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The effectiveness of computer and tablet assisted intervention in early childhood students' understanding of numbers. An empirical study conducted in Greece

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Abstract The present study aimed to assess the effect of two different types of digital technologies (computers and tablets) in early childhood students' understanding of numbers. Three hundred and sixty-five children (mean age in months, $M = 62.0$, $SD = 5.5$) from 21 kindergarten classes were randomly assigned to two intervention groups and a business-as-usual control group. The interventions were conducted over 24 half-hour lessons. Data was collected during the 2013–2014 school year using a three-step research procedure. Students' knowledge about numbers was assessed using the Test of Early Mathematics Ability-3 (TEMA-3). Findings were that (a) both experimental groups significantly outperformed the control group on the posttest, (b) the group that used tablet computers significantly outperformed the group that used personal computers on the posttest, and (c) there was no significant difference between genders on the posttest. Our findings support that computers and especially tablets, when combined with the use of developmentally appropriate software into the children's daily routines, may provide a substantial contribution to early childhood students' comprehension of numbers.

Keywords Curriculum and pedagogy · Media and technology · Quantitative research

1 Introduction

The importance of mathematics education in the early years has gained increasing attention worldwide (Lee and Pant 2017; Moomaw 2015) as evidence shows.

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Important changes in mathematics education in prekindergarten through first grade are strong predictors of future academic and economic success (Lee 2010; Ryoo et al. 2014; Schacter and Jo 2017). Prior studies examining the longitudinal relations between number sense skills (e.g., counting, number knowledge, and number transformation) and later mathematics learning have shown promising results about the effect of these skills on elementary and middle school mathematics achievement (Aubrey and Dahl 2014; Aunio and Niemivirta 2010; İvrendi 2016; Jordan et al. 2009).

The research into the use of digital technologies in developmentally appropriate ways in mathematics education is not new (Larkin and Calder 2016). For over three decades, digital technologies have been part of mathematics educators' repertoire of tools, knowledge, and processes used 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 the Information and Communication technologies (ICT) can result in improvements to student engagement, motivation, persistence, curiosity and attention (Clements 2002; Larkin 2013; Lieberman et al. 2009; Moore-Russo et al. 2015; Orlando and Attard 2016; Schacter and Jo 2017; Shamir et al. 2017b; Weiss et al. 2006) even with preschoolers with concurrent risk for mathematics difficulties (Bryant et al. 2008).

Technology no longer refers solely to computers (Moore-Russo et al. 2015). Touchscreen use has exploded over the last decade and children have also quite suddenly become early adopters and major consumers of touchscreen devices (Eisen and Lillard 2017; Kyriakides et al. 2016; Seo and Lee 2017). Smart mobile devices such as tablets have made a dynamic entrance in the field of education particularly in the early childhood setting (Papadakis et al. 2018). The use of tablet technologies in mathematics certainly seems enticing (Ingram et al. 2016). Tablets with multi-touch technology have the potential to foster important aspects of child development of number awareness (Baccaglini-Frank and Maracci 2015) and at the same time can provide the opportunity to address some of the traditional barriers such as difficulties relating to accessibility (Orlando and Attard 2016). Compared to traditional media, the special feature of touchscreen technologies is finger-based touch or interactivity (Wang et al. 2016) as well as their high accessibility, ease of use, relatively low cost and accurate, digital measurement abilities which provide everything needed to successfully conduct cognitive experiments with young children (Semmelmann et al. 2016). Research indicates that young children may be able to make significant gains in numeracy performance in a short period of time while interacting with the iPad apps (Moyer-Packenham et al. 2016) while other results showed that there were positive long-term effects when children used a touch-screen device (Paek et al. 2013).

Digital technologies may have the potential to 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 and Tangney 2016) as they provide children with an opportunity to learn and practice skills in an engaging and interactive environment (Chmiliar 2017). Thus, we believe that using different and appropriate forms of technology in the classroom is necessary and can improve learning experiences and motivation. Given the importance of early mathematical achievement, this study seeks to examine if early childhood education students benefit from the integration of digital technology (computers and especially mobile devices) as supplemental mathematic instruction in supporting their understanding of numbers. Although research on newer technologies such as tablets with preschool children has emerged (Chmiliar 2017), in Greece tablets are a very new addition to classrooms, so there is a lack of relevant data about the application of mobile devices in the teaching of mathematics in ECE.

Therefore, the present experimental study aims to address the following three issues: (1) Do the students who learn with the tablet-assisted learning approach show better learning achievements than those who learn with a conventional learning approach and those who learn with a computer-assisted learning approach? (2) Do the students who learn with the computer-assisted learning approach show better learning achievements than those who learn with a conventional learning approach? (3) Do the boys show better learning achievements than the girls?

The next section presents a literature review of the related works on mathematical across different digital platforms (in particular among computers and tablets) as well as the importance of mathematics in Early Childhood Education. In the third section, the research methodology is presented, with full details of the participants, the digital applications, the instrument and procedures used. The research results are then presented. The research findings are discussed, and conclusions are drawn in the final section as well as the limitations of the present study.

