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Using an Augmented Reality Enhanced Tabletop System to Promote Learning of Mathematics: A Case Study with Students with Special Educational Needs

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ABSTRACT
The main objective of this research is to determine the feasibility of using a multi touch tabletop system for applied mathematics learning in primary education with students with special needs (SEN). The instructional content designed on the tabletop focuses on understanding and managing money, coins, and banknotes. The study also analyzes the impact of this technology on students' motivation. The tabletop system was used in a real educational setting, where we compared the learning experience of the students before and after using the tabletop. The evaluation method focused on three elements: the increase of knowledge, the relationship between the acquired learning depending on the educational level and the type of educational needs, and the student's satisfaction and motivation after using the tabletop. Our results reveal that the tabletop is a feasible technology that can be successfully applied in special educational needs contexts.
Keywords: Mathematics learning, multi touch interaction, special educational needs, tabletop

INTRODUCTION

Mathematics, understood as "a system of tools, products and processes" used by people in their lives to make daily decisions and guide their actions is very important in society (Niss, 1995). From this point of view, mathematics must give priority to problem-solving methods based on the experience of everyday life (Schliemann & Carraher, 2002). Learning applied mathematics is more important for people with special educational needs (SEN). Although these students will probably not obtain standard mathematical skills (list, numeracy, problem solving, etc.) as the rest of their fellows (Fletcher, Lyon, Fuchs, & Barnes, 2007), they

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State of the literature

- Learning applied mathematics is very important for people with special educational needs. Emphasizing the skills and competencies needed to cope with daily problems can be beneficial for this group of students.
- SEN students cannot fully benefit from mathematics instruction and curriculum in general education classrooms due to the rapid pace of introducing new mathematical concepts, the lack of examples, and insufficient explanations, practices, and reviews.
- Technology can adapt and individualize mathematics instruction for SEN students. Researchers and teachers in the field of special education have made efforts to incorporate technology into math curricula for these students to improve their results.

Contribution of this paper to the literature

- The study provides evidence to suggest several reasons why the tabletop instructional effectiveness is higher than that using traditional construction tools with this kind of students.
- The tabletop is shown as a new technology-based artifact which offers new ways of interacting with the European monetary system, and using technology as an "object-to-think-with".
- The study shows the tabletop as a tool to increase the motivation of students throughout the teaching/learning process, and thus, increasing their assimilation of knowledge, as well as the collaboration between them, solving problems together by using the tabletop system.

do need to use practical mathematics to face their everyday lives. For this reason, mathematics instruction from a pragmatic point of view, emphasizing the skills and competencies needed to cope with daily problems (Leonelli & Schwendeman, 1994), can be beneficial for this group of students. Many researchers in the field of special education are trying to increase mathematics performance in students with learning difficulties (Fuchs et al., 2008; Gersten, Jordania, & Flojo, 2005).

According to the current Spanish legislation regulated by the "Ley Orgánica de la Educación" (2006), the concept of SEN covers the students who require additional educational support due to disabilities or important behavioral disorders. The legislation also reinforces the principle of student's diversity and defines education in terms of inclusion, flexibility, and equity, which guarantees equal educational opportunities for all. Hence, schools and teachers should be prepared to fulfill these principles and give the appropriate support to all students. However, there has been evidence (Cawley & Miller, 1989; Cawley, Parmar, Yan, & Miller, 1998) that students, with special educational needs cannot fully benefit from mathematics instruction and curriculum in general education classrooms (Salend, 1994). According to the author, it is very common that SEN students struggle with the rapid pace of introducing new mathematical concepts, the lack of examples, and insufficient explanations, practice, and reviews in general education classrooms (Salend, 1994).

To address the challenges faced by these students, many researchers recommend using technology because of its power and flexibility (Woodward & Carnine, 1993). Technology can adapt and individualize mathematics instruction for students with special educational needs (Bryant & Bryant, 1998; "National Council of Teachers of Mathematics", 2000), provide students with a variety of individualized math instruction tailored to their characteristics, and increase students' performance (Hasselbring, Goin, & Bransford, 1988; Symington & Stranger, 2000). Interaction with technology makes students actively participate in the learning process, improves instruction understanding, and improves learning outcomes (Chou, 2003; Crowther, Keller, & Waddoups, 2004; Hinostroza & Mellar, 2001). However, what technology is the most useful for SEN students? Are there any differences among the technological tools currently available?

