

TEACHING EARLY MATHEMATIC IN SCHOOL USING INFORMATION AND COMMUNICATIONS TECHNOLOGY. INTERVENTION EVIDENCE-BASED

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Abstract

In the school-age population, the prevalence of mathematics disabilities is 5%–9% (Geary, 2004; Jordan, 2007). Lifelong opportunities associated with math disability form a critical problem. Math skills accounts for an important part of the variance in work productivity, income, and employment, even more than reading and intelligence (Fuchs, Powell, Seethaler, et al., 2009). It is therefore important to search for ways to prevent mathematics difficulties. Research shows that early intervention activities can substantially improve math performance (Clements & Sarama, 2007). However, not all approaches are effective for all students. For example, after a one-year prevention program for first-grade students, approximately 3%–6% of the school population continued to manifest severe mathematical deficits (Compton, Fuchs, & Fuchs, 2007). This study evaluated the effectiveness of educational intervention software, *Playing with Numbers-2* on early mathematics learning. This software trains learning and mathematical reasoning skills, using an evidenced-based procedure. A total of 128 second-year preschool boys and girls (Mean age = 53.28 months) were assessed by the Early Numeracy Test (ENT), a computerized test to evaluate early math competency. We used an experimental design with control group and pre and post-intervention assessments. The experimental group ($n = 30$) was composed by students from each classroom with the lowest ENT scores (≤ 19). Control group ($n = 98$) was composed by all the other students across classrooms. The intervention was carried out during 30 sessions (3 sessions per week, 30-45 minutes each), using the software, *Playing with Numbers-2*. The experimental group significantly improved the ENT scores, matching the control group (??). Significant differences between pre- and post- intervention for the experimental group were obtained ($t=13.037$, $p<.005$). The average increase for ENT scores achieved by the experimental group was significantly higher than the control group. The intervention effect size showed higher values for the experimental group ($d = 2.75$, $r = .80$). This groups' score was higher than the control group in all of the ENT subtests and over the total test. This educational intervention using computer-based software, while it does not replace face-to-face instruction, may help to improve the performance of young students at risk of developing problems learning mathematics.

Keywords: early mathematics, low math achievement, Early Numeracy Test, *Playing with Numbers-2*.

Introduction

Mathematical performance contributes an important part of the variance ascribed to income, employment, and work productivity, even more than intelligence. In the school-age population, the prevalence of mathematics disability is 5%–9%, and lifelong opportunities associated with math disability form a major barrier to school and later career success (Fuchs, Powell, Seethaler, et al., 2009). It is therefore important to investigate if early mathematic assessment and treatment can improve math performance (Clements & Sarama, 2007; Navarro, Aguilar, Marchena, Ruiz, Menacho & Van Luit, 2011). The early identification of children at risk of lower mathematical achievement is needed because of the major impact it has on school and life for every student. Considering the importance of early math learning in schools, and the use of new ICT teaching methodology, the authors present different aspects of assessment and intervention in early math for young children applying an evidence-based procedure. The main aims of this presentation are:

- (a) To identify the cognitive processes that underlies the individual differences in early mathematical performance in elementary school children. Taking into account the Baddeley (1997) framework multicomponent model, the inhibitory processes, working memory, phonological awareness, and naming speed are thought to be related to early math learning.
- (b) To present an early math intervention program with preschool Spanish children. This program is a piece of software, *Playing with Numbers II*. The activities of "*Playing with Numbers II*" are designed in within the theoretical framework of Gelman and Gallistel (1978) and Piaget (1965). The software includes activities aimed at learning the concepts related to the development of abilities such as: comparison, classification and seriation of objects and combination and distribution as problem-solving strategies. Lastly, the software introduces, "*The Number Line*" activities, which consolidates counting skills.

Methodology

Procedure: A total of 128 second-year preschool boys and girls (Mean age = 53.28 months) were assessed by the Early Numeracy Test (ENT), a computerized test to evaluate early math competence. We used an experimental design with control group and pre and post-intervention assessment. The experimental group ($n = 30$) was composed by students from each classroom with lowest ENT scores (≤ 19). Control group ($n = 98$) was composed by all the other students. The intervention was carried out during 30 sessions (3 sessions per week, 30-45 minutes each), using the software *Playing with Numbers-2*.

