 4).

Figure 4 Examples of ground-level apps

At the first level, the children are expected to respond to questions such as, "How many of the apples in her basket can Helen buy with 5 euro if each fruit costs 1 euro?" Another example problem is, "Each child needs a ticket to enter the castle. How many children will not be able to enter?" (Figure 5).

At the second level, the children are asked to solve problems such as, "Place as many eggs as you would like in the fridge," after the choice is made, the eggs are concealed. "Helen took one egg from the fridge. How many eggs are left?" (Figure 6).

Finally, students have to answer more complex questions for the third level applications, such as, "Johnny has five pieces of candy. His uncle came and gave him some more candy.

Figure 5 Examples of first level portable applications

Figure 6 Example of a second-level portable applications

Now Johnny has eight pieces of candy. How many pieces of candy did his uncle give him?" Alternatively, in the case of subtraction, the children are told that a monkey has cut some bananas from the tree. Some of his animal friends suddenly appear and eat an unknown number of those bananas. The remaining bananas are displayed, and the children are asked to find the number of bananas that were eaten (Figure 7).

Figure 7 Examples of third level portable applications

The researchers designed 32 different digital games for computer (16) and tablet (16) use. A framework that connected the mathematical content with the tasks and children's activity (Tzekaki, 2014) orientated the design's digital activities. The main purpose of the software, which was game-based in nature, was to foster early childhood students' understanding of numbers. The different applications teach the following early mathematics skills: one-to-one counting, cardinal counting, numeral identification, number composition and decomposition, subitizing, matching numerals to collections, addition, and subtraction up to the number ten. The structure, plot, and script of the activities were similar for both types of digital applications.

Considering the categorization of Naismith et al. (2004), we can claim that the mobile applications we created follow either the behavioral or the constructivist teaching method from a pedagogical point of view. Some applications follow the behaviorist perspective by providing fast and immediate feedback while utilizing reinforcing learning elements like confirming an answer's correctness. Others utilize the constructivist perspective as they provide open-type learning experiences for the students. All applications provide feedback both in the case of error and the successful completion of an activity. This feedback is in both visual and audible form so that it is easily understandable by pupils. Simple feedback is provided through graphic characters (e.g., the appearance of a happy or sad face), while the narrator provides more complex feedback through an audio message (e.g., "Try again" or "Well done, you did it!").

The design process of the educational software had three main components:

- The research and development of the original applications before their implementation in kindergarten.

- The modification of the existing applications during the pilot test to respond more effectively to children and kindergarten educators' needs.
- The creation of new applications that meet the demands of preschool educators.

The produced software should have the following characteristics: a) It should be user-friendly so that children can easily handle it without any special assistance from an adult. b) It should not require any reading and writing knowledge for its use to be suitable for the preschool age. c) It should combine animation and sound. At the preschool age, sound is essential, as speaking is the only way to give children instructions.

5 Intervention description – results

This research's different aspects have already been described in four different papers (Papadakis et al., 2016a; Papadakis et al., 2016b; Papadakis et al., 2018; Zaranis et al., 2013). Thus, in this section, we summarize the main concepts of them. Participants were recruited from 21 early childhood classes (state or private) during the 2013–2014 school year, adapting a simple randomization approach (without taking stratification of prognostic variables into account) (Suresh, 2011). The sample was homogeneous in terms of demographics such as ethnicity and language. Only children who completed all two rounds of testing (pretest, posttest) were included in the final experimental sample (N =365 out of 450). Of the total sample of 365 children, 177 were boys (48.5%), and 188 were girls (51.5%). At the time of the first measurement (in autumn 2013), the children's mean age was five years (in months, M = 62.0, SD = 5.5).

The Test of Early Mathematics Ability - Third Edition (TEMA-3) as a pre-/post training mathematical achievement test was used in the present study to assess students' mathematical skills (Manolitsis et al., 2013). The TEMA-3 is a standardized achievement test, normed in the United States, designed to assess conceptual understanding and skills for children aged from 3:0 to 8:11 years (Ginsburg & Baroody, 2003). The latest version of this instrument consists of 72 items measuring children's informal and formal mathematics ability. To shorten the testing time, entry points, basals, and ceiling were used. The content domains tested by the TEMA-3 were numbering, number comparisons, calculation, concepts, numeral literacy, number facts, and calculation.

