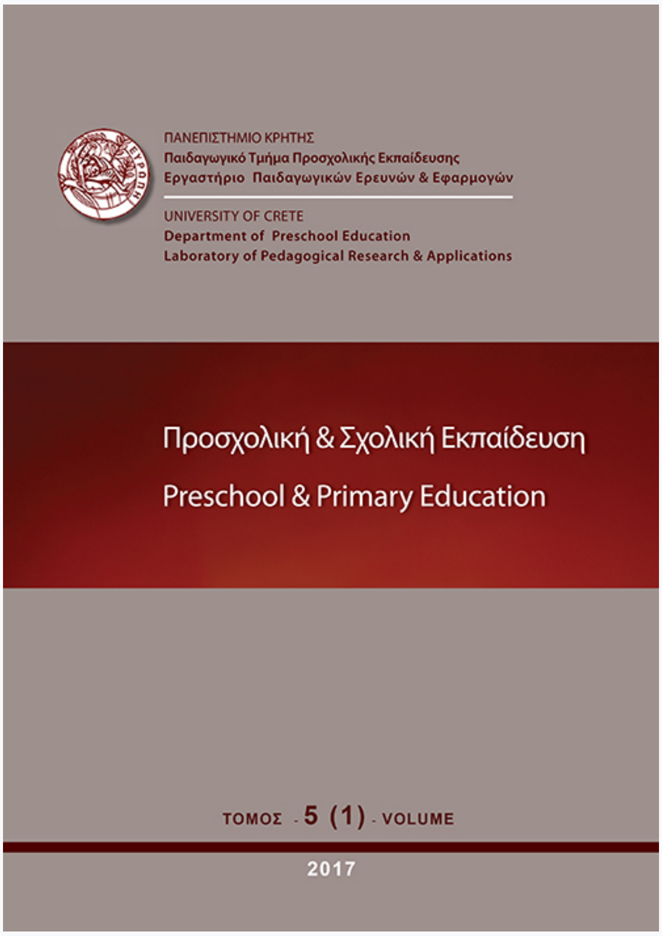
Preschool and Primary Education

Τόμ. 5, Αρ. 1 (2017)



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doi: [10.12681/ppej.9058](https://doi.org/10.12681/ppej.9058)

Preschool & Primary Education
2017, Volume 5, Issue 1, pp. 46-62
e-ISSN: 2241-7206

doi: http://dx.doi.org/10.12681/ppej.9058

Does the use of Information and Communication Technology through the use of Realistic Mathematics Education help kindergarten students to enhance their effectiveness in addition and subtraction?

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Summary. The purpose of this research is to answer the question if and how information and communications technology (ICT) combined with the Realistic Mathematics Education (RME) helps kindergarten students to enhance their effectiveness in addition and subtraction. Our research compares the level of mathematical competence of the students taught using our ICT oriented learning method which specifically takes advantage of Realistic Mathematics Education (RME) for the concepts of addition and subtraction, as opposed to traditional teaching methodology. The study dealt with kindergarten students in the city of Rethymno. The students were divided into two groups (experimental and control) during the school year 2012-13. The experimental group consisted of 165 students who were taught addition and subtraction with the support of computers and RME. There were 170 students in the control group who were not exposed to the computer oriented curriculum. Students in both groups were pre-tested and post-tested for their mathematical achievement. The educational software consisted of math activities designed on the principles of Realistic Mathematics Education for the domain of addition and subtraction. The results of the research supported a positive correlation between kindergarten children's early numeracy competence based on Realistic Mathematics Education and the integration of computers in teaching and learning addition and subtraction.

Keywords: Information and Communication Technology (ICT), Realistic Mathematics Education (RME), addition, subtraction, kindergarten

Introduction

A growing body of literature provides increasing evidence of the effectiveness of using computer technologies to facilitate teaching and learning in a variety of school subjects (Dimakos & Zaranis, 2010; McKenney & Voogt, 2009; Papadakis, Kalogiannakis, & Zaranis, 2016a; Trundle & Bell, 2010). Specifically, studies have shown that computers support the development of certain skills in children's memory, problem solving, language and mathematics (Ihmedieh, 2010; Judge, 2005; Kroesbergen, Van de Rijt, & Van Luit, 2007; Walcott et al. 2009; Zaranis, Kalogiannakis, & Papadakis, 2013). Indeed, ICT can play a key role in achieving the objectives of the kindergarten curriculum, if supported by appropriate

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e-publisher: *National Documentation Centre, National Hellenic Research Foundation*
URL: http://ejournals.epublishing.ekt.gr/index.php/education

software applications embedded in proper educational scenarios (Dwyer 2007; Fisher, Denning, Higgins, & Loveless, 2012; Lee, 2009; Zaranis, 2014).

Despite the fact that computers can be a valuable tool, there are drawbacks to integrating them into the classroom. When computers and other technological tools are used continuously, students can develop a dependency on these tools. For example, students who are never required to do math without a calculator lose their ability to solve math problems by hand. Students that use computers for almost every activity have a reduced ability to spell words correctly and even to write by hand. Students should practice these simple skills without technological tools regularly to ensure that their skills do not atrophy (Sáinz & Eccles, 2012).