Materials: The software program presented in this paper target the learning of specific math concepts. Stressing the importance of significant mathematical learning for all students, Bryant and Nunes (2002), have suggested that the basis of the development of maths skill in children is logical thinking, the learning of conventional number systems, and the setting of maths (??). The software, "*Playing with Numbers 2*", includes activities aimed at learning the concepts related to number acquisition and counting ability, the development of concepts of comparison, discrimination, seriation and problem-solving. Eleven different computer games are included in the software:

1. "*Learning to Count*" consists of 5 counting activities that help students start learning the number sequence, through activities designed to differentiate between counted and uncounted objects. It has four sub-programs, each with a different level of difficulty based on four variables: (a) whether the number of objects is the same or different to the number the program requires the student to count, (b) if the program speaks/vocalizes the number when the object is touched or not, (c) if the number required appears on the screen, and (d) if the objects appear in order or out of order. The difficulty of the different levels is shown by whether the object counted disappears, is modified or remains unchanged.
2. "*Number Chain*". This program strengthens student learning of the number sequence through activities aimed at the acquisition of forwards and backwards counting, starting from a predetermined number less than ten. These activities allow not only the acquisition of the number sequence, but the ability to discover, through doing operations, how many numbers there are between the two requested numbers. It has two sub-programs with nine levels of complexity: in the first four levels (N1, N2, N3, N4) the activities focus on counting forwards, the following four (N5, N6, N7, N8) focus on counting backwards. The last level (N9) asks for the number of squares between the two numbers indicated, requiring forwards or backwards counting.

3. "*Calculation*". The program aims to develop the concept of the cardinal value of numbers through practical activities. By presenting different tasks, students will discover that the last number of the counting process represents the value or quantity of the specific set of objects counted. The program consists of five activities that randomly ask students to indicate how many objects there are, the number varying from 1 to 20. In each of the activities, the computer asks the student to count how many items appear on the screen and indicate the number on the calculator that appears on the right of the screen.
4. "*Number Cruncher*". This aims to develop the graphic discrimination of numbers, and the association with their respective label, through practical activities. At the end of the program, a screen appears showing the following information: the number of correct answers, number of errors, number of intermediate errors and the final score.
5. "*Comparison*". By presenting different tasks and levels of complexity, students discover the differences and similarities between two or more situations. The program features activities designed to differentiate between two objects and differentiate objects from a model. It has two subprograms: "Comparisons Level 1" and "Comparisons Level 2".
6. "*Classification*". This helps the student to start learning the concept of object grouping. By presenting different tasks, students will discover classification and the possibility of distinguishing between objects and groups of them. It has three levels of difficulty. Each level has 3 activities aimed at grouping objects by one feature, the number of cubes per colour in level 1 and 2 is always the same and in level 3 each group of cubes is different.
7. "*Ordering*". This program helps the student to start learning the concept of object ordering. By presenting different tasks, students will discover order in a series of discrete objects according to a specific characteristic. It has three levels of difficulty. There are several activities aimed at discriminating groups of objects (level 1) or groups of numbers (level 2 to 9 and level 3 exercises 10 to 20) that are ordered, from those which are not.
8. "*Combination*". Students start to learn "part and whole" problem-solving. They work on static problems in "Combination I" in which they are given the details of both parts and they are asked for the whole and in "Combination Level 2" the whole and one of the parts appears in the statement of the problem and they are asked for the other part.
9. "*Discrimination*". The activities in this program aim to teach the child to differentiate between the cardinal value of numbers and the physical size of their representation. To this end, we present three sub-programs with different levels of complexity depending on whether the numbers have one, two or three digits and whether the two numbers being compared are the same size or a different size, with no relationship between the cardinal value and the physical size (Figure 1).
10. "*Distribution*". This program involves the ability to distribute a group or groups of objects into equal or unequal groups via problems in which a number of objects has to be shared among a number of subjects with the requirement that each has the same number of objects. The difficulty increases when we change the number of subjects or we increase the number of objects to be shared.
11. "*The Number Line*". This strengthens counting ability through Number Line activities. The program asks the child to indicate a number on the number line. There are four sub-programs where the level of difficulty lies in the sequence of numbers presented (from the easiest level, where there are ten single digit numbers, to the following levels where twenty, two-digit numbers are presented, sometimes at random) or in the presentation of all, some or only the beginning and end of the sequence (the missing number is replaced by a line). The first, last and middle numbers are represented by a circle, the position of other numbers with a line.



Figure 1. *Playing with numbers 2*. Some examples of *Discrimination* and *The Number Line* activities.

Results and discussion

Descriptive results were calculated before and after intervention using the Spanish version of the Early Numeracy Test-R as a dependent variable (Table 1). On pre test phase, control group was $Mean = 24.34$ ($sd = 5.57$), and experimental group $Mean = 14.33$ ($sd = 2.61$).

		Pre-test		Post-test	
		<i>Mean</i>	<i>sd</i>	<i>Mean</i>	<i>sd</i>
Experimental Group	Piagetian tasks	9.20	2.64	13.93	2.31
	Numerical tasks	5.13	2.04	12.07	3.75
	Total Test	14.33	2.61	26.00	5.46
Control Group	Piagetian tasks	12.69	2.67	12.56	2.46
	Numerical tasks	11.64	4.13	12.91	3.76
	Total Test	24.34	5.57	25.47	5.16

Table 1. Descriptive results (*mean* and *sd*) for experimental and control groups before and after intervention using the Spanish version of Early Numeracy Test-R.