2 Literature view

In this section, the related works regarding the importance of early numeracy performance at the beginning of the school career as well as the potential of digital technologies to support preschoolers' thinking about number, are introduced in order to provide background information for this study.

3 The importance of mathematics in early childhood education

The perception that children come to school being able to access powerful mathematical ideas is not new and has received renewed emphasis through several initiatives (Nunes and Bryant 1996). In Australia programs such as "Count Me In Too" (Bobis and Gould 2000), "Early Numeracy Research Project" (Clarke and Clarke 2004), "First Steps" (Willis et al. 2004) or the "Rightstart", "Pre-K Mathematics" and "Building Blocks" project in the United States (Clements and Sarama 2011; Sarama and Clements 2009a) have revolutionized early numeracy teaching and learning (Perry and Dockett 2007). Concepts of quantification, counting, and symbolic representation are important components of number sense that develop during the preschool and kindergarten years and can be targeted in a games-based curriculum (Moomaw 2015).

The importance of mathematics education in the early years has gained increasing attention worldwide (Moomaw 2015) as evidence shows that important changes in mathematics education in prekindergarten through first grade is a strong predictor of future academic and economic success (Lee 2010; Mononen and Aunio 2013; Munn 2006; Ryoo et al. 2014; Schacter and Jo 2017; Susperreguy and Davis-Kean 2016). Early mathematics difficulties lead to long-term educational problems (Dyson et al. 2015). Knowledge of mathematics in early childhood predicts later reading achievement even better than early reading skills (Clements and Sarama 2011; Schroeder and Kirkorian 2016).

Research in early childhood mathematics education highlights its importance; young children working in appropriate educational and pedagogical environments show interest in and have the potential to develop remarkable mathematical ideas (Tzekaki 2014). Quality mathematics in ECE is a joy, not a pressure under the assumption that mathematical activities do not involve pushing elementary arithmetic onto younger children (Clements 1999, 2001). However, even today, children learn mathematics through traditional approaches, namely through mathematics lessons that are often presented as separate activities, either unconnected to the mathematical taught, or only loosely connected to mathematical-related topics (Eke 2011). As a result, in most early childhood classrooms, counting from one to 100 is often seen as a boring drill and is usually considered a difficult task (Ginsburg 2006). Moreover, traditional mathematical activities, carried out by marking the right answer on a workbook lead children to consider that mathematics is not attractive (Doliopoulou 1994). Children's interests and play should be the source of their first mathematical experiences (Clements 1999) and a classroom environment that contains mathematics-related objects can help children recognize and apply mathematical knowledge (Frye et al. 2013).

4 Digital technology and learning mathematics in early childhood education

The considerable potential of digital technologies to support students' learning of mathematics is well recognized (Aunio and Niemivirta 2010; Ingram et al. 2016). The research literature has firmly established that varied media use is becoming ubiquitous in early childhood, and when used within developmentally appropriate frameworks, can effectively promote learning and development for young children in comparison to a typical public classroom setting (Calder 2015; Rothschild and Williams 2015; Shamir et al. 2017a).

Studies have shown that when computers are used in developmentally appropriate ways (Pelton and Francis Pelton 2012; Papadakis et al. 2016a) in mathematics education, new opportunities for understanding mathematical concepts and processes open up (Calder 2015) and enhance young students' conceptual and procedural knowledge of mathematics while improving the understanding of number recognition, counting, shape recognition, and composition and sorting (Larkin 2015). Attard and Northcote (2011) state that children learn mathematics more efficiently when using ICT, as the various forms of ICT can introduce children to abstract concepts that were previously considered too advanced for their age group, such as the concepts of mathematics, dynamic systems, and communication competence (Lieberman et al. 2009). As mathematical activities with the use of ICT combine “boring” aspects of mathematical learning/instruction with animation, they attract the interest of young children, giving another dimension to the teaching of mathematics in ECE (Clements 1999; Weiss et al. 2006). The most powerful benefits of using ICT in the teaching of mathematics include the implementation of a higher level of thinking and mathematics skills development, such as classification, numbering, and identification of numbers (Clements and Sarama 2013).

While much of the available literature on digital technologies in ECE focuses on the role and use of computers by young children (Bolstad 2004; Dwyer 2007; Lindahl and Folkesson 2012; Nikolopoulou and 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 mobile technologies and mobile applications (Ciampa and Gallagher 2013).

The intuitive nature of mobile touch screen tablet devices reduces the mental and spatial demands required to operate and navigate the device (Wood et al. 2016; Papadakis and Kalogiannakis 2017). These devices permit very young children to engage interactively in an intuitive fashion with actions as simple as touching, swiping and pinching (Lovato and Waxman 2016). The iPad and other tablets are viewed as tools that increase student learning and achievement (Milman et al. 2014), mainly due to their multi-sensor properties and the variety of their accompanying applications (Ciampa and Gallagher 2013; Zaranis et al. 2013). The touch and swipe actions required for touchscreen tablets remove the complex spatial knowledge required to associate actions with the mouse or keyboard to actions on the screen. These reduced cognitive demands should increase attention to content, and potentially promote greater and more immediate learning with mobile tablet devices than with desktop computers (Wood et al. 2016). 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 (Melhuish and Falloon 2010).

