Designing virtual world educational applications

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***Abstract*— Different studies show the benefits of using virtual worlds for educational purposes, where you can develop a wide variety of innovative teaching and learning activities. During the last six years we have been developing educational applications using virtual worlds and mixed reality. In this paper we summarize our experiences from the point of view of the design of the educational materials that have been developed in these virtual worlds.**

Keywords*— *virtual worlds; tangible user interfaces; mixed reality; e-Learning

I. Motivation and Previous Work

Different studies show the benefits of using virtual worlds for educational purposes, where you can develop a wide variety of innovative teaching and learning activities. A review of such systems can be found in [1] and [2]. The nature of virtual worlds allows the application of innovative learning methodologies, such as the constructivist approach [3]. In a virtual world the students may explore; interact with the environment; interact with other students and with the teacher; and build their own constructions. These are all elements that make up the idea of constructivist learning [4].

An evolution of virtual worlds is mixed reality, defined as the space where virtual worlds merge with reality [5]. In [2] a review of educational applications based on this paradigm can be found. To implement this idea we employ tangible user interfaces in conjunction with virtual worlds. The term "tangible user interface" [6] is an evolution of the term "graspable user interface" introduced in [7]. Tangible user interfaces allow everyday objects to take the role of computer user interfaces: interacting with them you interact with the computer application, in our case with the virtual world.

The experiences described in this article are part of the results of the development of a toolkit for building mixed reality systems for education. This toolkit is called Virtual Touch, and allows the construction of tangible user interfaces based on three technologies: Phidgets [8], Kinect [9] and Arduino [10]. These three technologies allow to associate user interface functionality to everyday objects. We have developed a middleware that enables interacting with the virtual world through the tangible artifacts implemented with any of these three technologies. Anyone with basic technical knowledge can create applications using mixed reality modules applying a Lego-like philosophy.

In the rest of this paper various educational experiences are described which we have deployed in secondary educational institutions in Spain done using with virtual worlds and mixed reality systems, focusing on some aspects of the design of the educational materials involved in these experiences. In [11], [12], [13], and [14] a more extensive description of these experiences and their results can be found.

II. Cubica: Developing Materials for Computer Science Teaching

In this first experience both the virtual world and the educational materials were designed by someone with computer programming experience [11]. A virtual world called "Algorithm Island" was created: a place where students could visit thematic houses where educational materials about sorting algorithms were deployed. In this island students could find animations, bulletin boards, exercises, links to websites, QR codes linked to video animations, and other educational materials related to sorting algorithms. They were developed by the teacher of the course, who was also the lead developer of the Virtual Touch toolkit and coauthor of this paper.

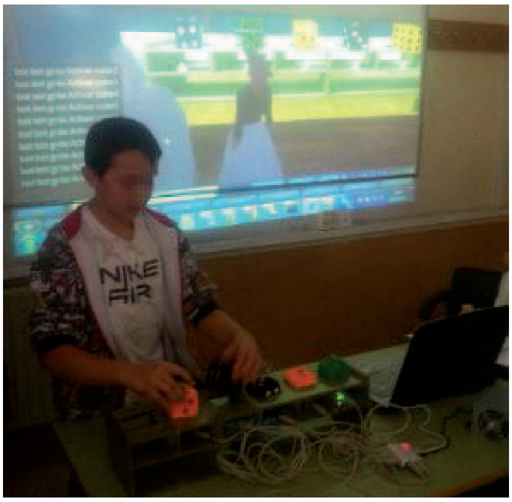

Figure 1: A student interacting with the mixed reality system in Algoritmia Island

Firstly, the teacher explained to the students various abstract concepts related to sorting algorithms. Then, to exemplify these concepts, students explored the four "thematic houses" in the virtual world. One house offered an introduction to the concepts of algorithm, iteration, arrays, etc. The other three houses were focused on three specific sorting algorithms. In every house there were a series of educational resources such as panels, QR codes that linked to videos (i.e. the bubble sort algorithm explained with a Hungarian folk dance), animations of sorting algorithms, exercises, etc.

While exploring each house, students interacted with a virtual model of the tangible interface, showing an animation of the sorting algorithm. Students subsequently used the tangible interface to check whether they had understood the algorithm (see Figure 1). At all times the system maintained the consistency between the virtual world and the tangible interface, offering an experience of "mixed reality". At the end of the experience a LCD screen indicated whether what the student had made coincided with any of the algorithms studied or whether, on the contrary, it was advisable to revisit some of the houses.