The quality and availability of technological tools have increased over the past decades. Researchers and teachers in the field of special education have made efforts to incorporate technology into math curricula for students with learning difficulties to improve their results effectively and efficiently (Anderson-Inman, Knox-Quinn, & Horney, 1996; Ferretti & Okolo, 1996, Raskind & Higgins, 1998; Torgesen & Barker, 1995, Woodward & Carnine, 1993; Robinson, DePascale, & Roberts, 1989). As it is expected, students' effort is also required. Due to the comprehensive nature of mathematics, students with learning disabilities need a sufficient number of practice sessions, and various representative examples to learn and understand the material (Fuchs et al., 2008).

Based on the studies mentioned earlier, this work tries to explore the use of tabletop systems as a technological tool to support an active learning approach in mathematics for students with special educational needs, in line with other works in the literature (Goh, Shou, Tan & Lum, 2012; Higgins, Mercier, Burd & Joyce-Gibbons, 2012; Hwang, Shadiev, Tseng & Huang, 2015; Roldan-Alvarez et al., 2015). An initial description of the educational application developed to teach the use of the monetary system is provided in the next section. Finally, an experimental design implemented to evaluate the impact of the tool on the learning process is presented. The evaluation is focused on quantitative results to assess the overall effectiveness of tabletops and the motivation that they can provide to children with special educational needs.

METHOD

Participants

A convenience sample of twenty-two students with SEN, whose age ranged between 6 and 12, enrolled in primary education in a public school in Alicante (Spain) was selected. Their curricular competence level is described in **Table 1**. The sample grouped by type of educational need is illustrated in **Table 2**.

Table 1. Students' educational level according to their competence-based curriculum

Educational level	First	Second	Third
Number of participants	8	4	10

Table 2. Participants according their special educational needs

Type of special educational need	Delayed maturation	Attention Deficit Hyperactivity Disorder	Learning disorder not otherwise specified	Learning Disabilities	Mild mental retardation
Number of participants	2	5	8	5	2

Apparatus

Our methodological approach focused on the use of the monetary system and solving different problems using our own developed tabletop system (Self ref.). The tabletop is comprised of a video projector and two cameras with stereoscopic view of the interaction area (**Figure 1**). The main advantage of this system is that it can be used by multiple users supporting multi-touch interaction. The system recognizes multiple fingers and hands. This means that multiple users can interact with the system while allowing cooperative interaction. The tabletop system implements an application protocol interface (API) based on the TUIO protocol (Kaltenbrunner, Bovermann, Bencina, & Constanza, 2005), which provides information about the status, position and orientation of the fingers, and supports augmented reality applications. The system is capable of recognizing different types of augmented reality markers, and returning the marker's location and orientation in 3D space. The main feature of this tabletop design is its ability to transform any type of table into an interactive surface. Because of this, students' desks can be used as interactive surfaces allowing an easy installation in any classroom. Additionally, the auto-calibration capability is robust enough to allow tabletop system movement anywhere in the classroom, without changing its configuration.

Figure 1. Tabletop system

Figure 2. Students using the tabletop

Materials

A set of interactive 3D educational materials related to the European monetary system were developed for this tabletop. The application allows visualization and manipulation of all coins and notes of the European monetary system. It also promotes the association of coins and notes with the corresponding amount, creating a scenario where students can solve mathematical problems in a virtual shopping simulation game (see **Figure 2** and **3**).

Figure 3. Students working collaboratively

Figure 4. Augmented book launching page for the application

Launching the software is accomplished by the augmented reality capabilities of the tabletop system. An augmented book was developed to explain the advanced features of the tabletop software and serve as a launching mechanism for a series of educational contents. Showing the page corresponding to the monetary system application is sufficient to launch the application, which is made possible by the marker less augmented reality feature (an image is used as an augmented reality marker) (see **Figure 4**)

Procedure

Once parent consent was obtained, participating students were informed about the study schedule (see **Table 3**) and the goal of the learning activities. A regular class was used for this introduction, so students would not be distracted by the tabletop and miss important points. In this class, all students' questions were answered.

Table 3. Events during the implementation

Week 1	Week 2	Week 3
Explanation	Tabletop activity	Tabletop activity
Pre-achievement test		Post-achievement test
Tabletop activity		Motivation achievement scale

After this explanatory class, during the first week, the selected students individually passed the pre-achievement test. In subsequent classes, students performed the program

with the tabletop. During a three week period, students worked with the tabletop for three hours per week. During lesson development, students worked collaboratively in groups with the teacher's assistance. In the third week, children passed the post achievement test and the motivation questionnaire.

