ABSTRACT. The best way to learn is by having a good teacher and the best language learning takes place when the learner is immersed in an environment where the language is natively spoken. 3D multi-user virtual worlds have been claimed to be useful for learning, and the field of exploiting them for education is becoming more and more active thanks to the availability of open source 3D multi-user virtual world development tools. The research question we wanted to respond to was whether we could deploy an engaging learning experience to foster communication skills within a 3D multi-user virtual world with minimum teacher’s help. We base our instructional design on the combination of two constructivist learning strategies: situated learning and cooperative/collaborative learning. We extend the capabilities of the Open Wonderland development toolkit to provide natural text chatting with non-player characters, textual tagging of virtual objects, automatic reading of texts in learning sequences and the orchestration of learning activities to foster collaboration. Our preliminary evaluation of the experience deems it to be very promising.

KEYWORDS: 3D virtual learning environment, Learning system architecture, Open Wonderland, Technology-enhanced language learning education

One of the best ways to learn a foreign language is to be exposed to real situations in which it must be used to communicate (Genesee, 1985; Nieminen, 2006). Considerable advantages can be obtained by introducing collaborative activities (Zhang, 2010), promoting the participants’ interaction with the environment and other members
of the community. Nevertheless, the context must be somehow controlled; otherwise boredom or frustration might impede learning (Csikszentmihalyi, 1990).

A sound alternative to get the required level of linguistic immersion without losing control over the learning process are 3D multi-user virtual worlds (3DVWs). A 3D multi-user virtual world provides a shared, realistic, and immersive space where learners, by means of their avatars, can explore, interact, and modify the world (Bell, 2008; Calongne, 2008; Dalgarno, Lee, 2010; Dickey, 2005; Dillenbourg et al., 2002; Eschenbrenner et al., 2008; Girvan, Savage, 2010; Kallonis, Sampson, 2010). Furthermore, 3DVWs offer a rich environment in which learners can strongly interact with each other, increasing student’s motivations for language learning (Andreas et al., 2010; Chittaro, Ranon, 2007; Hendaoui et al., 2008; Kluge, Riley, 2008; Lee, 2009).

Being immersed in a real environment and being able to interact with members of the educational community is not enough to learn a new language. As in any learning process, instructional design that focuses on specific learning outcomes is very important. In relation to learning outcomes, The Instituto Cervantes in the Common European Framework of Reference for Languages states that the “communicative language competences are put into operation with the completion of various activities that include language comprehension, expression and interaction. These activities can be classified as passive (reading, listening) or active (writing, speaking)” (Instituto Cervantes, 2002). When students communicate in a foreign language, they should demonstrate literacy in all those four essential skills (Hinkel, 2006; Nation, Newton 2009).

Our project is inspired by Language Learning projects that already use 3D Virtual Reality Technologies (Avatar Languages, 2009; Three Immersions, 2008; Koenraad, 2008; Shih, Yang, 2008) that simulate real environments and in some cases, real situations to promote speaking skills. We conceive the 3D learning system as a whole, as an integrated set of technological and pedagogical issues that are tightly related to one another, having to be dealt with them independently but under a unifying light. This dual nature of our work will be reflected in this paper, in which we will describe both, the didactical developments as conceived, in the first place, and how they eventually have been brought into life by means of existing 3D
technologies enhanced with our own developments. An analysis of existing related work will complete this schema. Finally we present a preliminary evaluation of our learning environment in terms of motivation, immersion, and participation in collaborative activities.

**Related work**

Current instructional design models encourage active, rather than passive learning; they are based on constructivist theories whose central assumption is that humans create knowledge as opposed to acquiring it (Dewey, 1916; Ertmer, Newby, 1993; Vrasidas, 2000). Within the constructivist theory, there are two prominent schools: personal constructivism and social constructivism (Vrasidas, 2000). The former states that knowledge is constructed in the head of the learner, these principles follow Piaget theories. The latter assumes that knowledge is constructed in communities of practice, through social interaction (Vygotsky, 1978). Both schools emphasize the influence that the environment has on learners (Jonassen, 1994; Wilson, 1997).

