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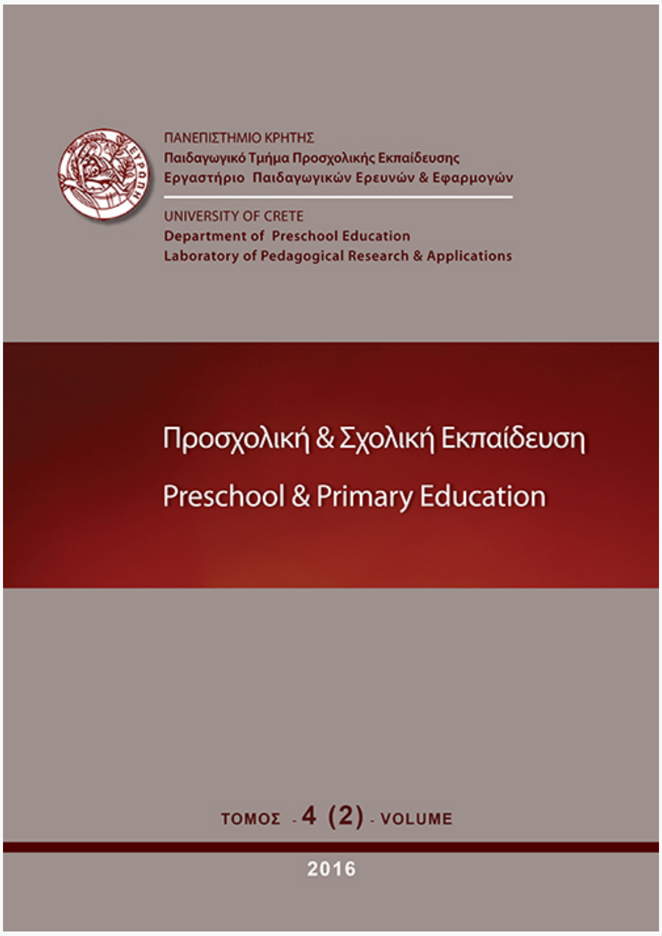

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Comparing tablets and PCs in teaching mathematics: An attempt to improve mathematics competence in early childhood education

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Summary. The present study investigates and compares the influence of using computers and tablets in the development of mathematical competence in early childhood education. To implement the survey we conducted a 14-week intervention, which included one experimental and one control group. Children in both groups were taught mathematics as per the Greek curriculum for early childhood education, using either the same educational software which, depending on the group, running on computers or on tablets. In order to evaluate the mathematical performance of children we used the Test of Early Mathematics Ability (TEMA-3). The sample consisted of 256 children in Greece. The results showed that teaching with tablets compared to teaching with computers contributed significantly to the development of children's mathematical ability. Moreover, factors such as gender and age did not seem to differentiate the development of mathematical competence of children.

Keywords: tablets, computers, early childhood education, mathematical competence

Introduction

Despite the initial wavering and debates (Cordes & Miller, 2000), most educational institutions and researchers nowadays support the rational integration of information and communications technology (ICT) in early childhood education (Murray & Olcese, 2011; OECD, 2013; Pegrum, Oakley, & Faulkner, 2013; Peirce, 2013). Kerckaert, Vanderlinde, & van Braak (2015) distinguish between two types of ICT use in early childhood education: 'ICT use supporting basic ICT skills and attitudes', and 'ICT use supporting contents and individual learning needs'. An interactive functional learning environment affects learning in several ways, including raising the level of student engagement in a classroom, motivating students and promoting enthusiasm for learning, probably the most important advantage of using ICT in the learning process, even in early childhood education (Clements & Sarama, 2007; Zevenbergen & Logan, 2008). On the other hand, in non-computer assisted teaching methods, children try to reinforce their mathematical skills using recitation techniques or complete, practical sets of exercises. Such traditional methods lack immediate feedback and reduce pupils' interest in learning (Panagiotakopoulos, Sarris, & Koleza, 2013; Papadakis, Kalogiannakis, & Zaranis, 2016). Teaching should make it possible for children

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to use spreadsheets, graphing tools, and other software to support application and authentic use of mathematics (Nunes, Bryant, & Watson, 2009). An interactive environment with the use of computers can act positively and help children improve their mathematical knowledge (Kafousi & Skoumpourdi, 2008; Nunes & Bryant, 1996; Tzekaki, 2007; Zacharos, 2007).

