SMART: A SysteM of Augmented Reality for Teaching 2nd Grade Students

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ABSTRACT

In this paper, we describe the design and evaluation of SMART, an educational system that uses augmented reality for teaching 2nd grade-level concepts, adequate and integrated with national curriculum guidelines. SMART puts children exploring concepts like means of transportation, types of animals and similar semantic categories through the use of a set of racquets that are used to manipulate a TV-show style game with 3D models which are superimposed to the real time video feed of the whole class.

Experiments were performed with several classes of students in three different, local primary schools. Results suggest that SMART is effective in maintaining high levels of motivation among children, and also that SMART has a positive impact on the students' learning experience, especially among the weaker students.

Categories and Subject Descriptors

H.5 [**Information Interfaces and Presentation**] (e.g., HCI): H.5.1 Multimedia Information Systems, H.5.2 User Interfaces

General Terms

Design, Human Factors.

Keywords

Human-computer interfaces; Interactive learning environments; Pedagogical issues; Augmented reality; Virtual reality.

1. INTRODUCTION

Using advanced technology for teaching concepts for today's 2nd graders is becoming increasingly popular because children are moving towards a new level of interaction with technology and there is a need to children to educational contents through the use of novel, attractive technologies.

SMART (System of Augmented Reality for Teaching) is a first step towards that goal. SMART puts children exploring concepts like means of transportation, types of animals and similar semantic categories through the use of a set of racquets that are used to manipulate a TV-show style game with 3D models which are superimposed to the real time video feed of the whole class.

SMART is essentially a collaborative Augmented Reality (AR) system. AR is a growing area within virtual reality research. Basically, an AR system generates, in real time, a composite view for the user. It is a combination of the real scene viewed by the user and a virtual scene generated by the computer that augments the scene with additional information [8].

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Our motivation for designing such a system stems from the fact that we are trying to achieve natural interaction games that follow the successful line of products such as Nintendo Wii. Instead of using traditional computer interfaces, based on the WIMP (Windows, Icons, Menus and Pointing device) paradigm, we augment the real school environment with 3d virtual models that can be manipulated using simple table tennis racquets. Our hypothesis is that introducing this technology in a smooth way will increase the learning rate of children, as well as contribute to a highly motivated learning environment.

This paper is organized in the following way: section 2 describes related work, organized briefly in general multimedia systems applied to 2nd grade students and existing augmented reality systems for educational activities. Section 3 describes both the SMART system and the method we used to investigate whether the use of AR technology could improve students' results and motivation levels. Section 4 presents the obtained results based on several experiments conducted at three different primary schools and section 5 discusses those results.

2. RELATED WORK

2.1 Interactive Systems for 2nd Graders

One good way to motivate children to learn using technology is to apply games, which are well known, exploiting the power of popular TV shows. With the goal of minimizing the amount of effort and requirements to set up a situated learning environment, Lin [1] integrated scenarios of the popular video game Pokemon in classroom education of 2nd grade math concepts.

Observations showed that, in such arrangement, they could engage some students into the scenarios where math is applied.

Since most children inevitably spend much time playing digital games, it is argued that digital game-based learning is one way to involve kids to do the right things with computer [1].

Lee et al. [2] performed a study to investigate whether educational video games could be integrated into a classroom with positive effects for the teacher and students. They conducted the study with 39 2nd grade students using their mathematic drill software "Skills Arena" [2]. Early data from the study suggested that not only do teachers and students enjoy using "Skills Arena", students even exceeded expectations by doing three times more math problems in 19 days than they would have using traditional worksheets.

2.2 Augmented Reality Educational Systems

The use of augmented reality systems in educational settings, *per se*, is not novel. Shelton and Hedley [8] describe a research project in which they used augmented reality to help teach undergraduate geography students about earth-sun relationships. They examined over thirty students who participated in an aug-

augmented reality exercise containing models designed to teach concepts of rotation/revolution, solstice/equinox, and seasonal variation of light and temperature, and found a significant overall improvement in student understanding after the augmented reality exercise, as well as a reduction in student misunderstandings.

Some other important conclusions about this system were that AR interfaces do not merely change the delivery mechanism of instructional content: They may fundamentally change the way that content is understood, through a unique combination of visual and sensory information that results in a powerful cognitive and learning experience [8].

Simulations in virtual environments are becoming an important research tool for educators [7]. Augmented reality, in particular, has been used by Tettegah and colleagues [7] to teach physical models in chemistry education. They evaluated their perceptions regarding these two representations in learning about amino acids. The results showed that some students enjoyed manipulating AR models by rotating the markers to observe different orientations of the virtual objects.