The experiment showed that using a tangible interface helped students to understand abstract concepts, such as (in this case) “array”, “algorithm”, “sorting methods”, etc. [11]

III. INVOLVING NON-TECHNICAL TEACHERS IN THE DEVELOPMENT OF MATERIALS FOR MIXED REALITY EDUCATIONAL APPLICATIONS

The second experiment involved a high school teacher in the development of the educational materials that were to be delivered using a mixed reality system [12]. In this case she was a social sciences teacher with previous experience in the use of virtual worlds, but with no technical background. The students involved in this experience belonged to the “welcome course” at the Ernest Lluch public High School in Cunit, Catalonia, Spain. One of the problems that face immigrant students in Catalonia is the need to learn the Catalan language (and culture) to be able to integrate into regular secondary school classes. To this end the Catalan educational system has implemented the "welcome courses" in which such students participate in order to learn the language.

The virtual world used for this activity had several educational spaces. The students could perform there different activities that allowed them to practice language skills (see Figures 2 and 3). Students could interact with other students and teachers in real time through their avatars (virtual representations in the world), making extensive use of language in a specific context.

Two types of interaction were used for these educational spaces: natural gestures and tangible objects. To achieve this the Virtual Touch middleware connected a Kinect device with the virtual world.

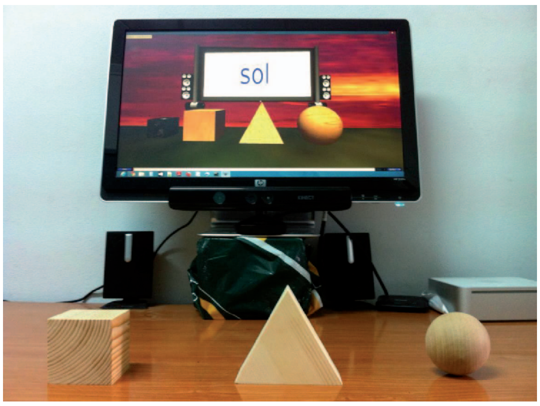

Figure 2. Using wooden figures to interact with the virtual world.

As an example of the interaction, tangible wooden blocks represented concepts. For example, the cube represented a noun, the pyramid represented a verb, and the sphere represented an adjective (see Figure 2). Different words were shown to the student, who had to manipulate the wooden blocks to solve the exercise.

The purpose of this activity was to learn at the elementary level the vehicular language of the education in Catalonia, Catalan. It was aimed at students recently arrived from other countries (with other mother tongues such as English, Chinese, Russian, Arabic, etc.) or from other areas of Spain (with Spanish as the mother tongue).

Some of the activities involved grammatical structures, where the student had to order correctly the different parts of the phrase (subject, predicate, modifiers, etc.) Other activities were focused to gender concordance. Finally other activities were oriented to properly construct plural forms. All of them used the tangible interface to interact with the virtual world where the activities were done.

The design of the activities was made the by the classroom teacher, who had previous experience as a user of virtual worlds (Second Life). For the interaction with tangible interfaces she counted with the help of a specialist. The results of the experiment were quite satisfactory, mainly in terms of motivating the students to involve in learning activities [12].

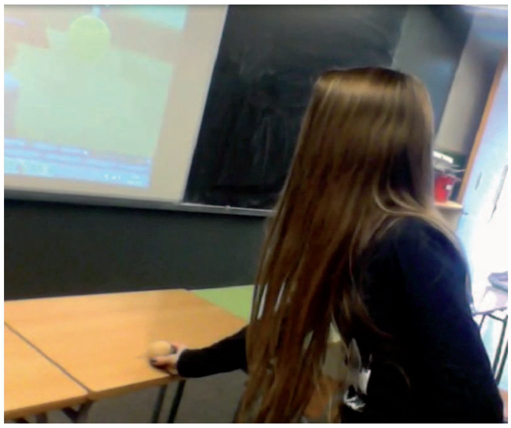

Figure 3. A student in the “welcome course” interacting with the virtual world.