Recently, with the rapid insertion of smart mobile devices in the lives of young children in the form of mobile phones and tablets (OECD, 2015; Rideout, 2014), the debate and scientific research has extended to the use of these digital technologies in early childhood education (Zaranis, Kalogiannakis, & Papadakis, 2013). A growing body of research indicates that tablets offer innovative opportunities and appreciable improvements in student mathematical achievement, even in preschool education (Judge, Floyd, & Jeffs, 2015; Neumann & Neumann, 2014; Ting, 2013; Verenikina & Kervin, 2011). The ease of use, the suitability for 'anytime and anywhere learning' provided by tablets, creates a particularly friendly, creative and pleasant environment for children, which enhances the learning process (Beschorner & Hutchison, 2013; Couse & Chen, 2010; Judge et al., 2015; McManis & Gunnewig, 2012; Neumann & Neumann, 2014). Many early-year practitioners and researchers state that the interactive environment created in a kindergarten by using tablets is stronger in maintaining children's interest towards digital activities, and encourages them to become more closely and effectively involved in digital mathematical activities (Liu, 2013; Risconscente, 2012).

The purpose of this controlled experiment was to determine whether the type of ICT used (computers or tablets) in the natural kindergarten environment influences the development of mathematical competence in early childhood education.

Theoretical Background

ICT and teaching mathematics concepts in early years

In the 1980s there was vigorous debate about the role of technology, and computers in particular, in early childhood curricula (Yelland, 2005). Thirty years later, there is considerable research supporting the potential of ICT to create an innovative, effective and attractive learning environment for young children, which highlights the positive relationship between the use of ICT and the development of mathematical thinking in early childhood education (Carr, 2012; Clements, 2002; Panagiotakopoulos et al., 2013; Sarama & Clements, 2004, 2006). When computers and other new technologies are used in an open-ended exploratory way, they can play a role in early childhood education, and more particularly they can enhance a good understanding of mathematical ideas (Clements & Sarama, 2003; Haugland, 1999; Yelland, 2005).

Mathematical operations in conjunction with the contribution of ICT not only facilitate the development of mathematical thinking in young children, but also encourage the creation of new teaching methods which are expected to radically change the way that the teaching of mathematical concepts takes place in early childhood (Pegrum et al., 2013). In the context of developing early mathematical thinking, even the use of "drill and practice" software can help children develop their mathematical skills in basic math concepts (Clements, 2002; Clements, & Sarama, 2007; Siraj-Blatchford & Whitebread, 2003). As McManis and Gunnewig (2012) describe, when young children use computers with adult support, their math skills increase for number recognition, counting, shape recognition and composition, and sorting. The most powerful benefits of using ICT are the enhancement of a higher level of thinking and the development of mathematical skills such as classification, counting and number recognition (Lieberman, Bates, & So, 2009; Sarama & Clements, 2009). Student-controlled ICT supports the development of knowledge about mathematics and its applications, and also provides authentic working methods (Nunes et al., 2009).