Construct3D [5] is a three-dimensional geometric construction tool specifically designed for mathematics and geometry education. In order to support various teacher-student interaction scenarios, flexible methods were implemented for context and user dependent rendering of parts of the construction. Together with hybrid hardware setups they allowed the use of Construct3D in classrooms and provided a test bed for future evaluations. Construct3D is easy to learn, encourages experimentation with geometric constructions, and improves spatial skills [5].

AR has also been used in [3] summer schools. Balog et al. [3] describe findings from usability testing of AR educational systems and conclude that using both quantitative and qualitative data is a cost-effective support for the user-centered design of AR-based education technologies.

The wide range of AR educational applications also extends to physics. Duarte et al. [4] use AR to dynamically present information associated to the change of scenery being used in the real world. In this case, the authors perform an experiment in the field of physics to display information that varies in time, such as velocity and acceleration, which can be estimated and displayed in real time.

The visualization of real and estimated data during the experiment, along with the use of AR techniques, proved to be quite efficient, since the experiments could be more detailed and interesting, thus promoting the cognitive mechanisms of learning [4].

The use of AR in formal education could prove a key component in the learning environments of the future. These environments will be abundantly populated with a blend of hardware and software applications. However, relatively little is known about the potential of this technology to support teaching and learning with groups of young children in the classroom, like in our present study. Except for Kerawalla et al. [6] and a few other studies, few researchers actually present results of experiments using this kind of technology in real life schools. Kerawalla et al. [6] analyzed teacher-child dialogues in a comparative study between use of an AR virtual mirror interface and more traditional science teaching methods for 10-year-old children. This study revealed that the children using AR were less engaged than those using traditional resources. This shows that using AR alone is not only insufficient to keep children engaged, it could even reduce their level of engagement, which proves the challenge posed to researchers when trying to deploy and study systems like the ones we propose.

3. METHOD

We investigated the potential of AR to improve education of second-graders at several local schools, including their motivation level. Our research goal was twofold: on the one hand, we were interested in studying how AR technology could be used in an unobtrusive way that could effectively help students learn; and on the other hand, we were interested in establishing design guidelines from the experiences as a whole. These guidelines, built as summarizations of lessons learned, could be useful to educators interested in novel technologies for education, and also to user interface designers interested in designing new kinds of systems.

We designed and evaluated informally several games, but this study refers only to the formal studies of two concrete games, which were introduced in the schools in the exact, appropriate time frame, according to the national second grade curriculum guidelines. One of the games is the animal classification game, where children hold one racquet to visualize and explore different 3D animated models of animals. With the other hand, children must choose the racquet that correctly corresponds to that animal's category. The second game is similar to the animal classification game, except that children need to identify the transportations' category (helicopter is an aerial means of transportation, automobile and motorbike are terrestrial and so on). An example of the 3D models that can be manipulated using the racquets by children is shown in Figure 1.

Upon a correct identification of the category, the game will provide audio feedback using an applause-like sound. If it's incorrect, the game plays a "wrong-buzzer" sound. This helps make it sound like a TV-show game, which proved successful for motivating the class.

Figure 1: some of the 3D models that can be freely manipulated using SMART's racquets.

3.1 Participants

The participants of our study were students from three different classes from three distinct local schools, as well as their teachers, who acted as moderators of the game. Students' age varied between 7 and 8, and overall there were 32 females and 22 males. In each of the three schools, participants were randomly divided into two groups of equal dimension: a control group, composed of students who took the class using traditional methods, and the experimental group, composed of students who used the SMART system.

3.2 The system and the materials

The system is composed of several racquets with 3D augmented reality markers, a web camera (the system works with any regular web camera), a PC and any kind of display such as LCD or projectors. For all the experiments described in this paper, we used a small laptop and a light, high-brightness projector for the experiments in the schools for portability reasons, fostering collaboration with a large projected surface where the whole class could watch and be watched and for dealing with the several lighting conditions and setups, which obviously vary a lot from school to school.

3.3 Procedure

We started by making sure the game prototypes were well tested in the University's labs and under different lighting conditions – augmented reality won't work in dark environments because it is based on the camera's recognition of the black and white printed markers.

We followed the same procedure for the three different schools. First, there were introductory sessions with the teachers alone. The system was explained, teachers' observations and suggestions were recorded, and the plan was established.

Each class was divided into three phases: a pretest phase, when students answered a random set of questions about the subject being taught (categories of transportation systems), without being taught anything about it. Then came the learning phase itself. It consisted of a traditional lesson in the control group and an "augmented" session, with the help of the SMART system, in the experimental group.

