Tabletops for Collaborative Learning: A Case Study on Geometry Learning at the Primary School

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Abstract: The use of learning systems based on tabletops, favors the paradigm of teaching based on constructivism, and appears as a powerful tool for collaborative learning. This article presents the preliminary results of using a tabletop as a learning tool for basic Geometry contents. Study participants were fifth of primary school pupils that were arranged on two groups: one of them used the tabletop as a learning tool and the other one followed the regular course activities. Results show a significant improvement comparing the tabletop based learning group and the regular one. Students working with the tabletop showed high interest and motivation, and a very rich collaborative interaction.

Introduction

Augmented reality (AR) and new HCI technologies like multi-touch surfaces, tangible and sketch based interfaces, appear as promising tools to improve students' motivation and interest, develop cognitive abilities and support the learning and teaching process in educational contexts. True learning is experiential. The more senses are involved (sound, sight, touch, emotions, etc.), the more powerful will be the learning experience. Current development in HCI technology opens the opportunity of creating real user centered applications that promote collaboration an interaction between students and teachers.

This paper presents the preliminary results of using a tabletop developed at our research institute, to support learning activities. The tabletop is able to recognize multiple fingers from different hands and augmented reality marks, and supports educational applications developed on Adobe Flash. This system has been used to conduct a quasi experimental study about a thematic unit on geometric bodies for fifth of primary school pupils. Results show a significant better performance of the group using the tabletop with respect to the group following the regular teaching method.

Related Work

Several studies (Slavin, 1980; Watson, 1991) suggest that teamwork is beneficial for learning. When students work sitting around a traditional table, the space between them is used for communication. In that context, look, gestures and nonverbal behaviors are important elements. Participants can see each other and communication is shared with objects and matter under discussion. However, when students work in teams but in front of a computer, their focus is on the screen space (Piper, O'Brien, Morris, & Winograd, 2006), significantly reducing the communication possibilities, leading to a cooperative model of teamwork. Tabletop systems provide a big interactive surface, suitable to gather around it to multiple users that can interact with the information collaboratively. Hence the new interfaces based on tabletops are a good solution (Harris et al., 2009) as a teaching tool, from the point of view of favoring a true collaborative environment, and promoting learning based on constructivism.

Another type of works focuses on the advantages of using tangible elements to enhance collaborative work. Resnick et al. (1998) present an excellent work in defending children's learning based on "manipulative interfaces". Johann Heinrich Pestalozzi (1746-1827) asserted that students need to learn through their senses and through physical activity, arguing for "things before words, concrete before abstract". O'Malley and Stanton-Fraser (2004) discuss how this type of interaction is helpful in learning tasks, providing students with a kind of tools that encourage collaboration. Pontual and Price (2009) provide an example with good results, using a tabletop with tangible elements. Ishii and Ullmer (1997) and Ishii (2007) propose the use of tangibles as a tool to improve interaction by making it more natural and closer to interactions that take place in the real world. Moreover, augmented reality (AR) is also used and analyzed in several works as an educational instrument. Woods et al. (2004) show the educational benefits arising from the virtual reality (VR) and augmented reality, particularly improving the interpretation of spatial, temporal and contextual content.

Tabletop System

The tabletop system used in this study was developed by members of our research group (Figure 1). The system comprises a video projector and two cameras that provide stereoscopic view of the interaction surface. It supports both multi-user and multi-touch interaction. At the same time, the system is able to recognize augmented reality markers, that can be used to identify each participant student, providing a method to customize the behavior of the applications according to the learning profile of each student. This hardware configuration allows any type of table as the projection and interaction surface. This is a valuable quality for installation in a classroom. The self-calibration capability of the tabletop provides a robust system that can be moved to any location in the classroom, using several students' tables to create the surface of interaction. Current version of the system also supports markerless interaction, which basically is used for augmenting the content of regular textbooks. The system was adapted to be used by children over 10 years. To verify the correct operation, a first experiment was designed (see Figure 1) in which 20 children tested the tabletop, guided by a usability expert.

Figure 1. Tabletop (First Version) Designed by our Research Team.