Also, computers present an added challenge for teachers, as teachers have to deal with students with different levels of computer knowledge. Some students enter the classroom fully familiar with computer applications, while others come with no prior experience. Board games or card games are as engaging as computer games, but computer games do not offer the same level of player interaction as more traditional games do.

Regarding the above advantages and disadvantages of using computers we will introduce a new blended learning model with computer and non-computer oriented activities.

ICT and RME

The results of various studies link the appropriate use of computers with the ability of students to more effectively understand various mathematical concepts (Howie & Blignaut, 2009; Trouche & Drijvers, 2010; Walcott et al. 2009). A large number of studies show a positive correlation between using computers and the development of mathematical thinking in school (Clements, 2002; Papadakis, Kalogiannakis, & Zaranis, 2016b; Vale & Leder, 2004). Activities using computers should reflect and be based on theoretical ideas of a pedagogical theory (Clements & Sarama, 2004; Dissanayake, Karunananda, & Lekamge, 2007; Kroesbergenet et al., 2007; Zaranis, 2014).

Following this principle, the software designed, developed and tested for the purpose of this study was inspired by the framework of Realistic Mathematics Education (RME) (Freudenthal, 1973). RME is a theory of teaching and learning mathematics which started as a movement in the late 60s in the Netherlands in an effort to reconsider mathematics education, where until then, the mechanistic approach had been dominant. This began in 1968 with the *Wiskobas Project*, the Dutch abbreviation for mathematics in primary school (Treffers, 1987), a program initiated by the Dutch government. This project was a new approach to mathematics education that made its first steps offering an alternative to the American "New Mathematics" (Van den Heuvel-Panhuizen, 2001; Van den Heuvel-Panhuizen & Buys, 2008).

However, the fundamental ideas underlying RME were mainly inspired and influenced by its founder, Freudenthal (1973). He was the one to segregate Wiskobas from traditional arithmetic and New Mathematics and to put it towards RME (Treffers, 1993). RME was based and developed principally upon Freudenthal's view of mathematics 'as a human activity.' According to his perspective, in order for mathematics to be of human value, it has to be taught so as to be useful, and to be close to children and relevant to society (Van den Heuvel-Panhuizen, 2001, 2008). As far as numbers are concerned, Freudenthal (1973) pointed out the significance of the number sequence, the cornerstone of mathematics, and placed counting as a top teaching and learning priority that can later help students learn how to calculate.

In the whole teaching and learning trajectories of RME three levels of calculation and sensing of numbers are involved. These levels should be the main focus of the learning and teaching procedure concerning whole numbers in kindergarten. Not all children are expected to attain these levels at the same time (Van den Heuven-Panhuizen, 2008).

The first level, context-bound counting and calculating, involves young students with problem situations, in which questions of comparisons, or 'how many' questions, are posed so as to be meaningful for children, relevant to their experiences and always within a context. Examples of such questions could be 'how far', 'what time is it', 'how much does it cost', etc.

At the second level, object-bound counting and calculating, students should be able to handle direct 'how many' questions and answer them. Attention is focused on quantification, where the involvement of numbers is immediate. As a result, questions should relate to distinctive objects or quantities, such as 'how many candles are there' or 'which tin has the most sweets in it.' At this level students should be able to organize the way of counting objects, using clear patterns so as to avoid mistakes. Activities at this level could involve comparisons of quantities, problems with visible or not objects, etc. It is also important to change the starting points when using the number sequence either upwards or downwards, so that children experience different situations of calculating with numbers. Moreover, children are also able to select a suitable strategy for simple addition or subtraction problems counting up to ten objects.

At the third level, pure counting and calculating via symbolization, students no longer need the natural presence of objects in order to count, but can do so with "physical or mental representations", like numbers, fingers, dots, lines, etc. In this way, counting ceases to be object-bound and is, instead, transferred to physical or mental representations of the objects. These representations can occupy very different levels of abstraction, including that of 'pure' arithmetical numbers. A nice assignment is to ask a child to show his age without using words, for example pointing at the number 5.

Prior knowledge that children bring with them when entering kindergarten can be incorporated into these three levels (Buys, 2008). In conclusion, the RME identifies four different levels of elementary arithmetic senses (ground or zero, first, second and third), which characterize children's knowledge of numbers and mathematical skills that they have or may develop during kindergarten (Van den Heuven-Panhuizen, 2008).

These must be the main levels of the learning and teaching process used for addition and subtraction in kindergarten. Following the theoretical framework that combines the Realistic Mathematics Education (RME) and the use of ICT in kindergarten, we designed a new model referred to as the Kindergarten Addition Subtraction Model (KASM), which consisted of five phases. The Kindergarten Addition Subtraction Model (KASM) was designed in 2012 by a team of kindergarten teachers and developed in collaboration with the researcher from the Department of Preschool Education of the University of Crete in compliance with the kindergarten curriculum (Zaranis, 2014). The main purpose of the model is to foster young students' mathematical knowledge of and skills in addition and subtraction, and also to engage them in self-regulated learning, using computer and non-computer activities based on Realistic Mathematics Education. In this article the abbreviation KASM is used for the Kindergarten Addition Subtraction Model. Our study was based on the international literature mentioned above. We set out to investigate the following research questions:

1. Will the children who are taught mathematics based on the KASM have significant improvement in their overall math achievement compared to those taught using the traditional teaching method based on the current kindergarten curriculum?
2. Will the children taught mathematics based on the KASM have a significant improvement in addition compared to those taught using traditional teaching method based on the current kindergarten curriculum?
3. What is the mathematical level of children who had the greatest benefit from the KASM in addition?