The research procedure consisted of two stages. The first stage lasted from January to October of 2013 and involved the pilot tests of digital educational applications and the adaptation and check of the TEMA-3 criterion in Greek settings. The pre-experimental procedure, which was common to all three groups, took place during November and December of the 2013–2014 school year. In this phase, children were asked to tackle questions and/or activities of the TEMA-3. The experimental interventions occurred over 14 weeks between January and April of the 2013–2014 school year, in which the sample was divided into three groups, the control and two experimental groups. Participants were randomly assigned to one of three groups. Children's regular mathematics classroom instruction was not interrupted by the study.

Trained undergraduate or graduate students, implemented the mathematical interventions. Twenty-four 30-min activities using computers and/or tablets were carried out in children's classrooms. In the first experimental group, computers with educational software were used to enhance the regular mathematics classroom instruction, while, in the second experimental group, the instruction was enriched with the use of software running on tablets. The educational software focused on key areas of early mathematics, such as number word sequence, enumeration, and basic addition and subtraction skills. Each device was pre-loaded with the necessary applications. The children in the control group had no added software aid. They received the school's form of 30-min research-based, hands-on mathematics instruction delivered by their classroom teachers in addition to their regular mathematics instruction period. The extra mathematics activities were designed to be exactly similar to those in the digital applications. The third and final phase of the research was carried out in May of the 2013–2014 school year. During this phase, each child was examined again in TEMA-3. The same examination procedure used in the pretest phase was also followed.

The pretest and post-test analysis revealed that the second experimental group students (tablets) were significantly better after the teaching intervention than those of the first experimental group students (computers) and the control group students. The tablet-based learning approach significantly impacted the students' learning outcomes - understanding of numbers. Accordingly, it was found that the first experimental group students' learning achievements were significantly better than those of the students in the control group. The experimental group's significantly better score than that of the control group suggests that the educational computer learning approach has improved the learning outcomes - thinking of students about the number. The third research question examined whether the experimental intervention's effect on children's mathematical ability performance is affected and thus differs by children's gender. The results revealed no significant differences due to the effect of gender in mathematical performance.

6 Discussion

The introduction of smart mobile devices in children's daily lives positively supports integrating digital applications in childhood education. There must be a positive continuum between the everyday life of children and their school life. Moreover, the school's specialized instruction must equip children with the necessary knowledge and skills for later life. The debate on using ICT in mathematical education is limited by and focused on the tool itself rather than on the appropriate introduction of activities and the specific problem situation to students. In contrast, the activities and applications that we have created refer to real-world problems and situations.

The present study findings indicate that the touchscreen has positive effects on learning. Furthermore, like other studies, these findings provide evidence that preschoolers can learn from interactive gaming experiences on touchscreen devices (Aladé et al., 2016). There is also evidence that supports the use of apps in learning programs and the contention that, if used appropriately, they enhance mathematical thinking (Calder, 2015) as well as a positive influence on both attitudes to mathematics learning and student motivation (Berkowitz et al., 2015) in both preschool and primary school settings. The current study also found a significant difference between the computer group scores and the control group. These results support the contention that performance on number tasks can be increased through training-based computers, emphasizing using developmentally appropriate software. These findings were consistent with previous research suggesting that when the mathematical activities in a school are meaningful and help children approach mathematical knowledge and discover mathematical concepts through various stimuli, this can effectively help them develop their mathematical ability. Furthermore, children's gender did not play a key role since we did not obtain statistically significant differences in mathematical performance between boys and girls, supporting other studies' results that in young children, gender differences in mathematical performance either do not exist or are very small.

Furthermore, children's low math performance internationally reflects the need for a different approach to teaching math concepts, distinct from the traditional approach to learning and teaching mathematics. Based on the systematic research that we conducted in the last years, we can support the idea that it would be interesting for kindergarten educators during mathematics teaching to emphasize creating a different learning environment. In more detail, the didactic approach, which is based on the principles of RME, the idea of building knowledge by the children themselves, is considered highly fruitful for teaching mathematics. As part of this approach, kindergartners can derive the most benefit from their informal mathematical knowledge and use it as a foundation for further mathematical development.

In conclusion, the present study supports the introduction in the kindergarten of a multimedia environment that provides early childhood students with the opportunity to be cognitively engaged in real-world contexts with multi-presentations, affecting their mathematical skills. The study reinforces that digital technologies can play a positive role in improving early mathematics skills. The use of mobile technologies in mathematics education can encourage meaningful student engagement with mathematics by embedding the subject in authentic contexts. Ideally, mobile technologies should be integrated into mathematics teaching and learning to create a new learning ecology. For this to happen, apps must be developmentally appropriate, applicable, and appealing. We suggest that enriched instruction digital materials should be designed so that learners from all performance levels are given good opportunities by combining computers and tablets.

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