Learning Contents

For the study, a series of educational applications about "geometric shapes" were developed for fifth course of primary education (10-year-old children). The applications were developed using Adobe Flash and Action Script programming language. On one hand, a teacher application called "Geometric Shapes Examiner" (Figure 2) was developed, mainly to be used by the teacher to make the explanation using the tabletop. It is a 3D interactive application that allows manipulating and visualizing the different elementary geometric shapes. On the other hand, a set of games (Figures 2 and 3) was developed to practice the concepts explained by the teacher in a fun way, thus ensuring a higher and prolonged in time level of attention. Four applications/games were developed: a relationship game, a classification game, a "memory" game and an action game called "the cannon".

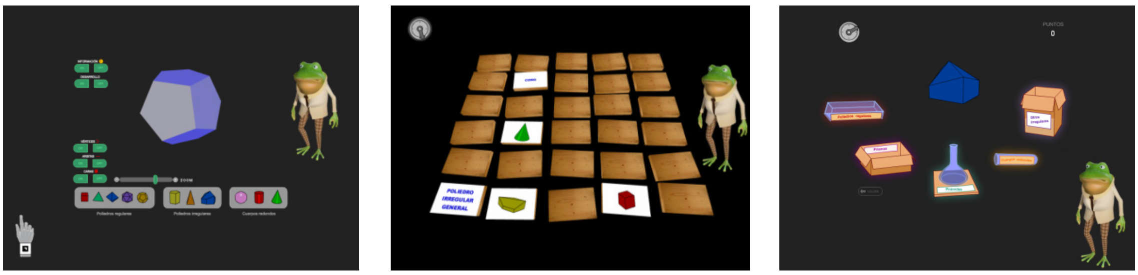

Figure 2. Geometric Shapes Examiner (Left), Memory (Center) and Classification (Right) Games.

Taking into account the observations performed during the usability tests, memory, classification and relationships games were deliberately conceived as turn-based for a single user. Although the tabletop supports multi-user interaction, it was decided to simplify the design of the game and analyze the effect of collaboration between students and competition between groups.

Tangible items were used in the design of the fourth game, called "cannon game", which consists of hitting with a cannonball, a geometric body requested by the system. The cannon is represented by a tangible item, which is simply an AR marker inside a cannon drawing over cardboard. The game is designed to be played by two players. One student handles the cannon and the other is responsible for controlling the power of the shot. Both of them must collaborate to solve the common problem.

One of the main objectives of the research was to design a natural interface that hides the complexity of the technology, and responds to natural movements and actions of the user. Therefore to activate the system, the teacher simply has to switch on the computer and projector. From that moment, the system is active but projecting a black screen on the table. To launch different applications, students and the teacher have a textbook that incorporates augmented reality markers on its pages. It is enough to open the book on the table by the appropriate page and the system displays a menu next to the book with various applications related to the educational contents shown on the opened page.

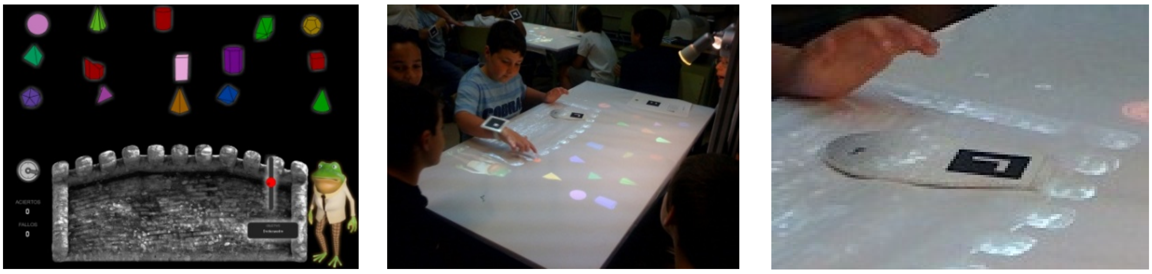

Figure 3. General View of the "Cannon Game".

Evaluation Context

The evaluation was performed on three groups of students in fifth grade of primary school. The first group (group A) consisted of 19 students, 10 boys and 9 girls. The second group (group B) consisted of 19 students, 14 boys and 5 girls. The third group (group C) consisted of 16 students, 9 boys and 7 girls.