Some of the recent research has produced positive outcomes with touchscreen devices as ubiquitous tools that can radically transform and enrich both formal and informal mathematics learning (Calder 2015; Melhuish and Falloon 2010; Milman et al. 2014; Moyer-Packenham et al. 2016; Muir and Geiger 2016; Spencer 2013). As Attard and Curry (2012) found, “the introduction and integration of iPads into mathematics teaching and learning appears to have had a positive impact on the teaching and learning of mathematics” (p.81). Larkin and Calder (2016) state that “mobile technologies and apps offer fresh opportunities to re-envisage some aspects of the mathematics learning experience and enhance students’ engagement and mathematical thinking”. An increasing number of studies looking at the use of tablets and the teaching of mathematics (Liu 2013; Moyer-Packenham et al. 2015; Risconscente 2012; Spencer 2013) demonstrated that tablet technology, through its unique characteristics (such as size, portability and lack of peripherals), has the potential to revolutionize teaching and learning as a way to motivate, engage, and enhance student mathematical learning. The portability of tablets and their touch-responsive interface make them particularly conducive to stimulating children’s concentration and engagement with early literacy activities in both independent and collaborative learning environments (Flewitt et al. 2015). As Bos and Lee (2013) state, major benefits of mobile devices for learning concepts in mathematics include supplemental learning aids, anytime/anywhere use, self-paced learning, and reinforcement of abstract concepts. Moreover, as children construct knowledge through their interactions and engagement with others, devices such as tablets are better able to facilitate social collaboration than PCs, which children must use singly (Henderson and Yeow 2012). Moreover, mathematical operations with the use of tablets not only facilitate the development of mathematical thinking in young children, but also encourage the creation of new didactic approaches which are expected to change radically the way in which the teaching of mathematics concepts takes place in early childhood classes (Zaranis et al. 2013).

5 Research methods

In the following subsections, the experiment is described, including a description about how to recruit the participants, the mathematical achievement test, the different digital assisted learning approaches, the digital applications, as well as the procedure of the experiment. Prior the research, we considered the University of Crete Code of Ethics (The University of Crete Senate, 229/22-3-12, https://goo.gl/JLbLH9 [In Greek]). The research protocol was reviewed and approved by the University of Crete Research Ethics Committee. In addition, before initiation of the first phase of research, all necessary permissions were taken from the Greek Institute of Education Policy (IEP) (No. Orig. U15/976/162735/C1).

6 Participants

After obtaining central office permission to conduct this study in school districts in the region of Crete, we contacted principals as per our institutional review board protocol to describe the study and request permission to meet with early childhood educators to explain the study and determine their interest in participating. 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 mean age of the children was 5 years (in months, $M = 62.0$, $SD = 5.5$). Early childhood classes were chosen because of their demographics in an effort to represent areas with the same socioeconomic status (SES), middle SES homes (Hellenic Statistical Authority 2012). Secondly, they were chosen because of the early childhood educators' willingness to take part in the research, the availability of enough space for the activities with tablets and computers, as well as the availability of a private room, free from distractions, to assess the pre and posttest. The selection of the sample took place in October 2013. Students were randomly assigned to one of three groups. The study adhered to university ethical guidelines. A common framework of ethical principles was adopted across the teaching intervention. Ethical principles relating to basic individual safety requirements were met with regard to information, informed consent, confidentially and the use of data.

7 Measures

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 and 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 are used. The content domains tested by the TEMA-3 are numbering, number comparisons, calculation, concepts, numeral literacy, number facts and calculation. Each of these abilities is represented by a set of trials and/or questions distributed across the test and are related to the level of knowledge that the children should have ideally achieved at the age each trial and/or question refers to. Although the TEMA-3 is not a timed test, a typical administration to a child can take up to 30 or 40 min. The TEMA-3 yields a raw score, age equivalent, grade equivalent, percentile rank and Mathematical Ability Score (standard score). In this study, we used the first option. There was no need for translation into the Greek language to administer the test, as there are no linguistic diversities in the activities used. For example, item 10 asks the child to select three tokens, or item 1 requires the child to identify the number of cats in a picture (Fig. 1). Only two cards were changed completely to meet the everyday experience of students. These cards depicted images of banknotes in dollars and were changed to euro banknotes. TEMA-3 is an one on one instructor guided assessment. The examiner uses a picture book and a few manipulatives to administer certain items of the TEMA-3 to individual children. These include a student worksheet of problems, tokens, blocks, and notecards (used as mats during the administration of items using tokens and blocks). Scoring the TEMA-3 is very simple. The child earns 1 point for each item passed. Incorrect items are scored 0. The TEMA-3 was administered to children individually by the researchers and without any distractions in the room. Each child's binary responses (pass/fail) were recorded on a form. Assessments were administered following the TEMA-3 administration rules using age-based item entry points and establishing basal and ceiling levels for each child.