4. Will the children taught mathematics based on the KASM have significant improvement in subtraction compared to those taught using traditional teaching method based on the current kindergarten curriculum?
5. What is the mathematical level of children who had the greatest benefit from the KASM in subtraction?

This research is an important contribution to the literature. We examined the effects of the KASM teaching model which supports computer and non-computer activities for teaching addition and subtraction under the Realistic Mathematics Education and compared them with the effects of teaching using the traditional method based on the current kindergarten curriculum.

Methodology

This research was organized in three stages. In the first and third stages, the pre-test and post-test were given to the classes respectively. The teaching intervention took place in the second stage.

Research Design

The present research was carried out during the 2012-13 school year in twenty-four public kindergartens located in the city of Rethymno, Crete. It was an experimental research which compared the KASM teaching process with the traditional teaching based on the kindergarten curriculum. The sample included 335 kindergarteners consisting of 159 girls and 176 boys aged five to six years old. There were two groups in the study, one control (n=170) and one experimental (n=165). The experimental group had 85 boys (51.50%) and 80 girls (48.50%). The control group had 91 boys (53.50%) and 80 girls (46.50%).

This study was a quasi-experimental design with one experimental group and one control group. Twenty-four kindergarten classes from Rethymno participated in this study. From these classes, we randomly assigned twelve classes to the control group (n=170) and the remaining twelve classes were assigned to the experimental group (n=165).

In the control group students were taught mathematics as the current kindergarten curriculum imposed. The kindergarten curriculum proposes educational software in mathematics offered by the Ministry of Education, but it does not encapsulate any pedagogical theory. It's a simple "drag and drop" program. Moreover, the majority of kindergarten teachers do not integrate ICT during the educational process. They usually have a 'computer corner,' but children rarely interact with the computer. Most of the time the computer is off, or it is an old model with which new educational programs do not work at all. Moreover, the majority of kindergartens in Greece do not have wireless internet in the classroom. There is only wired internet in kindergarten teachers' office and it is used for administrative work (Zaranis & Oikonomidis, 2009). As a result, like the control group, the majority of kindergarten schools do not use ICT during the educational process.

The classes in the experimental group had a computer for everyday use by children as part of the educational process and to teach math using computers. For the uniformity of the survey, instructions were given to the teachers who taught in the experimental and control groups. Teachers participating in the study were students from the University of Crete of the Department of Preschool Education in the fourth year of their studies and made the education process during their final thesis.

Ethical considerations and guidelines on the privacy of persons and other relevant ethical issues in social research were carefully considered throughout the process of research. Requirements relating to information, informed consent, confidentiality and use of data held was conducted both orally and in writing by informing preschool staff, children and guardians for the purpose of the study and their rights to refrain from participation.

Educational Measures

In the pre-experimental procedure, the pre-test was given to the classes of the experimental and control groups in early December 2012 to isolate the effects of the treatment by looking for inherent inequities in the mathematical achievement potential of the two groups. The pre-test was the Test of Early Mathematics Ability third edition, TEMA-3 (for the Greek adaptation see Manolitsis, Georgiou, & Tziraki, 2013).

The TEMA-3 is a norm-referenced, reliable, and valid test of early mathematical ability that is appropriate for children from age 3 years and 0 months to 8 years and 11 months. The form of TEMA-3 contains 72 items. Also, one of the aims in the development of TEMA-3 was to provide researchers with a statistical test based on theories on mathematical thinking. In particular, TEMA-3's availability would stimulate the study of mathematical thinking in young children (Ginsburg & Baroogy, 2003).

Due to the young age of the students, the pre-tests was administered to the children individually. These were the pencil-and-paper tasks in which children were asked to choose the correct answer in a problem, such as: reading and writing numbers, verbal counting, enumeration, cardinality rule, produce sets, choosing the greater and the lesser number, addition, subtraction, multiplication (Figure 1).

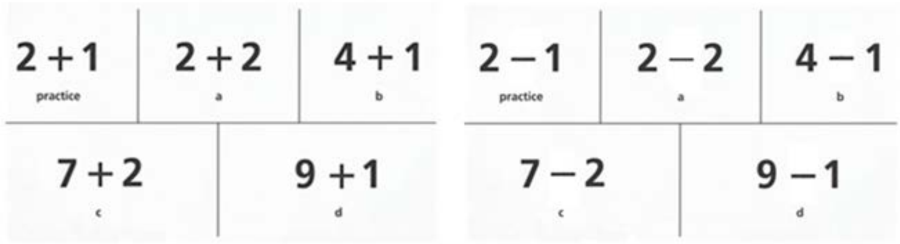

Figure 1 Student does addition (left) and subtraction (right)

Each TEMA item had a grade that was calculated from the student's answers. Scores were calculated for each of the individual mathematical tasks of TEMA-3. The TEMA-3 is not a timed test, therefore, no precise time limits are imposed on the children being tested. On average, children complete the relevant portion of the test in 45 to 60 minutes.