There were two different experiences. The first experiment (Experience 1) was developed on the groups "A" and "B" separately. The students studied for the first time the thematic unit "Geometric shapes" using only the tabletop. The objective of this experiment was to test the effectiveness of the system as a unique teaching tool. The second experience (Experience 2) was developed on the "group C" and it consisted of evaluating the result of the utilization of the tabletop in remedial classes. In this case the pupils studied the lesson following the traditional method and were evaluated (pre-evaluation). Later they received two additional lessons of reinforcement using the Tabletop in which the teacher proposed them to play different games. Finally they were evaluated again (post-evaluation). Table 1 and 2 show the planning and development of the experiences.

Table 1: "Experience 1". Planning and development of the sessions.

Session	Content	Resources	Methodology
1	Introduction to solid geometry	- Geometric shapes examiner	Teacher explains the lesson using the tabletop. The children stand around in groups of 10. The teacher eventually asks questions that children must solve on the tabletop.
2	Regular polyedra	- Geometric shapes examiner - Memory game (level 1)	Teacher explains the regular polyhedra with the tabletop, and then the children practice individually with the "memory game".
3	Irregular polyedra	- Geometric Shapes Examiner - Memory game (lev. 2&3)	Teacher explains the irregular polyhedra and review previous concepts to the children using the tabletop, and then students practice individually with the memory game.
4	Round bodies	- Geometric Shapes Examiner - Memory game (level 4) - Classification activity	Teacher explains the round bodies and review previous concepts to the children using the tabletop and then students practice with the memory and classification activity.
5 and 6	Overlearning exercises	- Memory - Relationships activity - Classification activity - Cannon game	Teacher organizes groups promoting competitiveness, and deciding the order of the games / exercises. Students themselves in a collaborative way try to solve their doubts, helping each other, under the supervision of the teacher.

Table 2: "Experience 2". Planning and development of the sessions.

Session	Content	Resources	Methodology
1 – 6	Solid geometry	- Traditional method	The teacher teaches by the traditional method.
7 – 8	Solid geometry overlearning	- Geometric shapes examiner - Memory game - Relationships activity - Classification activity - Cannon game	Teacher gives an overview of basic concepts in the "Geometric Shapes Examiner" in the first part of session 7, by actively involving students. Later on, students themselves in a collaborative way try to solve their doubts, helping each other, under the supervision of the teacher.

In both experiments, teachers and students of all groups received a brief training (ten minutes), just before the first contact with the tabletop. Two tabletops were in use for each participating group during each experience, arranging a maximum of 10 children around each tabletop. During the teacher's explanations, the students were taking a passive attitude, simply attending to the explanation. On the contrary, during the exercises they were taking a totally active attitude. Most exercises were done individually, by turns, while other students watched and helped the partner if the teacher allowed it. In the exercise developed with the "cannon game", the pupils were playing in couples.

Key Findings

System evaluation was conducted from the point of view of the effectiveness and usability. To evaluate the effectiveness of the system in the "Experience 1", the results (marks in a scale from 0 to 10 points) obtained by the group in a previous learning unit of similar complexity (selected by teachers) were compared to results obtained in the learning unit developed with the tabletop. Results for groups “A” and “B” are shown in Figure 4, by means of scatter diagrams, that provide marks obtained by traditional method (previous lesson) and those obtained with the tabletop for each participating student (results are better as the slope of the regression line tend to zero). A significant improvement observes in both groups, especially in the pupils that had worse previous marks.

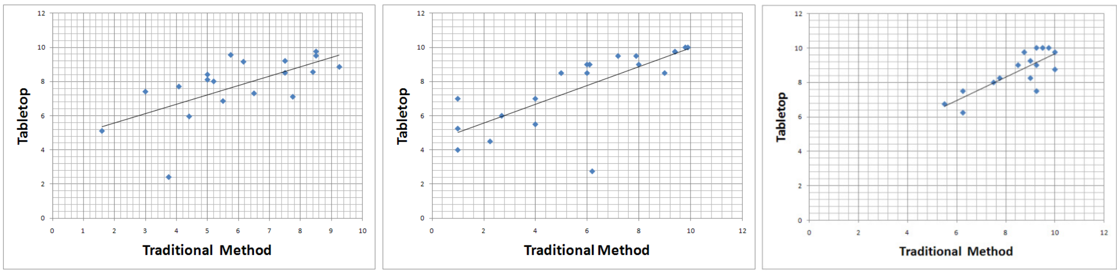

Figure 4. Evaluation of Effectiveness. Groups A (Left), B (Middle) and C (Right).