According to Ginsburg and Baroody (2003), the TEMA-3 shows a moderate to very high correlation with four other tests which similarly measure early mathematical ability, such as the Basic Concepts ($r = 0.54$), the Operations composites ($r = 0.63$), the Applied Problems subtest ($r = 0.55$) and the Young Children's Achievement Test ($r = 0.91$), which provides convincing evidence that the TEMA-3 holds criterion-prediction validity.

8 Research procedure

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. Pilot tests of the measure in three kindergartens, which were not included in the next stage of the research, showed no floor or ceiling effect (Mitchell and Jolley 2012). The second

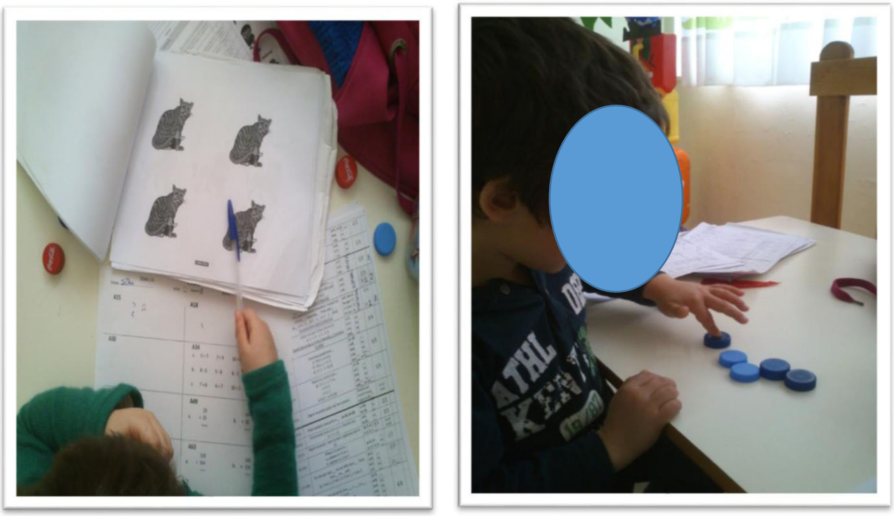

Fig. 1 Examples of TEMA-3 tasks

stage lasted from November 2013 until May 2014 and included the pre-experimental procedure, the experimental interventions and post-experimental procedure (Fig. 2).

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 with the use of 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

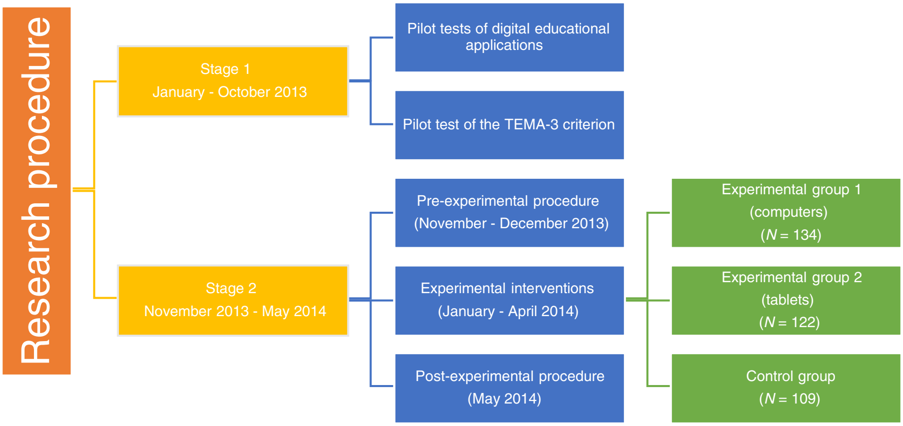

Fig. 2 Research design

instruction (Fig. 3), whereas in the second experimental group the instruction was enriched with the use of software running on tablets (Fig. 4).

The focus of the educational software was in key areas of early mathematics, such as number word sequence, enumeration, as well as basic addition and subtraction skills. In each of the two experimental groups, researchers took care that a sufficient number of laptops and tablets were available. The primary goal was to have children perform the activities simultaneously in mixed age and gender groups with no more than two members per group. Each device was pre-loaded with the necessary applications. The researchers throughout the study offered support for any queries or problems.

The children in the control group had no additional software aid. They received the school’s form of a 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 (Fig. 5). The activities began with carefully worded problems and used meaningful contexts that were engaging and motivated the students (Bicknell et al. 2016). Teachers in this group were provided with a list of activities along with numeral cards, dot cards, and pattern cubes. Additionally, teachers in the control group participated in a separate two-hour face to face training conducted by the lead author of the study. The project coordinator observed treatment sessions for each tutor for three sessions for the 14-week intervention to assess fidelity or quality of implementation of specific performance indicators.

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. To conduct the test properly, the same examination procedure used in the pre-test phase was followed.