IV. EXTENDING THE SYSTEM TO INVOLVE TEACHERS WITHOUT TECHNICAL KNOWLEDGE IN THE DEVELOPMENT OF MATERIALS FOR MIXED REALITY EDUCATIONAL APPLICATIONS

After the first two experiences in developing educational materials for mixed reality applications, it was clear that it was necessary to simplify the mechanism of interaction if you wanted to involve teachers without technical knowledge. To this end the concept of "tangible book" as a tangible user interface with the virtual world was developed [13].

The "tangible book" aims to link the written content of a book with the contents of a three-dimensional virtual world. Students study the theoretical content using this "real" and tangible book by reading text (and possibly looking at illustrations), engaging simultaneously in a number of practical activities in the virtual world.

The teacher of the course choose “Greek culture” as the theme for the experience, and in particular the Greek religion. She designed a book of six pages, each devoted to a Greek god. Students had to read that book, and activities in the virtual world were associated with each particular page of the book. In contrast with the two previous experiences, the development of the educational materials in the virtual world did not need any special technical expertise beyond that of a typical user of virtual worlds such as, for example, Second Life.

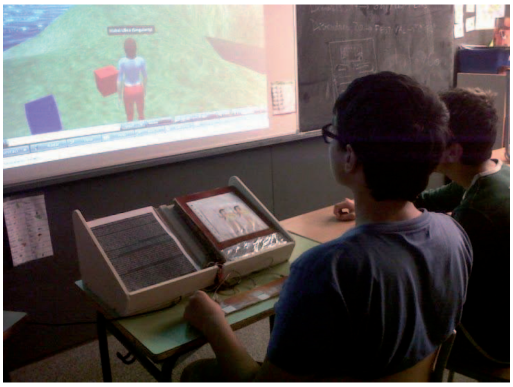

Figure 4. A student using the “tangible book”.

The realization of the tangible interface in the form of a book provided a metaphor that standardized the interaction with the virtual world and encapsulated the technical details, making them “invisible” to the teacher, while still maintaining a high degree of flexibility: the metaphor of the book allowed many different types of interaction. The teacher had just customize the book by adding six A4 pages with the information about the Greek gods, and then developing a virtual scenery representing Greece using standard end-user knowledge about OpenSim- Second Life.

In the developed system, students began the study of the theoretical contents related to a particular god by reading the tangible book. Then they used this information to find this god in the virtual world. For example, knowing that Poseidon is the god of the sea, and is often depicted with a trident, students had to guess where to find him in the virtual world, and how to recognize him when they found him. Once the god was found and recognized, students had to answer a series of questions about the information they had read in the book. If they answered correctly, they got a secret word that allowed them to access the “achievement” area of Olympus. The teacher reported very good results of the system, in terms of the interest and motivation the students showed in studying the topic [13].

V. MIXING TECHNICAL EXPERIENCES: COMPUTER SCIENCE STUDENTS DEVELOPING NEW TANGIBLE INTERFACES TO BE USED BY TEACHERS WITHOUT TECHNICAL EXPERTISE

In the following step it was found that the Virtual Touch toolkit allowed people with technical expertise (computer science students), but with no previous experience in virtual worlds or tangible interfaces, to easily develop new tangible interfaces. Moreover, it was found that these tangible interfaces were sufficiently encapsulated, so that a math teacher with no previous experience in these technologies could develop, with little technical help, educational materials to be taught through mixed reality [14].

Therefore, in this case the design was made in collaboration. People with computer experience designed the tangible interfaces, and the teacher designed the educational experience.

Two new tangible interfaces were developed. The first was FlyStick, which allowed users to control a virtual object in six degrees of freedom by detecting isotonic and isometric muscle contractions (Figure 5).

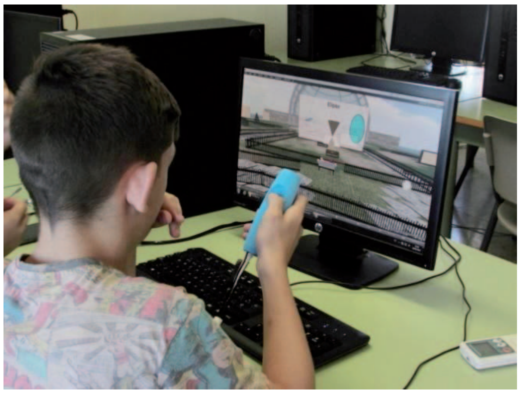

Figure 5. FlyStick, a tangible user interface based on isotonic and isometric interactions.