The experiment carried out at the “Second Experience” (Group C) was designed to evaluate the performance of the system as a tool for reinforcement. Figure 4, group C, shows the scatter diagram that relates marks obtained after studying the thematic unit by the traditional method and marks obtained after the reinforcement sessions with the tabletop. It should be noted that in this case it was a group with a high average score, so the results of the evaluation by the traditional method also shows high scores. However there is also an improvement in ratings after receiving reinforcement classes with the tabletop, which demonstrates the validity of utilization of the system as a tool for the consolidation of learning.

Table 3: Tool evaluation and development of the class questionnaires.

Tool evaluation		Development of the class	
Q1	*I prefer the classic book to using the new material*	Q6	*In this class I have been more attentive than in other classes*
Q2	*I found it easy to see the geometric shapes with this technology*	Q7	*This class has seemed to me to be useful and interesting*
Q3	*I believe that this material will help me to make a better examination*	Q8	*I would like to take more classes as those of today*
Q4	*It has been easy to learn to use this material*	Q9	*It is easier to follow the teacher's explanation in a class of this type*
Q5	*I would like to use this material at home*	Q10	*In class today I behaved better than in other classes*

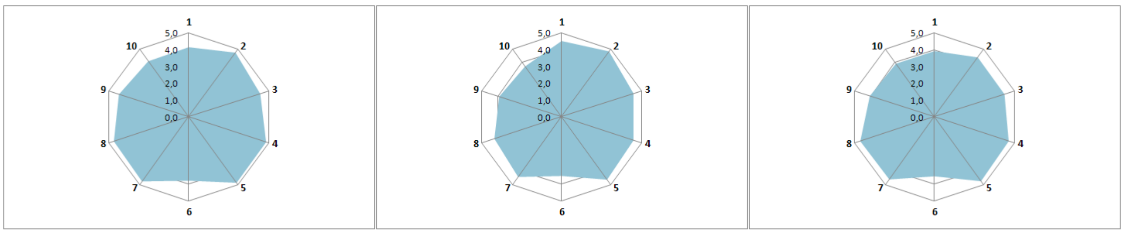

Figure 5. Evaluation of Usability. Groups A (Left), B (Middle) and C (Right).

To evaluate the usability of the system, a questionnaire was developed (Table 3) using a five level Likert scale (1-strongly disagree, 5-strongly agree). The first five questions were devoted to evaluate the tabletop as a learning tool and the second five aimed to assess the development of the class with the tabletop. First block of questions (Q1-Q5), shows clearly that students prefer the use of the new technology (Q1 is reversed in representation). Although no student had received prior training on the new tool, they think that its use was simple and transparent, as noted in Q2 and Q4. According to Q3, the majority of students recognize that this tool can help them positively in improving their results, and mostly would like to use these technologies at home too. With respect to the assessment of the development of the class (Q6 – Q10), with this type of technology, students show a greater attention in class, accompanied by a notable interest in the subject being taught and a improved behavior in these classes, compared to the rest of their course.

Conclusions and Future Work

The most impacting element over the experimental work has been the high degree of collaboration between students and self-correction while performing the exercises. During these sessions the teachers were taking a secondary paper and only they were entering in action when it was strictly necessary. An important factor was the introduction of competitiveness in some exercises, increasing notably interest and attention of students. A second element that surprised us was the speed to learn the interaction with the tabletop. Students were faster learners than their own teachers. Here the collaborative action of several students around the table was very important, because of the feedback established between them. The satisfaction and interest showed by the student was very high. The subjective perception by teachers was confirmed by the effectiveness and usability study. The high interest and motivation of the students clearly impacted on their learning performance.

Tabletops provide a big interaction surface that creates an atmosphere of true collaborative work. In this first experience practically we have not taken advantage of all advanced capabilities built into the tabletop system. New experiments are being designed to analyze the effect of the number of students around the table in the global performance of the group. Also, it is expected to analyze the effect over the learning process of the number of simultaneous users in the games. The developed games, presented in this work, can be easily extended to support several simultaneous users. Perhaps more users will mean less interaction with the no playing student looking at the table. In the present experience the single user setup has been a very powerful learning combination.

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