Advances in digital technologies and technological gadgets are dramatically altering the tools available to teachers and students, even in preschool education (Biancarosa & Griffiths, 2012). Although iPads and other similar tablets have not been extensively studied as teaching tools in the early childhood classroom, many educators are enthusiastic about using them; they rave about their versatility, connectivity, mobility, as well as the potential benefits of thousands of educational apps (Falloon, 2013; Mango, 2015). Usability studies with tablets find that preschool children learn to use the devices quickly, independently, and confidently and explore freely (McManis & Gunnewig, 2012). For Kucirkova (2014) tablets have three novel features with the potential to make a positive difference in early education: iPads are portable and light-weight, they eliminate the need for separate input devices (such as mouse and keyboard) and thirdly, they are specifically designed to accommodate a number of apps, many of which have a child friendly intuitive design. Concerning the pedagogical use of tablets in early childhood education, recent studies have concluded that tablets may have the potential to act as a valuable tool for educational use, especially in learning mathematical concepts (Pitchford, 2014; Shuler, Levine, & Ree, 2012; Zaranis et al., 2013). The regular use of tablets brings about significant learning gains to young children in areas such as arithmetic, recognition of numbers and formation of digits (Chiong & Shuler, 2010).

The present study

The purpose of the present study was to examine how the use of the same mathematical software on different hardware platforms influences the development of children's mathematical ability. To our knowledge, this is the first study to test the relationship between computers and tablets and math acquisition. Empirical findings lead to the conclusion that the kinaesthetic characteristics of tablets, and the opportunity to learn through playing, provide a positive approach to the teaching of mathematics (Guernsey, 2012). A co-examination of the effect of a variety of factors, such as gender and age, was conducted while assessing the impact of the forms of ICT on the development of mathematical ability.

We sought to examine the following hypotheses:

- (H1) The initial mathematical ability of the two groups will increase significantly after the intervention.
- (H2) The mathematical ability of children taught mathematics with computers is significantly less than the mathematical ability of children taught mathematics with tablets.
- (H3) The mathematical ability of children taught mathematics with computers is significantly less than the mathematical ability of children taught mathematics with tablets, and is not affected by various other factors such as gender and the age of children.

Methodology

Sample

The research sample was ethnically and language homogenous and consisted of 256 children (122 boys, 134 girls) from the prefecture of Crete, Greece. The age of the children ranged between 4.5 and 5.5 years (M = 63.0 months, SD = 4.9 months, at the first time of measurement). The children attended classes in public and private kindergartens during the 2013-2014 school year. Selection of the sample took place in October 2013, with the technique of multistage sampling (Cohen, Manion, & Morrison, 2007). Requirements concerning information, informed consent, confidentiality and usage of data were carefully met, both orally and in writing, by informing the preschool staff, children and guardians on the purpose of the study and their rights to refrain from participation. All necessary permissions were received from the Greek Institute of Education Policy (IEP) (No. Orig. Φ15/976/162735/Γ1).

Data collection instruments - Test of Early Mathematics Ability (TEMA 3)

For the evaluation of children's mathematical ability performance before and after the teaching intervention, a Greek adaptation of the Test of Early Mathematics Ability, 3rd Edition (TEMA-3; Ginsburg & Baroody, 2003) was administered (Manolitsis, Georgiou, & Tziraki, 2013). In short, the concepts examined by the TEMA-3 are identifying and writing numbers, counting, comparing sets and sorting numbers, as well as arithmetic operations (numbering skills, number-comparison facility, numeral literacy, mastery of number facts, calculation skills, and understanding of concepts). 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 which the children should have ideally achieved at the age each trial and/or question refers to.

Research design - Procedure

For the verification of the research hypotheses, an experimental procedure was designed, in which the sample was divided into two groups, the control group and the experimental group. The experimental design included three phases:

(a) the pre-experimental control phase, during which the measurement of the dependent variable was performed,

(b) the experimental phase/intervention, during which manipulation of the independent variable took place and

(c) the post-experimental control phase, during which post-control of the dependent variable was performed.

The research procedure consisted of two stages. The first stage, from January to October of 2013, involved the pilot tests of digital educational applications and the TEMA-3 criterion. The second stage, from November 2013 until May 2014, included the pre-experimental procedure, the experimental intervention and post-experimental procedure.