9 Description of digital mathematical applications

A preliminary analysis of apps available through the Apple App Store or the Google Play Store, which were supposedly designed for preschoolers’ mathematical learning, concluded that relatively few supported mathematical learning as advocated by the Greek Curriculum (Zacharos et al. 2014). Thus, the researchers designed 32 different

Fig. 3 Illustrations of kindergarten students’ activities with computers

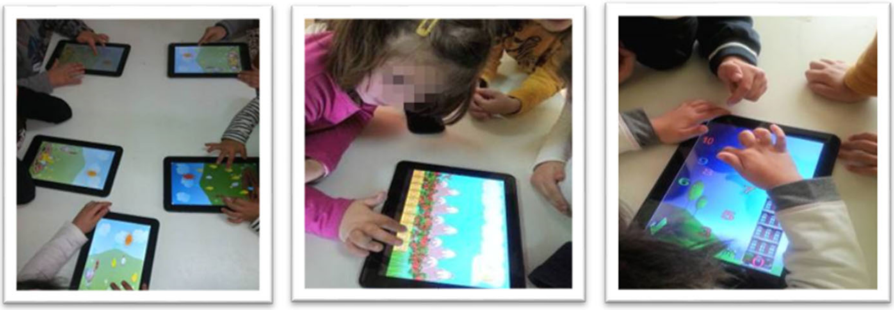

Fig. 4 Illustrations of kindergarten students' activities with tablets

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 of the 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 and addition and subtraction up to the number ten.

As research suggests, children learn best when they are cognitively active and engaged, when learning experiences are meaningful and socially interactive and when learning is guided by a specific goal (Hirsh-Pasek et al. 2015). Thus, the problems which children were asked to solve were presented in the form of stories and daily activities familiar to them such as visiting a grocery store or a museum. Particular attention was given to the numbers used so that they reflected children's reality (tickets, commodity prices, money). Through these digital applications, children could extend their knowledge and develop their own models for the mathematization of problems.

Fig. 5 Similarities between the control and experimental group activities

The structure, plot and script of the activities were similar for both types of digital applications. The scope was to ensure similarity between the two experimental groups to isolate the application type as the variable of interest. Respectively, icons, colors, props, sounds and other multimedia elements that were used to create mobile apps were identical to the corresponding applications on computers. Concerning the pedagogical dimension, children were not only able to learn through trial and error. Indeed, the feedback provided by the characters in the game not only indicated whether responses were correct or incorrect, but scaffolding children's comprehension of numbers (Hirsh-Pasek et al. 2015; Schroeder and Kirkorian 2016). The applications were easy to handle and did not require the presence of an adult.

During the design phase of the educational applications, it was taken into consideration that both the motor skills and hand-eye coordination of children of this age are still developing, and children generally cannot handle extended periods of demanding work. Therefore, every application required the minimum of children's motor skills and coordination. The researchers created the graphics art, music and sounds incorporated into the educational software, or they used a digital material which was not under copying, and distribution limitations. The development of the software was assessed in alignment with accepted standards and research-based approaches related to age classifications (young children ages 0 to 8) (Chau 2014; Haugland 1999; McManis and Parks 2011; Sesame Workshop 2012; Walker 2010; Wolock et al. 2006; Papadakis, Kalogiannakis & Zaranis, 2016b). Concluding, the apps matched the curriculum, had technical and user requirements that can be met within a classroom environment and enabled teaching to reflect productive pedagogies (Ingram et al. 2016).

Additionally, early childhood educators determined the developmental appropriateness of the software at the first stage of the research procedure with the help of a rubric that was created by the researchers (Papadakis et al. 2017). The term "developmentally appropriate" means challenging but attainable for most children of a given age range, flexible enough to respond to certain individual variation, and, most important, consistent with children's ways of thinking and learning (Clements 2002). The creation of the apps, as well as this study, is a part of a longitudinal, multidisciplinary project carried out by the researchers. Figure 6 illustrates three of the 32 digital applications used in the intervention.

In application A the children are called to help a climber successively cross all the mountains to reach his friend. For this purpose, the children must measure successively by one, starting from the number one and stopping at number ten, by pressing the correct sequence of buttons on the corresponding toolbox in order to complete the activity. In application B, as the application is starting up, the children see a relevant group of objects placed at scattered points on the screen. The children must count each group of objects and assign the correct number to them (e.g. six pears - number 6). Whenever the children make a correct match, a pleasant sound of short duration is played back, confirming that the children have made the right move. Simultaneously, the initial image (of the objects) is replaced by a pleasant figure of the corresponding number. If the children have not counted correctly, there is no change, so that the children to understand that the choice of the number is not correct. Every time the application begins, groups of objects appear randomly on the screen. When application C begins two crates with five pieces of fruit and an empty basket appear on the screen. The children simultaneously hear the following audio message: "Each fruit costs one

Fig. 6 Illustrations of digital applications

euro. Put as many fruits as you want in the basket. How much do the fruits you put in the basket cost?" The children can place as many fruits as they wish in the basket simply by dragging them from the crates. They must then select the button that corresponds to the number of fruits that they believe are in the basket. If they choose a wrong answer, they are informed with a suitably adapted audio message that "The fruits you put in the basket do not cost X euros. Try again". The children can try again for an unlimited number of times until they manage to calculate correctly the number of fruits in the basket. If they answer correctly, an appropriate audio and visual message rewards the children.