Table 4. Results obtained from the validation performed by education experts

		Criteria							
		Clarity		Relevance		Accessibility		Exclusivity	
Dimension	***N***	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**
1. Coin identification	10	3.53	.18	3.51	0.19	3.53	.15	3.73	0.23
2. Bill identification	10	3.58	.29	3.53	0.28	3.60	.25	3.57	0.21
3. Attach the correct amount	10	3.42	.30	3.37	0.27	3.38	.17	3.63	0.18
4. Money associated by number	10	3.67	.26	3.40	0.25	0.40	.21	3.64	0.11
GLOBAL	10	3.47	.14	3.45	0.16	3.47	.11	3.65	0.14

Note: Likert scales

Clarity: Writing clearly without ambiguity.

1: Not clear *2: Vaguely clear* *3: Clear* *4: Very clear*

Relevance: The importance for the assessment of the monetary system.

1: Not relevant *2: A little relevant 3: Relevant* *4: Very relevant*

Accessibility: the response using one or more instruments.

1: Not available *2: Soon available* *3: Accessible* *4: Very accessible*

Exclusivity: Content different from that included in other items.

1: Nothing exclusive *2: A little exclusive* *3: Exclusive* *4: Very accessible*

To evaluate the learning improvement using the tabletop system and the application, a quasi-experimental design was used with pre-posttests without a control group (due to the relative small number of participants). A test of knowledge comprised of four activities (Annex I) was used for both pre and posttests. The validation of this instrument was done by a group of ten experts in the area of special education using a multiple choice instrument (Annex II). This tool evaluated five criteria: clarity, relevance, accessibility, exclusivity, and adequacy. From the results shown in **Table 4**, we note that, in general, the reviewers assessed a score close to excellent (near to 4 points) with a significant degree of agreement between them, and obtained a significant Kendall coefficient of concordance ($W=0.89$, $p<.001$). Moreover, the multiple-choice instrument was found to be highly reliable (4 items; $\alpha=.83$).

On the other hand, student's motivation was evaluated with a fourteen item questionnaire based on a five level Likert scale (see **Table 5**).

Table 5. Motivation questionnaire and results

Question		Frequencies				
		1= Never	2= Rarely	3= Sometimes	4= Almost always	5= Always
1.	I want to know and learn to manage money with the tabletop system.	-	-	-	3	19
2.	For me, it was easy to learn the different euro notes and coins.	-	-	6	8	8
3.	For me, it was easy to learn the different euro notes and coins using the tabletop.	-	-	-	7	15
4.	My teacher has explained the monetary system and how to perform operations with coins and bills in the tabletop system.	-	9	8	4	1
5.	I have learnt the euro system better by completing exercises individually with paper and pencil as opposed to using the tabletop system.	-	21	1	-	-
6.	Solving activities and problems working in a group with the tabletop has helped me learn the monetary system better than using traditional methods, paper and pencil.	-	-	-	7	15
7.	I have performed all the activities to learn the monetary system in a group with the tabletop system.	-	-	-	4	18
8.	I like when my teammates help me when I do not know how to continue.	-	-	-	3	19
9.	When working with colleagues in the tabletop, I try to help them if they have difficulties understanding something.	-	2	13	7	-
10.	I find it enjoyable to study the monetary system with the tabletop.	-	-	-	7	15
11.	The use of a tabletop system has helped me understand the euro.	-	-	-	-	22
12.	Learning the euro is required to pass math.	-	-	-	8	14
13.	After studying the euro I have found that math is fun.	-	-	-	5	17
14.	Learning the euro and practicing with the tabletop has been a great effort.	-	6	8	6	2

Data analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS version 19.0) in Windows 7 Professional. Data analysis was performed at two different levels: a descriptive level and an inferential level. The descriptive level included both the results of the pre-test and the post-test of knowledge and the motivation questionnaire. The results of the four activities and the full test were expressed in frequencies and percentages.

Because of the small sample size, nonparametric statistics were used for the inferential analysis (Pardo & Ruiz Diaz Merino, 2005).

RESULTS AND DISCUSSION

Total pre-test and post-test results are summarized in **Table 6**. Detailed pre-test and post-test results by type of learning exercise are shown in **Table 7**.