The second device was PrimBox, a tangible cube that could be used to modify virtual objects in an intuitive way, changing attributes such as position, size, rotation and color (Figure 6).

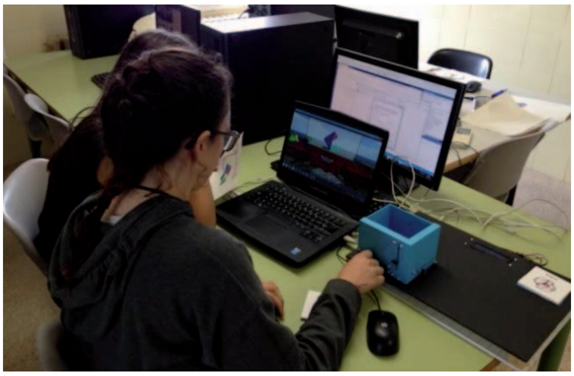

Figure 6. Primbox: A tangible user interface for object manipulation in the virtual world.

The teacher designed one educational experience for each of these tangibles. Using Flystick the student learned how a plane intersects a cone creating all the conical curves. Using Primbox a couple of students learned how to use geometrical language to convey geometrical information. The first student was given a sheet of paper with a geometrical construction depicted in it, and she had to describe it orally to the other student. The second student had to use that oral information to construct the geometrical figure in 3D using the tangible interface Primbox.

These two tangible interfaces were evaluated in the high school "Florida Secundaria" (Valencia, Spain). A group of students used the tool, and a second control group used a traditional learning method (class presentations). Afterwards, the students took two tests in the topic, with some weeks of interval between them. The results showed that Virtual Touch methodology allowed better retention of the knowledge.

VI. STUDENTS DEVELOPING MATERIALS FOR STUDENTS

Finally, we describe a last way of designing educational contents for virtual worlds. The I.E.S. Narcís Oller in Valls (Tarragona, Spain) is a public high school that is experimenting with a collaborative model in which the students themselves develop the educational contents that other students would use. There is an additional interesting feature in this experiment: the students that are creating the educational contents are students in the “reinforcing group”, a special group for students with learning disabilities such as Attention Deficit Disorder (ADD), hyperactivity, etc., in the 3rd year of Secondary Education (ESO). The materials are used afterwards by students that are also in the 3rd year of ESO, but in the ordinary group.

The experience is taking place in the virtual world based on the Open Simulator platform that has been created within the eIntegra project (Spanish Research Plan, project TIN2013-44586-R), which is researching on educational technologies for the social integration of groups at risk of discrimination.

Students in the reinforcement course, under the supervision of their teacher, create within the virtual world landscapes and situations that exemplify the 3D concepts they are studying in the subject of human geography. Examples of such concepts, related to the primary economic sector, are: factors affecting the agricultural area, farming systems, market agriculture, forestry and deforestation, intensive and extensive farms, fisheries resources and typology, aquaculture, etc.

These students often have problems of attention deficit and / or hyperactivity and / or understanding (some of them already diagnosed). Building three-dimensional structures to exemplify the abstract concepts being studied greatly improves their motivation and understanding. The rest of the students of the course that are not in the reinforcement group visit this virtual world and have to give an account of what they see in it, in the form a travel book, attending to the concepts they were taught at the classroom. These students also receive the benefit of studying a topic which can be arid and abstract in a practical and motivating way.

The idea is that this virtual world will grow over several years, accumulating landscapes, forests and farms, so that more and richer materials will be available for the study of this subject.

VII. CONCLUSIONS AND FUTURE WORK

In this paper we have presented our experiences in designing mixed reality systems for education in secondary education schools in Spain. We have illustrated how the teachers have been able to design and develop educational materials without the need of advanced technical skills.

In the next future we plan to encapsulate the Virtual Touch toolkit so it can be distributed and used by people with different technical skills.

ACKNOWLEDGMENT

We want to thank the IES Narcis Oller in Valls (Spain) the IES Ernest Lluch in Cunit (Spain); and the Florida Secundaria high school in Valencia (Spain) for all their support during these experiences.

The work reported in this paper was partially funded by the Spanish Research Plan (project TIN2013-44586-R) and by the Madrid Research Plan (project S2013/ICE-2715).

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