10 Experimental results

In the present study, the collected data was first examined by descriptive statistics to explore the group means, standard deviations and numbers. Then, a Chi-square test and one-directional analysis of variance (ANOVA) was performed on the pre-test grades. Raw scores were used for all analyses. The data (preschoolers' pre-test and post-test raw scores) fulfilled the assumptions for parametric tests (normality and parametric assumptions) and were analyzed using IBM SPSS 23.0 software, and the significance level adopted was 5% ($p < .05$).

A Chi-square test was run to test gender equivalence between three groups. No difference at a statistically significant level was found between the number of boys and girls, x2(2) = .75, $p > .05$. In order to discover the group differences in age and in the scores of TEMA-3 prior to the teaching intervention, a one-way analysis of variance (ANOVA) was calculated. The results revealed that the experimental groups and the control group did not differ in their age, $F(2, 362) = 2.85$, $p > .05$, but differed in performance at TEMA-3, $F(2, 362) = 9.75$, $p < .001$, at a statistically significant level (as shown in Table 1). Post hoc analysis using the Hochberg's GT2 criterion indicated that the control group differed significantly from the second experimental group (tablet practice) and the first experimental group (computer practice). The second experimental group did not differ significantly from the first experimental group. The best performance was accomplished by the control group ($M = 21.45$, $SD = 5.22$), followed by the second experimental group ($M = 19.34$, $SD = 6.02$), while the worst performance was recorded by the first experimental group ($M = 18.84$, $SD = 5.83$).

Previous analyses showed that the three groups are not equivalent in their scores in the pre-test of the TEMA-3 criterion. Thus, it cannot be ascertained to what extent the observed differences between the means after the intervention were due to the effectiveness of the intervention itself, or if they simply reflected existing differences between the groups before the intervention (Dyson et al. 2015). This study conducted an analysis of covariance (ANCOVA) using the preschoolers' pre-test scores as the covariate to exclude the impact of the pre-test on their learning. ANCOVA resulting output shows the effect of the independent variable after the effects of the covariates have been removed or accounted for (Vogt 1999). As shown in Table 2, the main effect of the independent variable (group type) was found to be statistically significant, $F(2, 361) = 26.13$, $p < .001$ partial $n^2 = .13$. In other words, the post-test scores were significantly different due to the different experimental learning processes. Furthermore, post hoc analysis was performed to examine specific differences in achievement between the experimental groups. An LSD test revealed that the second experimental group scores (tablets) were significantly higher than those of control group, comparing the adjusted mean of 25.86 for the experimental group with the control group score of 22.01 ($p < .001$). Additionally, the second experimental group scores (tablets) were also significantly higher than those of the first experimental group scores (computers) which scored 24.07 ($p < .001$). Also, the first experimental group scores (computers) were also significantly higher than those of the control group ($p < .001$).

Therefore, the learning achievements of the second experimental group students (tablets) were significantly better than those of the first experimental group students (computers) and the students in the control group. It is therefore concluded that the tablet-based learning approach had a significant impact on improving the students' learning outcomes - understanding of number. This finding showed that the main hypothesis of the study can be confirmed.

Accordingly, it was found that the learning achievements of the first experimental group students were significantly better than those of the students in the control group. The significantly better score of the experimental group than that of the control group suggests that the educational computer learning approach has improved the learning outcomes - thinking of students about number, and thus the second hypothesis was confirmed.

The third research question examined whether the effect of the experimental intervention on the performance of the children in mathematical ability is affected, and thus differs, by children's gender. Results of the ANOVA revealed no significant differences due to the effect of gender in mathematical performance, $F(1, 361) = 0.22$, $p > .05$,

Table 1 ANOVA summary table for different learning approaches

	Experimental group 1 (Computers) ($N = 134$)		Experimental group 2 (Tablets) ($N = 122$)		Control group ($N = 109$)		*F*	Sig.
	Mean	Std. deviation	Mean	Std. deviation	Mean	Std. deviation		
Pretest TEMA-3	18.84	5.83	19.34	6.02	21.45	5.22	9.75	.001*

$^*p < .001$

Table 2 Descriptive data and ANCOVA result for the learning achievement post-test for the three groups

Variable	Group	*N*	Mean	Std. deviation	Adjusted mean	*F*(2,361)	Post hoc
Post-test	(1) Experimental group 1 (Computers)	134	23.00	6.63	24.07	26.13*	(1) > (3) (2) > (1)
	(2) Experimental group 2 (Tablets)	122	25.26	6.52	25.86		(2) > (3)
	(3) Control group	109	23.48	5.27	22.01		

*$p < .001$

(boys $M = 23.63$, $SD = 0.60$) (girls $M = 24.03$, $SD = 0.60$). This means that the third hypothesis was not confirmed.