Children pre-test

The first phase, which was common for the two groups, took place during November and December of the 2013-2014 school year. In this phase, children were asked to tackle the questions-activities of the Test of Early Mathematics Ability (TEMA-3). The evaluation lasted for 10 to 30 minutes, depending on the performance of each child. All first-phase meetings ended early in the school year, before children began to be taught mathematics, which could have had a positive effect on their performance. Children who were absent on the days the tests were administered were not included in the sample.

Teaching intervention

The teaching intervention took place between January and April of the 2013-2014school year. It aimed to develop preschoolers' logical-mathematical thinking, such as numbering skills, numeral literacy, mastery of number facts, calculation skills and understanding of concepts.

The teaching was done by the teacher of each kindergarten in accordance with the thematic approach, as defined by the Greek Curriculum of Studies for Preschool Education, following the teaching plan drawn up by the teacher at the beginning of the school year. The objective of mathematical education in modern Greek kindergarten is to develop a way of thinking that exploits the features of mathematics. Preschool teachers shape the daily schedule of their teaching activities by combining knowledge from other school subjects taught in the preschool curriculum (Koustourakis, Zacharos, & Papadimitriou, 2013). It is intended that children begin to think in mathematical ways, realizing the value of using mathematics in real life (Kafousi & Skoumpourdi, 2008; Tzekaki, 2007) (Figure 1). Through daily actions and their interaction with the environment, children gradually explore all five axes whose trajectories are developed in the program of mathematics namely numbers and operations, space and geometry, measurements, stochastic mathematics and introduction to algebraic thinking (Zacharos, 2007).

Figure 1 Illustrations from the activities of children

In the control group, the teaching intervention was enhanced by using computers, whereas in the experimental group it was enriched by using tablets. Therefore, during the teaching intervention the technological equipment of each kindergarten was augmented by a sufficient number of computers (laptops) and tablets. In both teaching interventions, developmentally appropriate educational software was utilized, in the form of 32 different digital games for computers (16) and tablets (16), which were created especially for the purpose of this research. Before the teaching interventions, the researchers trained the children to use the computer (mouse – keyboard) or the tablet (gestures). Children who were absent for more than two teaching interventions were excluded from the survey. The second phase of the research was completed by the end of the teaching intervention.

Children post-test

The third and final phase of the research was carried out in May of the 2013-2014school year. During this phase, there was a meeting with every child. At this meeting, each child was examined once again in TEMA-3 criterion. For the proper conduct of the test, the same examination procedure as the one in the pre-test phase was followed.

Description of educational software

Educational applications in the form of digital games were designed according to the Greek Curriculum of Studies for Preschool Education. The notion of using games as a “mediator” in the learning process is not new and originates from Vygotsky’s theory (Panagiotakopoulos et al., 2013). 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 in order to reflect reality (tickets, commodity prices, money). Figure 2 illustrates some of children's activities with tablets.

Figure 2 Illustrations of children activities with tablets

The structure, plot, and script of the activities were similar for both types of digital applications. Respectively, icons, colours, props, sounds and other multimedia elements that were used to create mobile applications were identical to the corresponding applications on computers. The only difference between them was the different programming environment selected to implement them and the medium. With regard to the pedagogical dimension, the digital applications belonged to the category of "drill and practice" games with closed-ended questions. The applications were easy to handle and did not require the presence of an adult. Figure 3 illustrates some of the digital applications used in the intervention.

Figure 3 Illustrations of digital applications

Results

Prior to data analysis, we ensured the typical assumptions of a parametric test such as normality, homogeneity of variances, linearity and independence were met before various parametric statistical tests can be properly used.