Similarly, during the post-experimental procedure of the study, after the teaching intervention, the same test (TEMA-3) was given to all students in both the experimental and control groups as a post-test in early March 2013 to measure their improvement in general mathematical ability, addition and subtraction.

Instructional Intervention - Experimental group

In the experimental procedure, the control group was taught with traditional teaching according to the kindergarten curriculum. The experimental group covered the same material at roughly the same time according to the KASM procedure.

In the experimental group the content of the four-week KASM syllabus was divided into five phases. It consists of mathematical activities that focus on addition and subtraction according to the RME theory (Van den Heuven-Panhuizen, 2008).

The first phase of the teaching intervention began according to the zero level of the RME theory. The prior knowledge which children bring with them when entering kindergarten is incorporated at this level (Buys, 2008). In this phase a story titled 'An

Adventure in the Forest' was presented to the students using a computer (Fig. 2- left). It involved several characters from favourite fairy tales such as Little Red Riding Hood, Hansel and Gretel, Snow Whiteand the Seven Dwarfs and the Big Bad Wolf and it included addition and subtraction problems. It was designed using Flash CS3 Professional Edition and presented with a computer in the classroom. In this story Little Red Riding Hood, Hansel, Gretel and Snow White were friends and played games (Figure 2-left). Later in the story, the Big Bad Wolf kidnapped some of the Seven Dwarfs because he was hungry. In the end they became friends and everybody was happy. During the presentation the kindergarten teacher stopped the story and asked questions such as: "how many dwarves are playing in the forest now?" or "how many dwarves have been kidnapped by the Big Bad Wolf?" Then, a child repeated the story and the students drew some of their favourite characters from the story and counted them.

The second phase began according to the first level of the RME theory, the level of context bound counting and calculating. The students identified objects of addition and subtraction by counting them in specific context. For example, the kindergarten teacher said that Tony and Maria went for a walk and met Jason, who gave Tony three candies and gave two candies to Maria. Then, the teacher asked the children, "How many candies do Tony and Maria have all together?" Another activity was a dot dice game and the children had to add up the numbers by counting in the context of the dice game. There were two white dot dice for addition which had up to five dots. Also, there were two dice for subtraction: the white die with up to five dots and the yellow die with six to ten dots. After throwing the dice, the child had to subtract the value of the white die from the value of the yellow die and them move a pawn that number of steps on a board game (Figure 2 - right). Finally, the computer activities took place with problems of addition and subtraction inside a specific context. For instance, Little Red Riding Hood went for a walk in the forest and picked three daisies. Then, Little Red Riding Hood met Gretel who gave her two daisies. The question was "How many daisies does Little Red Riding Hood have?" The computer activities where repeated with different characters and problems.

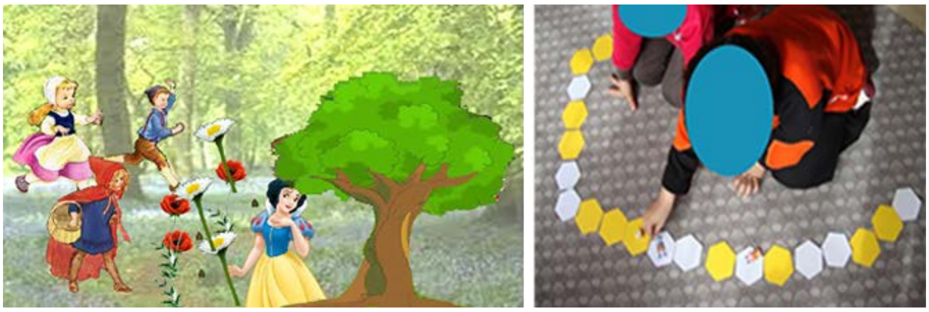

Figure 2 Students watched the story 'An Adventure in the Forest' of the first phase (left)and they had to add or subtract the numbers by counting during the dice game of the second phase (right)

The third phase of the teaching process, according to the second level of RME theory, was the level of object-bound counting and calculating with visible objects. First, the children played 'the supermarket' game. One student played the customer who wanted to buy something, and the other student acted as the cashier. For instance, the kindergarten teacher would say, "John has five euros and wants to buy two things." The student had to pick up two things whose total cost was five euros (e.g. one box of corn flakes for four euros and one bottle of milk for one euro). Next, the students had to construct the previous problem using mathematical symbols (e.g. numbers, the plus sign, the minus sign and the equal sign) in order to directly involve the numbers as symbols according to the second level of RME theory (Fig.

3-left). In the final part of this phase computer-based activities took place with visible objects based on the second level of RME addressing object-bound counting and calculating. For instance, Gretel picked up six mushrooms from the forest. There she met Little Red Riding Hood who had no mushrooms. Gretel gave Little Red Riding Hood four mushrooms. The question was "How many mushrooms was Gretel left with?" Next, the students had to construct the problem using mathematical symbols. The students were instructed by the computer to arrange and place the numbers and symbols (plus or minus) in the correct fields based on the problem that was previously presented (Fig. 3-right). The computer activities were repeated with different characters and problems.

Figure 3 The student had to construct the mathematical problem with computer (right) and non-computer (left) activities of the third phase.