11 Discussion

The present study is preliminary research on the effects of the different forms of digital technology on mathematical comprehension. From the results, the first major finding was that the scores of the tablet group were higher than computer group and the control group. This confirmed the findings of previous studies (Aladé et al. 2016; Calder 2015; Chen et al. 2014; Shamir et al. 2017b). In short, all these studies indicate that the touchscreen has positive effects on learning. Furthermore, 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 (Attard and Curry 2012; Berkowitz et al. 2015) in both preschool and primary school settings. Schroeder and Kirkorian (2016) state that a preschool children can indeed learn a novel measurement skill from child-directed, educational media presented on a touchscreen device.

Some studied argued that there may be several possible explanations why participants in tablet group scored significantly higher than those in the computer group and the control group. Aladé et al. (2016) state that children are better able to learn science and mathematical concepts when they are presented in multiple modalities and that haptic feedback is particularly useful for learning STEM concepts because it provides more of a “real-life” experience and a more immersive learning environment. Some studies also mention that compared with printed books, computers and video, one special feature of touchscreen is interactivity (Sheehan and Uttal 2016). Children can tap, drag, and touch the objects on the touchscreen and get a response from the objects. A touchscreen, gives children opportunities to interact with what they are learning about, not just watch and listen. These exchanges with the touchscreen device are thought to be the process that promotes children’s learning (Wang et al. 2016). As Sheehan and Uttal (2016) state touch screens may promote learning by providing a contingent response, which has been shown to help children learn from other symbolic media, such as computers and video, and may help focus children’s attention on the symbol. Moreover, Couse and Chen (2010) argue that interaction with tablets in the class room is viable: Children between the age of 3 and

6 are found to be curious about the new technology and “persisted without frustration” when learning to use them. This active interest actually seems to carry over to increased learning (Semmelmann et al. 2016). For very young children this form of interaction is more intuitive than traditional desktop computers that rely on mouse and keyboard interaction, since it exploits their natural exploration strategies that rely on a wider range of sensory-motor forms of interaction (Crescenzi et al. 2014).

The current study also found that, there was significant difference between the scores of the computer group and the control group. More specifically, statistical analysis showed that the didactic approaches which used computers and appropriate software had a positive effect and demonstrated a statistically significant improvement in children’s mathematical ability, supporting the development of the important prerequisite mathematical skills. These results support the contention that performance on number tasks can be increased through training based using computer with an emphasis on 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 kinds of stimuli, this can effectively assist them to develop their mathematical ability (Aunio and Niemivirta 2010; Balfanz et al. 2003; Ciampa and Gallagher 2013; Clements and Sarama 2013; Clements et al. 2004; Ginsburg 2004; Milman et al. 2014; Mononen and Aunio 2013; Nunes and Bryant 1996; Penuel et al. 2009; Sarama and Clements 2009a; Schacter and Jo 2017; Shamir et al. 2017b). It could be said that a multimedia environment that provides early childhood students with the opportunity to be cognitively engaged in real-world contexts with multi-presentations, in turn affected their mathematical skills (Weiss et al. 2006). The study reinforces other research conclusions that digital technologies can play a positive role in improving early mathematics skills (Ciampa and Gallagher 2013; Clements and Sarama 2013; Dwyer 2007; Milman et al. 2014; NCTM 2008; Pasnik and Llorente 2013; Penuel et al. 2009).

Our research findings are in line with previous research showing that the integration of digital technologies in early childhood classrooms offers a new didactic approach in the teaching of mathematics, by creating new activities which contribute to the approach of the subject in a wide variety of ways (Clements and Sarama 2008). Early Childhood Education students who are involved in a stimuli-rich multimedia environment which can simulate real world situations are eventually positively affected in the development of their mathematics skills (NCTM 2008). The inexpensiveness of digital technologies (e.g. computers and tablets) could make them more advantageous for developing mathematical thinking than physical objects as “compared with their physical counterparts, computer representations may be more manageable, flexible, extensible, and ‘clean’ (i.e., free of potentially distracting features)” (p. 147) (Sarama and Clements 2009b).

In addition, we attempted to investigate possible gender differences in mathematical performance. Gender was not found to play an important role, since we did not obtain statistically significant differences in mathematical performance between boys and girls. The results of the study regarding gender are consistent with the existing literature (Aunio and Niemivirta 2010; Aunio et al. 2008; Aunola et al. 2004; Hyde and Mertz 2009; Jordan et al. 2006; Mononen and Aunio 2013; Nunes and Bryant 1996; Spelke 2005) as it suggests that in young children gender differences in mathematical performance either do not exist or are very small (Chen et al. 2014; Dickhauser and Meyer 2006; Goodwin 2012; Lubienski et al. 2013).