Table 6. Results in the total test (normalized to 1)

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Total pretest	22	.30	.70	1.00	.37	.099
Total posttest	22	.29	.15	.44	.90	.068

Table 7. Pretest and posttest achievement results by activity (normalized to 1)

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Total pretest A1	22	.5	.13	.63	.44	.12
Total posttest A1	22	.25	.75	1.00	.95	.083
Total pretest A2	22	.57	.00	.57	.34	.13
Total posttest A2	22	.29	.71	1.00	.98	.067
Total pretest A3	22	.20	.20	.40	.34	.095
Total posttest A3	22	.40	.60	1.00	.87	.13
Total pretest A4	22	.29	.14	.43	.31	.12
Total posttest A4	22	.43	.57	1.00	.83	.11

Note: *A.1: students are asked to recognize all the euro bills and coins used in the activity.*
A.2: activity where students have to recognize euro banknotes.
A.3: shopping activity.
A.4: activity where students are asked to gather coins and notes to collect an exact amount of money.

Table 8 provides the total results grouped by the type of special educational need. Detailed results are provided for those student groups whose sample size was larger. Hence, it was studied: attention deficit disorder, learning disorder not otherwise specified and learning difficulties. **Table 9** organizes the results by educational level whereas **Table 10** organizes them by special educational need and activity. **Figure 5** summarizes relative frequencies for each of the four activities carried out by the students.

In the first activity, students were asked to associate each coin with the corresponding currency amount. After finishing the experiment, it was observed that all students knew the one euro currency. However, none of them recognized the two euro and 20 cent coins. After working with the tabletop, we found that only 4% of the students had problems with the 2-euro coin (**Figure 5**).

In the second activity, students were asked to match each bank note with the corresponding currency amount. Before the tabletop was used, almost 70% of the students knew the 5 euro note. Nevertheless, the number of correct answers decreased as the value of the banknotes increased. In fact, only 4% of the students were able to recognize the 500 euro note. After using the tabletop, almost everyone recognized all bills. Only about 4% of students had difficulty recognizing the 5, 100, and 200 euro bank notes (**Figure 5**).

In the third activity, students played a role game where they pretended to be customers in a general store. In this game, they had to select the exact amount of money to buy different objects individually. Before the tabletop system was used, 95% of the students were able to correctly select 20 cents, 63% of the students spent 1.30 euro properly, and only 10% of them were able to buy a 3-euro object. After using the tabletop, the results improved substantially, as shown in **Figure 5**. Results indicate that all students were able to select any amount of money, except the last one, which apparently was the most difficult. In this case, only 60% of the students were able to pay correctly.