Mean score for all participants' show a positive increments after intervention, in both numerical and Piagetian tasks. All participants increased scores in second evaluation. Differences in math competency were significant ($t = -13.037$; $p < .005$). After intervention, the control group increased the ENT-r scores reaching equivalent results than experimental group, reducing the gap between both groups.

Gaining obtained by experimental group after intervention were higher than control group scores for total test and different subtasks (Table 2). The math achievement for experimental group participants reached a $Mean = 11.6$ points, and for control group participants increased was just $Mean = 1.63$ points. Intervention had a positive impact especially for Piagetian tasks. Increasing scores for numerical tasks were lower than Piagetian tasks such as control group (increment score = .03) as experimental group (increment score = .73). Differences between pre and post intervention for control group were almost zero.

	Experimental Group		Control Group	
	Mean	sd	Mean	sd
Total Test	11.67	4.90	1.13	4.61
Piagetian tasks	4.73	2.71	- .13	2.63
Numerical tasks	.73	1.23	.03	.80

Table 2. Increase score for the Spanish version of Early Numeracy Test-R., after intervention sessions using “Jugando con Números-2” [Playing with numbers-2] software (post-test phase).

Considering the study characteristics, the *effect size* was calculated to determine the treatment impact of the experimental group. The value for size effect used was the truncated Cohen’s *d* (1988). Mean differences between pre test and post test were calculated by dividing the intra-group standard deviation. Data shows that experimental group had a progressive score increasing with significant differences between pre and post treatment ($d = 2.75$; $r = .80$) for the Spanish version of Early Numeracy Test-R score. However, data were not significant for control group ($d = .19$; $r = .095$.)

Conclusions

The main purpose of this presentation was to discuss an intervention program with preschool Spanish children in early math. This program was designed using the theoretical framework of Gelman, Gallistel and Piaget. It included activities aimed at learning concepts related to the development of specific mathematical skills such as: comparison, classification and seriation of objects, and the combination and distribution of problem-solving strategies. Lastly, the software introduces, “The Number Line” activities, which attempts to consolidate counting skills.

After the training sessions, results show that the experimental group significantly increased ENT-b scores, and differences between good (control group) and bad math performers (experimental group) dramatically were reduced. There were no gender differences between groups. Those results are similar to other mathematical training programs that used somewhat different methodologies (Clements y Sarama, 2007), and may be useful predictors for future math failure in young children (Siegler y Ramani, 2009). This is particularly important because of the implication for developing “number sense” in early math learning.

If the Piagetian and numerical tasks are considered, the training program significantly increased performance for Piagetian over the numerical ENT-subtests. This was an interesting finding because early math learning may require both Piagetian and numerical tasks as has been considered by different studies (Bryant, 2005; Fuchs, *et al.*, 2009). However, the Estimation task was clearly the most difficult ENT-subtest for both high and low performers. This suggests that task adjustment is a key issue in order to improve efficiency of students using *Playing with numbers-2*.

References

- Baddeley, A. (1997). *Working memory*. Oxford, UK: Clarendon Press.
- Bryant, D. P. (2005). Commentary on early identification and intervention for students with mathematics difficulties. *Journal of Learning Disabilities*, 38, 340–345.

Clements, D.H., Sarama, J. (2007). Building blocks for early childhood mathematics. *Early Childhood Research Quarterly* 19, 181–189.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, N.J.: Erlbaum.

Fuchs, L. S., Powell, S. R., Seethaler, P. M., Cirino, P. T., Fletcher, J. M., Fuchs, D., . . & Zumeta, R. O. (2009). Remediating number combination and word problem deficits among students with mathematics difficulties: A randomized control trial. *Journal of Educational Psychology*, 101, 561–576. doi:10.1037/a0014701.

Gelman, R., & Gallistel, C. (1978). *The child's understanding of number*. Cambridge, MA: Harvard University Press.

Navarro, J. I., Aguilar, M., Marchena, E., Ruiz, G., Menacho, I. & Van Luit, H. (2012). Longitudinal study of low and high achievers in early mathematics. *British Journal of Educational Psychology*, 82, 28-41. doi:10.1111/j.2044-8279.2011.02043.x.

Piaget, J. (1965) *The Child's Conception of Number*. New York: Norton.

Siegler, R. S. y Ramani, G. B. (2009). Playing Linear Number Board Games—But Not Circular Ones—Improves Low-Income Preschoolers' Numerical Understanding. *Journal of Educational Psychology*, 101, 545–560. doi:10.1037/a0014239

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