12 Limitations and future studies

There were limitations of this study that need to be addressed in future studies. The duration of the teaching intervention was 14 weeks. Although it is adequate to test experimentally the effect of the different didactic approaches, it is not sufficient to fulfill young children's needs in the development of the mathematical ability to a significantly greater extent. For this reason, it is necessary to implement a teaching intervention which will be long enough in duration to extensively investigate the effect of various didactic approaches in the development of mathematical ability in ECE.

The second limitation of this research is that the study did not implement a delayed post-test to measure whether numeracy knowledge gained from a tablet or computer assisted learning approach persisted (Schacter and Jo 2017). The implementation of a longitudinal study investigating the effects of different didactic approaches in the development of the mathematical ability of young children in the first grade would also constitute a significant extension of the present study.

Thirdly, the researchers carried out the application of the didactic approaches only for 30 min. This fact poses a restriction on ensuring all the necessary conditions that enhance the external validity of the research. It is evident that ICT can be used most effectively when it is fully integrated into the long-term planned program. A consistent theme in the research literature on the use of ICT by teachers is the lack of professional development and understanding of the pedagogy in the use of ICT (Dwyer 2007). The proper training of early childhood educators is therefore considered useful, and should be included in the implementation of future studies, so that early childhood educators can implement the different didactic approaches and study the consistency, stability, and the possibility of their application in the real environment of the early childhood classroom.

The present study did not include demographic information related to ethnicity and socio-economic status (SES) of participants (Kabali et al. 2015; Wood et al. 2016). Research suggests that children from minority and low-income groups later experience considerable difficulty in school mathematics (Clements 1999). A further analysis is thus needed to examine if children from low-resource communities who are members of linguistic and ethnic minority groups demonstrate the same levels of achievement as children from higher-resource, non-minority communities (Clements et al. 2011). Furthermore, a socioeconomic control is needed to deal with the possibility that wealthier children may have prior access to computers or tablets, and eliminate the possibility that the differences recorded in pre-tests in mathematical ability could be driven by this.

Finally, this study used a between-subjects design. All students participated in one of the three groups. The individual differences could not be measured in the present research (Chen et al. 2014).

13 Conclusions

In this twenty-first century, children are increasingly exposed to electronic media at a young age, often with the expectation that this provides them with better learning opportunities (Evans et al. 2017; Zimmermann et al. 2016). Further, similar to Olive et al. (2010, p.139) we suggest that technology can transform the traditional didactic triangle (student, teacher, and mathematics) into a didactic tetrahedron, by using developmentally appropriate interactions among students, teachers, tasks, and technologies. In this aspect, the technology in education must be used to transform learning and not simply to replace traditional worksheets with digital screens without current classroom practices (Papadakis et al. 2016c). The use of mobile technologies in mathematics education has the potential to encourage meaningful student engagement with mathematics, by embedding the subject in authentic contexts (Bray and Tangney 2016). When well designed, this technology can offer meaningful opportunities for young children to engage with STEM content, learn through exploration, and practice newly acquired skills (Aladé et al. 2016). Ideally, mobile technologies should be integrated in mathematics teaching and learning in ways that create a new learning ecology. For this to happen apps must be developmentally appropriate, applicable, and appealing.

Mathematics learning, as with all learning, relies on the quality of the teaching, particularly the teachers' mathematical knowledge for teaching (Ryoo et al. 2014). To capitalize on the advantages of mobile technologies, teachers need to be trained to successfully incorporate them into pedagogical practice (Kraut 2013; Lee and Pant 2017; Moore-Russo et al. 2015). Mathematics education can be enhanced, but never completely replaced by, digital and mobile technologies (Larkin and Calder 2016). Simply allowing children to work with technologies does not guarantee improvements in achievement (Moyer-Packenham et al. 2016).

As research on mobile devices in the early childhood setting in Greece is still in its infancy but the unique contribution of this research is that it provides evidence that mobile devices, with the use of appropriate development software, can be incorporated into the early childhood teaching practice and be effectively used to support interactive learning. We suggest that enriched instruction digital materials should be designed, so that by combining the usage of computers and especially tablets, learners from all performance levels are given good opportunities. This conforms with other research suggesting that screen media can become tools for learning if two critical factors are taken into consideration: content and context (Lerner and Barr 2014).

However, making a transition from a traditional to a technology-rich learning environment is challenging both for teachers and students (Chandra and Mills 2015) as digital technologies and mobile devices especially require educators to think differently about learning and teaching (Underwood and Dillon 2011). We highlight that special attention should be given to the teacher to support learning through this media, along with the greater emphasis on entertainment rather than learning with some apps also constrained the learning process. As Calder (2015) state just allowing learners access to mobile technology is not sufficient, nor educationally ethical. There are teachers who have the knowledge and propensity to use them effectively. Therefore, we suggest that leveraging the optimal pedagogical impact from tablets requires innovative pedagogical design and support (Cochrane et al. 2013; Moyer-Packenham et al. 2016). As Orlando and Attard (2016) note, teaching with technology is not a one size fits all approach as it depends on the types of technology in use at the time and also the curriculum content being taught.

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