Equivalence checking of the experimental groups

Initially, the equivalence of the two groups in terms of the children's gender was tested. The results, after applying the Chi-Square statistical criterion, showed that the two groups did not differ significantly in the number of boys and girls included, $\chi^2(2) = 0.51$, $p > 0.05$. Subsequently, the equivalence of the two groups in terms of the children's age was tested. An analysis of variance showed that the two groups were equivalent as to children's age, $F(1, 254) = 3.59$, $p > 0.05$. The one-way ANOVA was also used to investigate the equivalence of the two groups in terms of the average score in the questions, which describes the mathematical ability of the sample. According to the results of the ANOVA analysis, the two groups did not reveal a statistically significant difference in terms of the performance of children on the test of Early Mathematics Ability (TEMA-3) before the start of the teaching intervention, $F(1, 254) = 0.21$, $p > 0.05$. Taking into consideration the aggregated results concerning the formation of the research teams, we conclude that both groups are equivalent in terms of: (a) age, (b) gender and (c) mathematical ability.

Influence of the experimental intervention in the development of mathematical competence of children

Direct effects of the experimental intervention in the mathematical ability of children

The main purpose of this study was to investigate whether children's performance in mathematical ability increased significantly, as recorded by their performance in the TEMA-3 criterion, after teaching using educational software running on either computers or tablets. For this purpose, both groups were compared as to their mathematical ability in the TEMA-3 criterion before and after the experimental intervention, using dependent (paired samples) t-test. As the results presented in Table 1 reveal, the mathematical ability of both groups increased after the experimental intervention. The difference in the performance of children in each group during the two measurements is statistically significant.

Table 1 Results of the analysis of the *t*-test per group

			M	***SD***	***t* - test (*df* = 121)**
Teaching with tablets	Mathematical competence	Pre-test	19.34	6.02	-18.01, $p < 0.05$
		Post-test	25.26	6.52	
			M	***SD***	***t* - test (*df* = 133)**
Control Group	Mathematical competence	Pre-test	18.84	5.83	-10.98, $p < 0.05$
		Post-test	23.00	6.63	

To further investigate the first aim of the research it was considered useful to investigate whether these two groups differ on a statistically significant level with respect to the influence of the experimental interventions. For this reason, ANOVA analysis was conducted to investigate whether the groups differ on a statistically significant level. Specifically, the results of ANOVA showed a statistically significant difference in children's final performance in the TEMA-3 criterion between groups, $F(1, 254) = 19.40$, $p < 0.01$. Moreover, the mean of the improvement in the performance of the children in the experimental group (6.42) is significantly higher than the mean of the performance of the control group (4.12) (Figure 4).

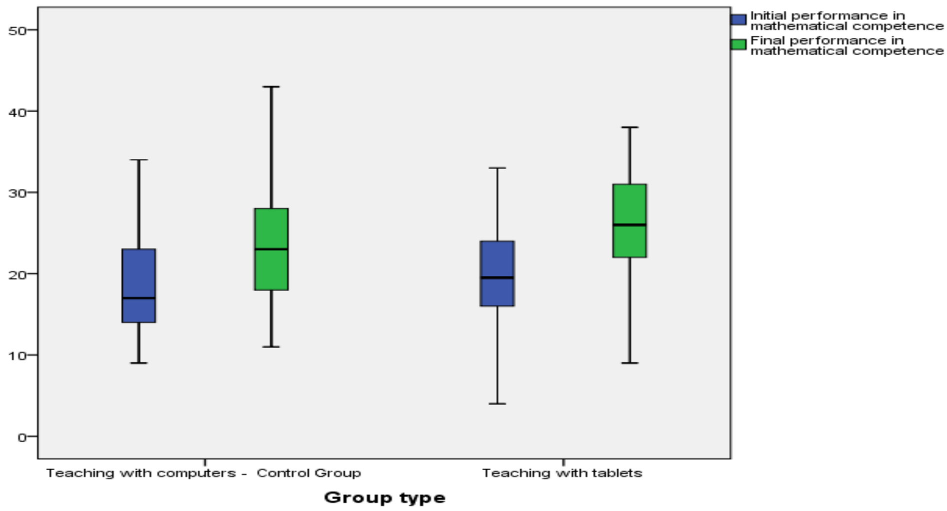

Figure 4 Box plot for initial and final performance of children groups in mathematical ability

Review of the impact of the experimental intervention on the performance improvement of children in TEMA-3 criterion

In addition to the final performance, it was considered useful to investigate the effect of the experimental intervention on the degree of improvement in the performance of children in mathematical ability. The results of ANOVA indicated that the effect of the intervention on the degree of improvement in children's performance in their mathematical ability is statistically significant, $F(1, 254) = 19.40$, $p < 0.01$. The greatest improvement in the performance in mathematical ability was demonstrated by the children of the experimental group (Table 2).