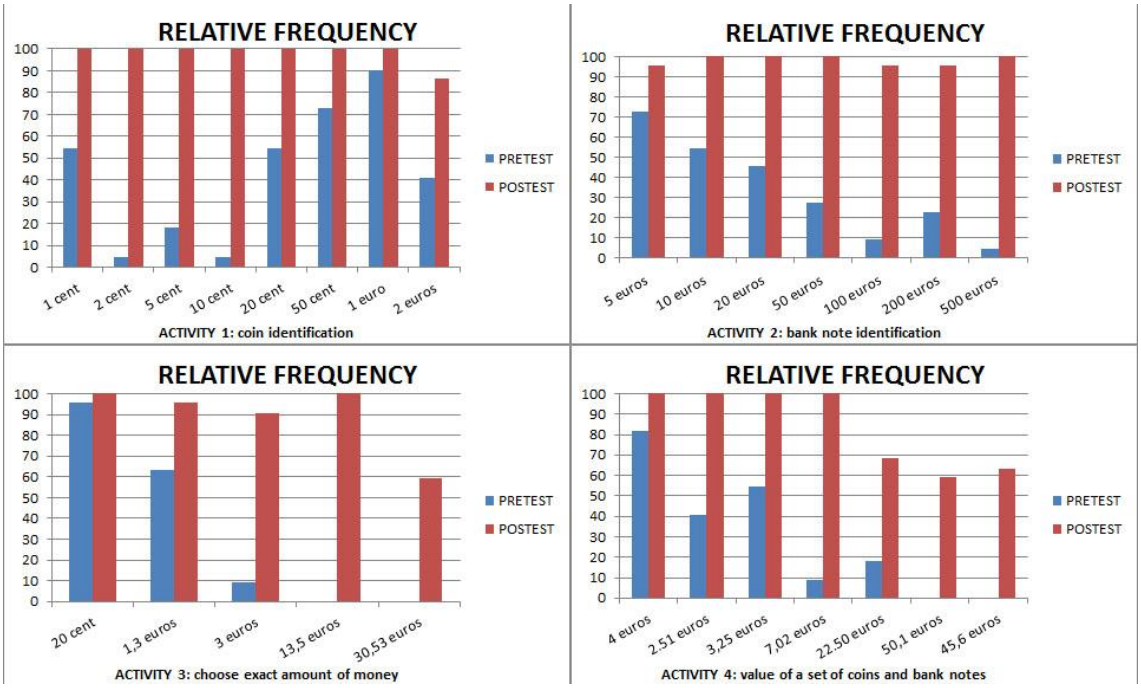

Figure 5. Frequency of right answers by activity

The fourth activity consisted in collecting different amounts of money by selecting several coins and banknotes. In this activity, students also had to gather the exact amount of money. Before the activity was performed in the tabletop system, 81% of children could select 4 euros correctly, whereas only 36% of them collected 2.51 euro. When asked to collect 3.25 euro, 54% succeeded. Only 9% of the students got 7.02 euro and finally, 18% put together the quantity of 22.50 euro. On the other hand, when the activity was played in the tabletop system, the results improved significantly, as shown in **Figure 5**. This time, everybody was able to select the first four quantities correctly. Although there were problems with the last three amounts, an improvement was observed: almost 60% of the students could answer all the activity questions.

Table 8. Pre-test and post-test achievement results by type of special educational need (normalized to 1)

Special educational need		N	Range	Min.	Max.	Mean	Std. Deviation
Attention Deficit Hyperactivity Disorder	Total pre-test	5	.26	.15	.41	.30	.12
	Total post-test	5	.22	.70	.93	.86	.092
Learning disorder not otherwise specified	Total pre-test	8	.040	.41	.44	.42	.019
	Total post-test	8	.15	.81	.96	.90	.048
Learning Disabilities	Total pre-test	5	.040	.41	.44	.44	.016
	Total post-test	5	.15	.85	1.00	.95	.062

For each activity, we conducted four pairwise comparisons using a Wilcoxon test to evaluate differences in medians among the two treatments, pre-tests and post-tests (Andel, 2007, Quinn & Keough, 2002), controlling for the Type I errors across theses comparisons at the .05 level using the least significant difference procedure. For the four activities, the median concern for the results obtained in the global knowledge tests after the study was significantly greater than the median concern for the results obtained in the global knowledge test before the study, $p<.001$, as shown in **Table 11**.

Table 9. Pre-test and post-test achievement results by students' educational level (normalized to 1)

Educational level		N	Range	Min.	Max.	Mean	Std. Deviation
First	Total pre-test	8	.26	.19	.44	.38	.088
	Total post-test	8	.07	.85	.93	.89	.034
Second	Total pre-test	4	.04	.41	.44	.42	.018
	Total post-test	4	.07	.93	1.00	.95	.035
Third	Total pre-test	10	.30	.15	.44	.35	.120
	Total post-test	10	.30	.70	1.00	.88	.088

Table 10. Pre-test and post-test results by students' special educational need and activity (normalized to 1)

Special educational need			N	Range	Min.	Max.	Mean	Std. Deviation
Attention Deficit Hyperactivity Disorder	Total A.1	*pre*	5	.38	.13	.50	.35	.16
		post	5	.25	.75	1.00	.93	.11
	Total A.2	*pre*	5	.43	.00	.43	.26	.18
		post	5	.29	.71	1.00	.91	.13
	Total A.3	*pre*	5	.20	.20	.40	.24	.089
		post	5	.40	.60	1.00	.84	.16
	Total A.4	*pre*	5	.29	.14	.43	.26	.16
		post	5	.29	.71	1.00	.86	.10
Learning disorder not otherwise specified	Total A.1	*pre*	8	.25	.38	.63	.50	.067
		post	8	.25	.75	1.00	.97	.088
	Total A.2	*pre*	8	.14	.43	.57	.45	.051
		post	8	.00	1.00	1.00	1.00	.00
	Total A.3	*pre*	8	.00	.40	.40	.40	.00
		post	8	.40	.60	1.00	.83	.13
	Total A.4	*pre*	8	.14	.29	.43	.32	.066
		post	8	.29	.71	1.00	.82	.101
Learning Disabilities	Total A.1	*pre*	5	.13	.38	.50	.48	.056
		post	5	.13	.88	1.00	.95	.068
	Total A.2	*pre*	5	.14	.29	.43	.31	.064
		post	5	.00	1.00	1.00	1.00	.00
	Total A.3	*pre*	5	.00	.40	.40	.40	.00
		post	5	.20	.80	1.00	.96	.089
	Total A.4	*pre*	5	.00	.43	.43	.43	.00
		post	5	.29	.71	1.00	.89	.12

Note: A.1: students are asked to recognize all euro bills and coins used in the activity.
A.2: activity where students have to recognize euro banknotes.
A.3: shopping activity.
A.4: activity where students are asked to gather coins and notes to collect an exact amount of money.