When the class of the experimental group started, the system started and a screen recording software was automatically launched and ran in background. Therefore, students were being digitally videotaped while they used SMART. We later analyzed thoroughly all the recorded movies for gathering reliable results on motivation levels and the overall class reaction and use of the system.

Teachers acted as mediators, or even TV-show presenters. Besides teaching the concepts with simultaneous use of the system, they mediated the use of it, by deciding who would play with the system and when.

At the end of the class, students performed a similar posttest, so that we could quantify their average degree of learning obtained by each of the groups.

One way to measure the degree of learning obtained through a particular mode of education is quantified by the <g> score [10], which is calculated the following way:

$$\langle g \rangle = (\text{posttest\%} - \text{pretest\%}) / (100\% - \text{pretest\%})$$

where posttest% is the percentage of correct answers in the posttest and pretest% is the percentage of correct answers in the pretest.

The procedure for the control groups was similar, except that the teacher was asked to give the class about the exact same subject but using traditional methods like the whiteboard.

4. RESULTS

Figure 2: some of the students's reaction to the system and the overall setting of the system in the classroom.

Figure 2 shows the overall context of one of the classrooms where SMART was used. We can see the role of the teacher as a mediator, and we can also observe how the whole class watches the projected screen where the student is manipulating the game's racquets. As soon as one student ended the game, he or she would return to his seat and another student would play the game. When the student chose the right racquet, the system would play an applause sound, like in a TV-show quiz. This caused the whole class to respond and also to cheer and applaud, which helped to maintain the attention of the majority of students. This happened in the three different schools where we performed the experiment.

We divided the students into three groups: weak, average and good students. This division was based on the students' average of grades. In the Portuguese system, this is expressed as a percentage, where less than 50% means weak, 50%-70% means average and more than 70% means good. Their respective teachers provided this data to us.

Tables 1, 2 and 3 show the evolution from pre-tests to post-tests for each of these groups of students. The results refer to the pre and post-test percentage of correct answers, the right-most column shows the <g> value.

Table 1. Evolution of weak students.

	Pre-Test	Post-Test	<g>
Control group (without SMART)	61.1	72.2	29%
Experimental group (using SMART)	40.7	61.1	34%

Table 2. Evolution of average students.

	Pre-Test	Post-Test	<g>
Control group (without SMART)	59.7	77.8	45%
Experimental group (using SMART)	72.9	89.6	62%

Table 3. Evolution of good students.

	Pre-Test	Post-Test	<g>
Control group (without SMART)	84.2	94.0	62%
Experimental group (using SMART)	84.6	89.7	33%

The results obtained are within our expectations, since good students don't improve much their learning rate using SMART, i.e., their evolution is less noticed. SMART doesn't necessarily help them to actually learn, although all students enjoy the technology, as they mentioned in questionnaires about motivation we performed at the end of the classes.

The effect is much higher among weak and average students. As we can see from tables 2 and 3, for those students, SMART had a positive impact in their learning.

More experiences have to be performed in order to make these claims stronger. However, these initial results seem promising.

We also gathered written questionnaires regarding motivation, and all values were high, although this was just a mere formality, since it was evident that motivation was high in every class. Besides these formal experiences, we performed many other sessions, including sessions to study how children used the system in pairs. The informal results obtained were similar.

Finally, all the recorded videos were thoroughly analyzed (manually) to discover usability errors and more importantly to investigate children's reaction and learning results. Again, motivation was evident, not only by the students using SMART, but also from surrounding students observing their colleagues.

5. DISCUSSION

The results obtained so far indicate that using our augmented reality system is a positive step forward towards achieving the goal of reducing the distance between children and knowledge.

One of the interesting observations we made was the impact SMART had on the whole class collaboration. In fact, by turning the whole classroom environment into a TV-show style game, where "contestants" (the children) were all participating, SMART managed to provide a unique, compelling educational experience. This is not directly related to the use of AR technology, but instead it suggests the power that good games have in fostering an education-prone environment, especially if it takes the form of familiar, popular TV quizzes. This was perhaps a common thread to all three schools involved in our experiments, and we believe this could be a good "heuristic" in designing this type of educational systems.

Another issue was related to why poorer students perform better in their learning than the good students. One possible explanation for this would be the fact that good students are already good students, thus the potential for improving learning in poor students is obviously higher. Also, poor students are, in general, more prone to physical activity, and playing with the physical racquets might positively influence their learning behavior.

Future work will include more schools and more students being tested. We are also interested in disseminating SMART as an online toolkit that any parent or educator can easily and freely use. For that matter, an online package setup is already available and can be freely downloaded from the website[1].

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