In the fourth phase of the teaching process, according to the second level RME theory, the students participated in object-bound calculating with non-visible objects. In this phase the objects were hidden. For instance, the kindergarten teacher would say that Nick went for a walk and met Jason, who gave Nick a chocolate that he put in his bag. Then, Nick met Anna who gave him three chocolates that he also put in his bag. The teacher asked the children, "How many chocolates does Nick have now?" The children had to construct the mathematical problem from the hidden objects (Fig. 4 – left). Next, the children played a card game where each card had an addition or subtraction problem which was shown to the students only for 10 seconds. If a child answered correctly he/she could move his/her pawn the same number of steps as the correct answer; otherwise the pawn was not moved. Finally, a software activity followed with hidden objects based on the second level of object-bound calculating with non-visible objects. For example, Snow White gave six apples to Happy Dwarf who put them in his bag. Happy Dwarf went for a walk in the forest. There he met the Gretel who gave him two apples which he put in his bag. The question was "How many apples does Happy Dwarf have now?" Then the children had to construct the mathematical problem of the hidden objects (Fig. 4 – right). The computer activities were repeated with different characters and problems.

Figure 4 Students had to construct the mathematical problem of the hidden objects with non-computer (left) and computer (right) activities of the fourth phase.

In the final and fifth phase of the educational process, the activities focused on pure calculating, as implied by the third level of the RME theory. The students were divided into groups and played 'the advanced supermarket game - the version of the unknown number'. One student was the customer and the other was the cashier of the super market. The customer wanted to buy two things. The students knew how much money the customer had and the cost of the first item that he bought. The children had to find how much money the second item cost (Figure 5 - left). Afterwards, there were computer activities where the children had to find the missing number of an addition or subtraction problem. For example, Snow White gave seven apples to Happy Dwarf who put them in his bag. Happy Dwarf went for a walk in the field. There he met Grumpy Dwarf who had no apples. The Happy Dwarf gave some apples to Grumpy Dwarf. When Happy Dwarf arrived at Hansel's house, they counted the apples in his bag and they found five apples. The question was "How many apples did Happy Dwarf give to Grumpy Dwarf?" (Figure 5 - right) The computer activities were repeated with different characters and problems.

Figure 5 Students played games with unknown numbers without a computer (left) and with computer activities (right) in the fifth level

In the software presented above, once a child selects an activity, a math problem is announced verbally and instructions are given to the user through a recorded message. The feedback that the users get, having followed these instructions, is represented by one of the two appropriate screens, either one with a happy cartoon or another with a sad cartoon. In both cases, though, there was an effort to make the make the cartoons as bland as possible so that children's interest was focused more on the mathematical procedure of the application rather than the result.

Instructional Intervention - Control group

The children of the control group were also taught about addition and subtraction at the same time as the experimental group. The control group was taught in accordance with the monthly teaching plan the teachers had made based on the official curriculum which follows only the first level of the RME theory. The content of the teaching was a four week syllabus. It comprised mathematical activities focusing on addition and subtraction. Additional relevant activities were given to the children of the control group in order to cover the time corresponding to the computer activities of experimental group.

Quizzes were given at regular intervals and activities were assigned daily to be carried out individually or in small groups. In the zoo activity, the kindergarten teacher asked Mary to get five animals for the basket and George took three from Mary. Then the teacher asked a student, "How many animals does Mary have now?" The teacher corrected the child if he was wrong and the child had to repeat the right number. Another activity was the fisherman. The children had to catch two fish from the 'Lake.' Each fish had a price and the child had to find out how much money the two fish cost together (Figure 6 - left).

Figure 6 Students played "The fisherman" (left) in practising addition and "The blocks of house" (right)

A common activity was a game with the abacus in which children had to add and subtract numbers by counting. The activity with the 'floors of the house' was very engaging for the children (Figure 6 - right). In this activity the kindergarten teacher would say, "Jason is on the first floor and he wants to visit Pinocchio who lives on the fifth floor". Then the teacher asked Jason, "How many floors do you have to go up to reach Pinocchio's floor?" The teacher corrected Jason if she was wrong and Jason had to repeat the correct number.

Results

Analysis of the data was carried out using the SPSS (ver. 19) statistical analysis computer program. The independent variable was the group (experimental group and control group). The dependent variable was the students' TEMA-3 post-test score.

Evaluate the effectiveness of KASM for general mathematical achievement

The first analysis was a t-test among the students' TEMA-3 pre-test scores of mathematical achievement in order to examine whether the experimental and control group started at the same level. There was no significant difference in the students' TEMA-3 pre-test scores for the experimental (M =45.65, SD =20.51) and the control groups (M =43.68, SD = 23.76); $t(328.56)$ = .814, p =.416.

Before conducting the analysis of ANCOVA on the students' TEMA-3 post-test scores for general mathematical achievement to evaluate the effectiveness of the intervention, checks were performed to confirm that there were no violations of the assumptions of homogeneity of variances (Pallant, 2001). The result of Levene's test when pre-test for general mathematical achievement was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 333) = .223$, $p = .637$ - hence the assumption of homogeneity of variance was not violated.