Table 2 Mean and standard deviation per group

	Extent of improvement of the performance of children between the two measurements of TEMA-3	***M***	***SD***
Mathematical competence	Teaching with tablets	6.42	3.93
	Control Group	4.12	4.38

Effect of other factors on the development of children's mathematical ability

A key question in this study was whether the effect of the experimental intervention on the performance of the children in mathematical ability is affected by other factors. For the investigation of this research aim a test of the degree of interdependence between the independent variables was conducted by using the Pearson product-moment correlation coefficient. The results indicated that there is no correlation between the age of children and the improvement of their performance in mathematical ability, $r(254) = 0.09$, $p > 0.05$. Respectively, to investigate the effect of the gender of the children as a differentiating factor in the extent of improvement on performance in mathematical ability, a t-test for independent samples was applied. The results of the test showed that the effect of gender on the improvement in the performance of children's mathematical ability was not statistically significant, $t(254) = -0.42$, $p > 0.05$, namely, gender does not seem to influence in any way the improvement of children's performance in mathematical ability.

Additionally, there was a study of the effects of more than one independent variable on the dependent variable, namely the improvement in the performance of children's mathematical ability and the interactions between them. Initially, the main effects of the experimental intervention and of children's gender on the improvement in their performance in mathematics was examined through the criterion of factorial variance analysis. The results showed that the interaction between gender and the experimental intervention had no effect $F(1, 252) = 0.92$, $p > 0.05$. Additionally, the main effects of the experimental intervention and the age of children on improving their performance in mathematical ability were examined. The results from the application of the criterion showed that the interaction between the age and the experimental intervention had no effect $F(21, 214) = 0.48$, $p > 0.05$.

Investigation of research hypotheses

The first hypothesis (H1) predicted that the initial performance in mathematical ability of the experimental group and the control group would increase significantly after the intervention. Statistical analysis showed that both forms of ICT contributed significantly to the improvement of children's performance in the criterion of mathematical ability assessment. As a result, the first hypothesis (H1), which refers to the positive impact of both forms of ICT on the improvement of children's mathematical ability was verified.

The second hypothesis (H2) predicted that the performance of the experimental group and the control group in mathematical ability would differ significantly after the intervention, depending on each form of ICT. In the intervention, where teaching with the use of tablets was applied, children showed a higher final performance and a significantly greater improvement in their mathematical ability after the intervention compared to the control group. The above findings support the second hypothesis (H2).

The third hypothesis (H3) predicted that the performance of the experimental group and the control group in mathematical ability would differ significantly after the intervention, depending on the use of different forms of ICT, even after the control of various other factors related to the development of mathematical ability. The investigation of the interdependence of the independent variables on the extent of the improvement in children's final performance in mathematical ability showed that there is no correlation between age and gender on the extent of improvement in children's final performance in mathematical ability. Additionally, investigating the main effects, as well as the interactions, of more than one independent variable on the extent of children's improved performance in mathematical ability showed that the effect of the experimental intervention did not differ depending on age or gender. Based on these results, the H3 hypothesis of this study was verified.

Discussion

The preceding analysis is far from providing a complete picture of using smart mobile devices in the preschool classroom. However, it constitutes a first step in the direction of looking at systematically using such devices to teach mathematics. Holistically, our results suggest that teaching mathematics using computers and tablets are two teaching approaches with a positive effect of a different extent on the development of mathematical competence of preschool children.