Results were analyzed by dividing the sample into three groups according to the educational level. Once again, for each group and activity, pairwise comparisons were conducted using a Wilcoxon test. The median concern for the results obtained in the global knowledge tests by the students in first and third education level after the study was significantly greater than the median concern for the results obtained in the global knowledge test before the study, $p<.02$, as shown in **Table 12**. The median concern for the second grade students results obtained in the global knowledge tests after the study did not differ significantly from de median concern for the results obtained in the global knowledge test before the study, $p=.063$. Only in one of the activities, the median of the results obtained after the study was significantly greater than the median concern for the results obtained before the study, $p=.046$, as shown in **Table 12**.

Table 11. Results of Wilcoxon signed rank test. Variables: knowledge tests, pre-test and post-test by activity and global results

	A.1. Post-test Total vs. Pre-test Total	A.2. Post-test Total vs. Pre-test Total	A.3. Post-test Total vs. Pre-test Total	A.4. Post-test Total vs. Pre-test Total	Total Post-test vs. Pre-test
Z	-4.24[a]	-4.19[a]	-4.17[a]	-4.17[a]	-4.13[a]
Asymp. Sig. (2-tailed)	< .001	< .001	< .001	< .001	< .001

Note: a. Based on negative ranks.

Significance level .05, 95% confidence interval.

A.1: students are asked to recognize all the euro bills and coins used in the activity.

A.2: activity where students have to recognize euro banknotes.

A.3: shopping activity.

A.4: activity where students are asked to gather coins and notes to collect an exact amount of money.

Table 12. Results of Wilcoxon signed rank test. Variables: knowledge tests, pre-test and post-test by activity and educational level

Educational level		A.1. Post-test Total vs. Pre-test Total	A.2. Post-test Total vs. Pre-test Total	A.3. Post-test Total vs. Pre-test Total	A.4. Post-test Total vs. Pre-test Total	Total Post-test vs. Pre-test
First	Z	-2.56[a]	-2.56[a]	-2.54[a]	-2.54[a]	-2.55[a]
	Asymp. Sig. (2-tailed)	.011	.010	.011	.011	.011
Second	Z	-2.00[a]	-1.86[a]	-1.86[a]	-1.86[a]	-1.86[a]
	Asymp. Sig. (2-tailed)	.046	.063	.063	.063	.063
Third	Z	-2.88[a]	-2.89[a]	-2.87[a]	-2.87[a]	-2.81[a]
	Asymp. Sig. (2-tailed)	.004	.004	.004	.004	.005

Note: a. Based on negative ranks.

Significance level .05, 95% confidence interval.

A.1: students are asked to recognize all the euro bills and coins used in the activity.

A.2: activity where students have to recognize euro banknotes.

A.3: shopping activity.

A.4: activity where students are asked to gather coins and notes to collect an exact amount of money.

Table 13. Wilcoxon signed rank test. Variables: knowledge tests, pre-test and post-test by activity and type of SEN

Type of special educational need		A.1. Post-test Total vs. Pre-test Total	A.2. Post-test Total vs. Pre-test Total	A.3. Post-test Total vs. Pre-test Total	A.4. Post-test Total vs. Pre-test Total	Total Post-test vs. Pre-test
Developmental delay	Z	-1.41[a]	-1.41[a]	-1.34[a]	-1.34[a]	-1.34[a]
	Asymp. Sig. (2-tailed)	.16	.16	.18	.18	.18
Attention Deficit Hyperactivity Disorder	Z	-2.07[a]	-2.04[a]	-2.04[a]	-2.04[a]	-2.06[a]
	Asymp. Sig. (2-tailed)	.04	.04	.04	.04	.04
Learning disorder not otherwise specified	Z	-2.64[a]	-2.64[a]	-2.59[a]	-2.59[a]	-2.53[a]
	Asymp. Sig. (2-tailed)	.01	.01	.01	.01	.01
Learning Disabilities	Z	-2.12[a]	-2.12[a]	-2.04[a]	-2.04[a]	-2.04[a]
	Asymp. Sig. (2-tailed)	.03	.03	.04	.04	.04
Mild mental retardation	Z	-1.41[a]	-1.34[a]	-1.34[a]	-1.34[a]	-1.34[a]
	Asymp. Sig. (2-tailed)	.16	.18	.18	.18	.18

Note: *a. Based on negative ranks.*

Significance level .05, 95% confidence interval.