After adjusting for TEMA-3 scores for general mathematical achievement in the pre-test (covariate), the following results were obtained from the analysis of covariance (ANCOVA). A statistically significant main effect was found for type of intervention on the TEMA-3 post-test scores for general mathematical achievement, $F(1, 332) = 18.104$, $p < .001$, Partial Eta Squared = .052 (Table 1). The experimental group performed significantly higher in the TEMA-3 post-test for general mathematical achievement than the control group.

Evaluate the effectiveness of KASM on addition

The analysis was a t-test among the students' TEMA-3 pre-test scores of addition in order to examine whether the experimental and control group started at the same level. There was no significant difference in the students' TEMA-3 pre-test scores of addition for the experimental (*M* =5.15, *SD* =3.576) and the control groups (*M* =4.79, *SD* = 3.819); t(333) = .898, *p* =.370.

Table 1 Comparison of student scores for general mathematical achievement in post-test: ANCOVA analysis

Sources	Type III Sum of Squares	df	Mean Square	*F*	Sig.	Partial Eta Squared
Pre-test	145332.316	1	145332.316	1194.764	.000	.783
Group	2202.192	1	2202.192	18.104	.000	.052
Error	40384.824	332	121.641			

Also, the analysis of ANCOVA on the students' TEMA-3 post-test scores for addition was performed to evaluate the effectiveness of the intervention. The result of Levene's test when pre-test for addition was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 333) = .672$, $p = .413$ - hence the assumption of homogeneity of variance was not violated.

After adjusting for TEMA-3 scores for addition in the pre-test (covariate), the following results were obtained from the analysis of covariance (ANCOVA). A statistically significant main effect was found for type of intervention on the TEMA-3 post-test scores for addition, $F(1, 332) = 14.320$, $p < .001$, *Partial Eta Squared* = .041 (Table 2). The experimental group performed significantly higher in the TEMA-3 post-test for addition than the control group.

Table 2 Comparison of student scores on addition in post-test: ANCOVA analysis

Sources	Type III Sum of Squares	df	Mean Square	*F*	Sig.	Partial Eta Squared
Pre-test	3713.838	1	3713.838	391.296	.000	.541
Group	135.914	1	135.914	14.320	.000	.041
Error	3151.051	332	9.491			

Evaluating the stratification of students in addition according to their success in TEMA-3

Moreover, a stratification of the experimental and control groups according to their success in TEMA-3 in general mathematical achievement of the pre-test was divided into three equal categories: less than 34 (33.33th percentile - low), 34 to 56 (33.33th to 66.66th percentile - medium), and more than 56 (66.66th percentile - high). In the following Table 3 the students' performance is presented including both groups (i.e. the experimental and the control group) before teaching.

Table 3 Frequencies of the two groups in the pre-test of general mathematical achievement

Pre-test	Experimental Group		Control Group	
Grading	*N*	*f%*	*N*	*f%*
Low	49	29.4	61	36.5
Medium	59	35.5	52	30.9
High	57	33.9	57	34.1
Total	165		170	

Table 3 shows that 33.9% of the students of the experimental group achieved high grades, 35.5% achieved medium grades, whereas 29.4% achieved low grades. Likewise, 34.1% of the control group achieved high grades, 30.9% medium and 36.5% low. In other words, students' performance in the medium category of the experimental group appeared to be superior (i.e. 35.5% compared with 30.9% of the control group).

A two-way ANOVA was conducted that examined the effect of class (experimental versus control) and the students' level of mathematical achievement (low versus medium versus high) on their improvement in TEMA-3 in addition (post-test minus pre-test score). There was no significant interaction between the effects of class and mathematical level on students according to their success in TEMA-3, $F(2, 329) = .682$, $p = .506$, *Partial Eta Squared* = .004. On the contrary, the effect of mathematical level was significant ($F(1, 329) = 14.837$, $p < .001$, *Partial Eta Squared* = .083) with the improvements in addition in the low and high levels were lower (*low-* $M = 1.61$, $SD = 2.358$, *high-* $M = 2.69$, $SD = 3.426$) than those in the medium level ($M = 3.89$, $SD = 3.358$) after the teaching intervention (Table 4, Figure 7). Also, the effect of the group was also significant ($F(1, 329) = 11.693$, $p = .001$, *Partial Eta Squared* = .034), with children in the experimental group scoring higher ($M = 3.36$, $SD = 3.208$) than those in the control group ($M = 2.12$, SD 2.986) after the teaching intervention.

The Bonferroni post hoc tests indicated that students' improvement in addition among the experimental group of the medium-level group differed significantly from students' improvement in the low-level ($p < .001$) and the high-level ($p = .028$) groups.