Undoubtedly, children learn faster and more easily in an interactive functional learning environment (Kafousi & Skoumpourdi, 2008; Nunes & Bryant, 1996; Tzekaki, 2007; Zacharos, 2007) making this, perhaps, the most important advantage of using ICT in the learning process compared to "traditional" teaching methods. The interactive environment provided by using computers acted positively and helped children improve their mathematical knowledge (Clements & Sarama, 2007; Zevenbergen & Logan, 2008). However, using computers had less of an effect than using tablets. Possibly, the more passive role of children when dealing with their computers compared to their involvement with tablets inhibited and prevented children from working actively with the information provided by activities that were to be carried out by digital applications. This study is consistent with other studies, which show that the interactive environment created in a kindergarten with the use of tablets is stronger in maintaining children's interest in digital activities, and encourages them to become more effectively and closely involved digital mathematical activities (Liu, 2013; Risconscente, 2012).

The design of the didactic approach using tablets supports the integration of mobile technologies in teaching mathematics. The superior final performance of the control group when taught with tablets as opposed to computers and the extent of the improvement is seen as result of using the tablets. Characteristics such as increased portability, functionality, various multimedia capabilities, social interactivity, personalization, etc. that enable the implementation of a broader range of teaching strategies, make tablets attractive from an educational perspective (Zaranis et al., 2013). The findings are consistent with various international studies which find that using tablets is beneficial in kindergarten as they require minimal training, eliminate the disadvantages of handling additional material and increase children's motivation to learn. The kinesthetic orientation of learning through games provided by the use of tablets creates a particularly friendly, creative and pleasant environment for children, which enhances the learning process (Beschorner & Hutchison, 2013; Couse & Chen, 2010; Judge et al., 2015; McManis & Gunnewig, 2012; Neumann & Neumann, 2014). Kindergarten teachers' views confirm the superiority of tablets for educational use, as they stated that the portability of these devices provided them with a way to enhance their existing teaching practices. Moreover, they also stated that the use of tablets raised the level of student engagement in a classroom, motivated students and promoted enthusiasm for learning, and supported preschoolers' collaborative learning and creative play.

Additionally, our data suggest that gender and age are not important influencing factors in children's performance with regard to the criterion for the assessment of mathematical ability. The results of the study regarding gender are also supported by international studies (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004), which show that there is no gender differentiation in math performance in kindergarten. Finally, concerning age, the non-statistically significant effect of children's age contrasts with the findings of other studies that indicate age is a significant predictor of overall performance in number sense when they leave kindergarten (Jordan, Kaplan, Nabors Oláh, & Locuniak, 2006).

The results of this study provide a framework for the formulation of pedagogical proposals which could develop preschoolers' mathematical ability. The low math performance of children internationally reflects the need for a different approach to teaching math concepts, which is distinct from the traditional approach to learning and teaching mathematics (Kafousi & Skoumpourdi, 2008; Nunes & Bryant, 1996; Tzekaki, 2007; Zacharos, 2007). Targeted activities and successful examples of teaching interventions give preschoolers the opportunity to bridge the gap between formal mathematical knowledge provided by the school and the knowledge gained from their own daily experience (Kornilaki & Nunes, 2005).

Mobile technologies combined with an interdisciplinary approach to knowledge and organization of learning experiences that are meaningful to children could create a creative and interactive learning environment, different from that of traditional teaching in kindergartens. Therefore, regarding the didactic approach that should be followed by teachers, it is important to design mixed teaching techniques which will promote the teaching of mathematics harmoniously enhanced by use of ICT in the form of computers or tablets.

Technology is not a panacea. It is not the hardware or the software, but the combined use of ICT with the pedagogical approach that has the potential to make a significant contribution to young children's mathematical achievement. At this point elementary teachers' beliefs about mathematics must become the focus of extensive research, as it is widely accepted that they have a significant impact on what gets taught, how it gets taught, and what gets learnt in classrooms (Xenofontos, 2014). The teacher, being the prevailing source concerning the content of mathematical knowledge, is considered to be the factor that determines the epistemological level of the development of mathematical concepts in the classroom.

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