A.1: students are asked to recognize all the euro bills and coins used in the activity.

A.2: activity where students have to recognize euro banknotes.

A.3: shopping activity.

A.4: activity where students are asked to gather coins and notes to collect an exact amount of money.

Results were analyzed once again by dividing the sample into five groups according to the type of SEN. For each group and activity, pairwise comparisons were conducted using a Wilcoxon test. The median concern for the results obtained in the global knowledge tests by attention deficit hyperactivity disorder students, learning disorder not otherwise specified students and learning disabilities students after the study were significantly greater than the median concern for the results obtained by these students in the global knowledge test

before the study, $p<.05$ as shown in **Table 13**. The median concern for the results obtained in the global knowledge tests by developmental delay students and mild mental retardation students after the study did not differ significantly from the median concern for the results obtained in the global knowledge test before the study, $p>.15$, as shown in **Table 13**. The fact that there are no statistically significant differences could be possibly due to the small number of students in these two groups.

Finally, when asked about their opinion and experience using the tabletop, students reported they felt comfortable with this new way to work. The students investigated a given situation and were challenged to adjust their coins or bills to collect the exact amount of money determined by the item price (the machine did not give any change back). By performing this activity, students actively collaborated and worked together as well as combined coins and bills in different ways (e.g., two coins of one euro, or one coin of two euro) by tapping and dragging virtual money over the table. This type of experience and interaction is impossible to do on a paper and pencil environment, as the system allows student to go one step further from a traditional exercise performed on paper.

CONCLUSION

This pilot study settled a possible approach for using tabletop systems with students with special educational needs. The results indicate that tabletop activities related to the European monetary system were not only effective as a learning tool but they were also motivating for students with special educational needs.

This study provides evidence to suggest several reasons why the tabletop instructional effectiveness is higher than that using traditional construction tools. First, there was a novelty aspect regarding the use of tabletop as students had never been involved in a similar learning environment before. It was observed that students attended the lessons on time, participated in the activities enthusiastically, and stayed in the computer lab even after the class sessions were over so they could spend more time using the system. Second, the tabletop provided tools for students to make and test conjectures based on their observations. Furthermore, the interaction provided by the activities allowed the students to check several combinations in a minimal amount of time. Third, the interaction provided by the activities and inquiry-oriented lesson structure, allowed the students to manipulate virtual money and calculate item prices. Easiness to perform such actions was probably even more critical for students with special educational needs.

Results have shown that the use of the tabletop system contributes significantly to increase the knowledge acquired by the students. In addition, data tests have shown that all students improved both in recognizing coins and bills as well as selecting the indicated amount of money, although some had problems dealing with larger sums of money. It can be concluded that students with special educational needs have increased their math knowledge and improved their money dealing skills by using the tabletop system.

In this study, the relationship between the type of need and the increase of knowledge were also analyzed. A significant increase in the level of knowledge was found in students with learning disabilities, learning disorders not otherwise specified and attention deficit hyperactivity disorder.

As an important part of this research, we want to emphasize the tabletop as a new technology-based artifact which offers new ways of interacting with the European monetary system, and using technology as an "object-to-think-with", which would provide a new view of learning euro's monetary system with technology (Papert, 1993).

As for the relationship between the increased knowledge and the educational level, a statistically significant relationship was found among the increased knowledge and students who were at a level of knowledge of first grade and those who were at a level of knowledge of third grade. Moreover, this relationship was nonexistent for students in the second grade. A greater difficulty was observed when adding euro, as this task makes the student add and subtract as well as converting euro to cents and cents to euro. For this type of students, this fact adds a substantial complexity level.

Finally, students found the tabletop system attractive and motivating because they enjoyed learning with their mates. Working with the tabletop system increased the motivation of students throughout the teaching/learning process, and thus, assimilation of knowledge also increased. Additionally, students' collaboration was important because of the information feedback established among students, as they were capable of solving problems together by using the tabletop system.

There are two main limitations in this study. The first one is related to the relatively small sample size (22 students with Learning Disabilities). These students were selected according to the study criteria. Although the number of students included in each analysis was quite small, these strategies have been successfully used with a variety of students (Hock, Deschler and Shumaker, 1993). In a future research, other cases with Learning Disability students will be included to support the findings of this study. The second limitation is related to the fact that this experience was the first contact of these students with a tabletop system, which caused excitement and engagement. The novelty effect could have introduced some bias in the obtained results, especially regarding motivation responses.