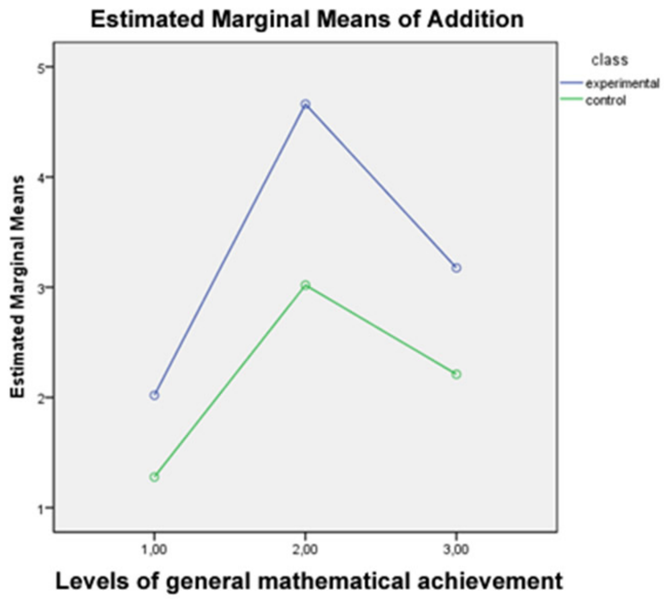

Figure 7 Mathematical improvement in addition after the teaching intervention according to the levels of general mathematical achievement

Evaluate the effectiveness of KASM for subtraction

Initially, a t-test analysis was preformed among the students' TEMA-3 pre-test scores of subtraction in order to examine whether the experimental and control group started at the same level. There was no significant difference in the students' TEMA-3 pre-test scores in subtraction for the experimental ($M = 1.99$, $SD = 1.628$) and the control groups ($M = 1.91$, $SD = 1.803$); $t(331.291) = .438$, $p = .662$.

Also, the analysis of ANCOVA on the students' TEMA-3 post-test scores for subtraction was performed to evaluate the effectiveness of the intervention. The result of Levene's test when the pre-test for subtraction was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 333) = 1.624$, $p = .203$ - hence the assumption of homogeneity of variance was not violated.

After adjusting for TEMA-3 scores for subtraction in the pre-test (covariate), the following results were obtained from the analysis of covariance (ANCOVA). A statistically significant main effect was found for type of intervention on the TEMA-3 post-test scores for subtraction, *F*(1, 332) = 201.801, *p*< .001, *Partial Eta Squared* = .378 (Table 5). The experimental group performed significantly higher in the TEMA-3 post-test for subtraction than the control group.

Table 4 Mean and Standard Deviation of mathematical improvement in addition according to the levels of general mathematical achievement

Level	Class	*M*	*SD*	N
Low	experimental	2.02	2.479	49
	control	1.28	2.222	61
	Total	1.61	2.358	110
Medium	experimental	4.66	2.795	59
	control	3.02	3.358	52
	Total	3.89	3.166	111
High	experimental	3.18	3.660	57
	control	2.21	3.132	57
	Total	2.69	3.426	144
Total	experimental	3.36	3.208	165
	control	2.21	2.986	170
	Total	2.73	3.154	335

Table 5 Comparison of student scores for subtraction in post-test: ANCOVA analysis

Sources	Type III Sum of Squares	df	Mean Square	*F*	Sig.	Partial Eta Squared
Pre-test	986.456	1	986.456	201.801	.000	.378
Group	22.263	1	22.263	4.554	.034	.014
Error	1622.899	332	4.888			

Evaluating the stratification of students in subtraction according to their success in TEMA-3

Moreover, a stratification of the experimental and control groups according to their success in general mathematical achievement in TEMA-3 was divided into three equal categories: less than 34 (33.33th percentile - low), 34 to 56 (33.33th to 66.66th percentile - medium), and more than 56 (66.66th percentile - high), as was shown in Table 3.

A two-way ANOVA was conducted that examined the effect of class (experimental versus control) and the students' level of mathematical achievement in subtraction (low versus medium versus high) on their improvement in TEMA-3 in subtraction (post-test minus pre-test score). There was no significant interaction between the effects of class and mathematical level on students' achievement in subtraction, *F*(2, 329) = .526, *p* = .592, *Partial Eta Squared* = .004. On the contrary, the effect of mathematical level in subtraction was significant (*F*(2, 329) = 10.319, *p*< .001, *Partial Eta Squared* = .059), with the improvements in subtraction in the low and medium levels being lower (*low- M* = .62, *SD* = 1.263, *medium - M* = 1.25, *SD* = 1.871) than those in the high level (*M* = 1.94, *SD* = 2.958) after the teaching intervention (Table 6, Figure 8). Also, the effect of the group was significant (*F*(1, 329) = 3.925, *p*= .048, *Partial Eta Squared* = .012).

The Bonferroni post hoc tests indicated that students' improvement in subtraction among the experimental group of the high-level group differed significantly from students' improvement in the low-level (*p*< .001).

Table 6 Mean and standard deviation of mathematical improvement on subtraction according to the levels of mathematical skills

Level	Class	*M*	*SD*	*N*
Low	experimental	.73	1.396	49
	control	.52	1.149	61
	Total	.62	1.263	110
Medium	experimental	1.44	1.887	59
	control	1.04	1.847	52
	Total	1.25	1.871	111
High	experimental	2.33	2.824	57
	control	1.54	3.059	57
	Total	1.94	2.958	114
Total	experimental	1.54	2.229	165
	control	1.02	2.186	170
	Total	1.28	2.219	335

Discussion

The overall aim of the study was to investigate the effect of the teaching intervention, using the Kindergarten Addition Subtraction Model (KASM). Mathematical activities and software based on Realistic Mathematics Education were designed for the purpose of teaching the mathematical concepts of addition and subtraction (Freudenthal, 1973; Van den Heuvel-Panhuizen, 2001, 2008). In this survey, we found that students taught by means of the educational intervention based on KASM had significant improvement in their overall math achievement compared to those taught using the traditional teaching method according to the kindergarten curriculum. Our findings agree with similar studies (Judge, 2005; Keong, Horani, & Daniel, 2005; Walcott et al., 2009; Zaranis, 2011), which implied that ICT combined with the RME theory helps students understand mathematical concepts more effectively. As a result, the first research question was answered positively.

Moreover, we found that students taught with the educational intervention based on KASM had significant improvement in addition compared to those taught using the traditional teaching method according to the kindergarten curriculum. Our results coincide with the results of other similar studies showing the positive impact of a computer-based model of teaching mathematics (Dissanayake et al., 2007; Kroesbergen et al., 2007). Therefore, the second research question was confirmed.

Also, our findings suggest that students belonging to the medium level of general mathematical achievement being taught addition with the educational intervention based on KASM had significant improvement, compared to the students in the low and high levels of general mathematical achievement. So the third research question was addressed.

Furthermore, as mentioned in the results section, the students taught with the educational intervention based on KASM had a significant improvement in compared to those taught using traditional teaching according to the kindergarten curriculum. Our results agree with the results of other similar studies showing the positive outcomes of a computer-based model of teaching mathematical concepts (Dimakos & Zaranis, 2010; Howie & Blignaut, 2009; Starkey, Klein, & Wakeley, 2004; Papadakis et al., 2016b; Trouche & Drijvers 2010; Zaranis et al., 2013). Therefore, the fourth research question was also answered positively.

Moreover, our findings suggest that students with a high level of general achievement in mathematics being taught subtraction with the educational intervention based on KASM had significant improvement, compared to those with a low level of general mathematical achievement. Subtraction is difficult for kindergarten students (Kamii, Lewis, & Kirkland, 2001) and as a result computers assist students of all levels of general mathematical achievement equally. On the contrary, addition is simpler for kindergarten students to understand and computers help students with a medium level of mathematical achievement more than the others. Our results exceeded the outcomes of other similar studies showing the positive results of a computer-based model of teaching mathematical concepts (Keong et al., 2005; Zaranis 2011). Thus, the fifth research question was also addressed.

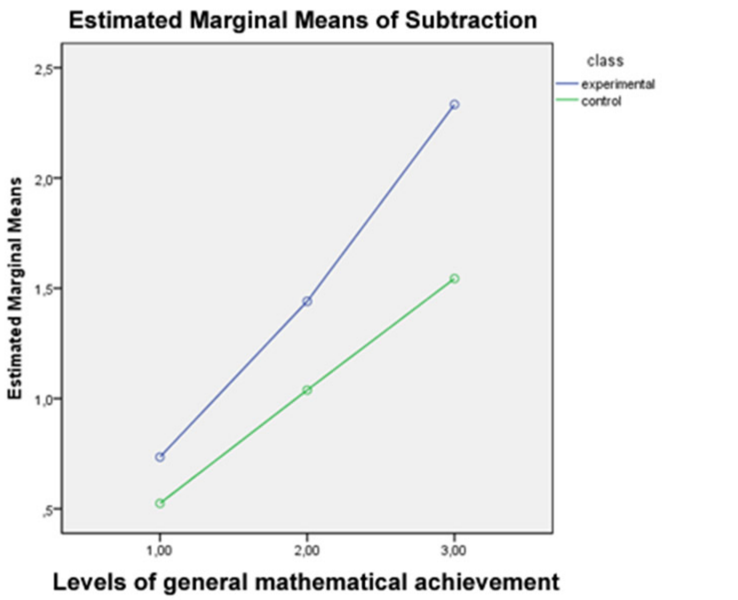

Figure 8 Mathematical improvement in subtraction after the teaching intervention according to the levels of general mathematical achievement

Regarding the educational value of the present study, its findings should be taken into account by a range of stakeholders such as students, teachers, researchers, and curriculum designers. Specifically, our teaching approaches could be set up as a broad range study to examine to what extent they help children understand addition and subtraction. We, as instructors of educators, will certainly try to inform our students about these results which they will need to keep in mind when designing activities for children. Moreover, the learning method based on Realistic Mathematics Education (RME) using ICT can be used in various mathematical subjects as a research plan. The result of this research can be extended by developing various similar studies in geometry and mathematics (geometry shapes, multiplication, division etc.) in the kindergarten and the first classes of the primary education.

The above discussion should be referenced in light of some of the limitations of this study. The first limitation of the study is that the data collected was from the participants residing the city of Rethymno, Crete. The second limitation was the generalizability of the study which was limited to participants attending public schools. The third limitation was that the intervention fidelity was not been controlled. Therefore, this research may be extended by developing tools to measure intervention fidelity. As a result, the outcomes from this research can be generalized only to similar groups of students. The results may not adequately describe students from other regions of Greece. However, as the study was in a specific context, any application of the findings should be carried out with caution.

Furthermore, the computer assisted educational procedure undertaken revealed an extended interest in the tasks involved on the part of the students. It is an ongoing challenge for the reflective teacher to decide how this technology can be best utilized in education;

especially in light of the current research on the effects of such an implementation. This study is one small piece in the puzzle of math education at the kindergarten level.

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Received: 6.6.2016, Revised: 27.8.2016, Approved: 28.8.2016