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APPENDIX

Annex I

The European monetary system

School: Level:

Date: Student:

Activity 1	1	2	3	4	5	6	7	8
Results								

Activity 2	1	2	3	4	5	6	7
Results							

Activity 3	1	2	3	4	5
Results					

Activity 4	1	2	3	4	5	6	7
Results							

Activity 1. Identify each coin and its exact amount of money.

		a	b	c
1		1 euro	1 cent	10 cent
2		2 cent	2 euro	20 cent
3		5 euro	5 cent	50 cent
4		10 cent	10 euro	1 euro
5		2 cent	20 cent	2 euro
6		5 cent	50 euro	50 cent
7		1 cent	1 euro	10 euro
8		20 cent	2 cent	2 euro

Activity 2. Identify each note and its exact amount of money.

		a	b	c
1		5 euro	5 cent	50 cent
2		10 cent	10 euro	1 euro
3		20 cent	2 euro	20 euro
4		50 euro	5 euro	50 cent
5		100 cent	10 euro	100 euro
6		20 euro	200 cent	200 euro
7		500 euro	500 cent	50 euro

Activity 3. Choose the exact amount of money.

		a	b	c
1	 20 cent			
2	 1.30 euro			
3	 3 euro			
4	 13.60 euro			

5	 30.53 euro			

Activity 4. Choose the correct option between a, b or c.

		a	b	c
1		2 euro	4 euro	3 euro
2		2.51 euro	2.06 euro	21.06 euro
3		2.25 euro	3.25 euro	3.52 euro
4		7.02 euro	7.20 euro	5.22 euro

5		100 cent	10 euro	100 euro
6		51 euro	50.01 euro	50.10 euro
7		45.60 euro	45.50 euro	40.51 euro

Annex II

We are developing a study to improve learning in students with Special Educational Needs. This questionnaire is provided to help our team to make the necessary adjustments to improve pre and post assessment questionnaires, which are an important part of our study. We sincerely appreciate your participation.

Please complete the following information:

Sex: Male: ☐ Female: ☐

Profession: Teacher/ Therapeutic Educator: ☐ University Professor: ☐

Years of work experience:

To which extent do you consider appropriate the title, presentation and identification variables? Use the following adequacy scale:

1: Not right 2: Just right 3: Adequate 4: Well suited

	Adequacy	Proposed Changes
Title		
Presentation		
Identification data		
Other observations		

Please assess the questionnaire items based on the following five criteria and apply the proper scale for each item. Feel free to add any other comments and/or suggestions for improvement in case the score was less than three.

• Clarity: Writing clearly without ambiguity.

1: Not clear 2: Vaguely clear 3: Clear 4: Very clear

•Relevance: The importance for the assessment of the monetary system.

1: Not relevant 2: Somewhat relevant 3: Relevant 4: Extremely relevant

•Accessibility: The response using one or more instruments.

1: Not available 2: Soon available 3: Accessible 4: Very accessible

• Exclusivity: Content different from that included in other items.

1: Nothing exclusive 2: Somewhat exclusive 3: Exclusive 4: Very exclusive

Dimension	Item	Criteria			
		Clarity	Relevance	Accessibility	Exclusivity
1. Coin identification	1. All coins are Euro coins.				
	2. Three possible answers are enough information.				
	3. Coins are evenly distributed among the three possible answers.				
	4. The image quality is good.				
	5. The letter font is appropriate.				
	6. The statement is clear and concrete.				
2. Bill identification	7. All bills are Euro banknotes.				
	8. Three possible answers are enough information.				
	9. Bills are evenly distributed among the three possible answers.				
	10. The image quality is good.				
	11. The letter font is appropriate.				
	12. The statement is clear and concrete.				
3. Attach the correct amount	13. The proposed amounts are adjusted to market.				
	14. System involves choosing various types of coins or bills				
	15. Three possible answers are enough information.				
	16. Coins and bills are evenly distributed among the three possible answers.				
	17. The image quality is good.				
	18. The letter font is appropriate.				
	19. The statement is clear and concrete.				

4. Money associated by number	20. There are various combinations.				
	21. The amounts of money proposed are common.				
	22. Three possible answers are enough information.				
	23. Coins and bills are evenly distributed among the three possible answers.				
	24. The image quality is good.				
	25. The letter font is appropriate.				