Nowadays, information and communication technologies provide mechanisms to design and develop environments which facilitate the construction of knowledge and support personal and social constructivism (Perkins, 1992). Among the emerging technologies that can be used for distance education, 3DVWs is the one where it is possible to deploy truly immersive spaces fostering learner's imagination with possibilities of interaction with the environment, the objects and other community members through avatars (Bell, 2008; Calongne, 2008; Dillenbourg et al., 2002; Eschenbrenner et al., 2008; Girvan, Savage, 2010; Kallonis, Sampson, 2010). Thus, 3DVWs have offered, from their very beginning, an excellent place for learning and teaching and some authors have issued guidelines for using the constructivist approach on them (Chittaro, Ranon, 2007; Dillenbourg et al., 2002; Huang et al., 2010). The principles stated suggest the use of visual elements of 3DVWs to immerse students into a situation where the problem to be solved is presented in a natural way. Besides, 3D objects and non-player characters (NPCs) are used as instruments of transmitting information and as tools for building knowledge as it is required by constructivist principles. Projects following these guidelines include those on 3D simulation,
public events organization and collaboration (Dalgaro, Lee, 2010; Livingstone, Kemp, 2008).

- 3D simulations. This family of projects immerses participants into learning situations where they can practice in a safe environment with possibilities of having an individualized feedback. Among the projects that use full interactive simulations, it is worth mentioning the “Genome Island” (Clark, 2009), where visitors find interactive versions of classical genetic experiments, or “The Heart Murmur Sim” (Boulos, 2007), a training space where learners should diagnose the illness of patients. In the context of learning foreign languages, simulations involve recreation of real-life situations to promote students engagement (Shih, Yang, 2008) or the recreation of English-speaking town where students can have rich conversations not only with native speakers but also with their peers (Koenraad, 2008).

- Organization of public events. These applications use 3DVWs as meeting points or as mediums to explore learning environments. This kind of activities are usual in Second Life, with examples like the “New Media Consortium Campus” (Linden Labs, 2006), but not exclusive of that platform: the project MiRTLE (“A Mixed Reality Teaching and Learning Environment”) (Callaghan et al., 2008), developed over Open Wonderland, is to be highlighted. Even if 3DVWs are one of the richest interfaces to be used for language learning, they are usually complemented with other tools and resources, like websites, audio chats, shared blackboards, etc. That is the case of the “3jSchool Chinese Language” (Three Immersions, 2008), whose virtual world, conceived for learning Mandarin, includes additional multimedia materials used in scheduled learning sessions.

- Collaboration. This last family of projects represents the essence of social constructivism, the possibility of creating knowledge within a learning community. Greenbush Edusim project (Greenbush Education Service Center, 2007) is an application in this category where students collaboratively build objects, as tangible knowledge.
A combination of these approaches is possible and even convenient for a foreign language learning environment. In terms of learning strategies based on constructivism, instructional designers on 3D virtual learning environments have several possibilities (Girvan, Savage, 2010; Huang et al., 2010), here we survey some of them:

• **Situated learning.** It states that knowledge should be presented in an authentic context where it is possible social interaction (Dewey, 1916; Ertmer, Newby, 1993). 3DVWs enable deployment of simulations in realistic looking environments.

• **Role playing.** Learners can assume different characteristics and personalities through their avatars (Holmes, 2007).

• **Cooperative/Collaborative learning.** 3DVWs can be seen as meeting points where learners can be aware of presence of peers, collaborate in building knowledge and communicate through the tools provided on these worlds (Chittaro, Ranon, 2007).

• **Problem-based learning.** 3DVWs allow to present ill-structured problems to solve, one of the principles of constructivism (Jonassen, 1994).

• **Creative learning.** H.M. Huang at al. (Huang et al., 2010) defends 3DVWs as environments that promote imagination and thus creativity.

If using 3D environments for teaching and learning seems a very sound option in general, when we focus on language learning the possibilities are really promising: 3DVWs become the ideal environment for deep linguistic immersion and realistic situated learning, without the need to travel to the places where the language to be learned is spoken. For the time being, our system includes 3D simulation of real conversations in downtown Madrid and group working specifically designed to enforce oral communication and information sharing. We base our instructional design on the combination of two constructivist learning strategies: situated learning and cooperative and collaborative learning.

All the learning foreign language projects reported concentrate their efforts in developing speaking skills but lacks of mechanisms to foster collaboration (Kreijns et al., 2003). In order to overcome these problems, the proposed system aims to develop the four communication skills orchestrated in a collaborative activity to achieve a final common goal.
Case study

The proposed learning experience takes place on a 3D multi-user virtual world that imitates cultural sights of Madrid in which a community of learners experience auditory and visual immersion. The scenery is filled with information about the life and work of D. Velázquez, one of the most important painters of Spain. Activities are designed to stimulate learners’ imagination, to motivate them to acquire knowledge and to promote collaboration. Learners represented by customized avatars of their choice, should explore freely the environment looking for information to achieve a final goal: to get access to The Prado Museum.

In our 3D learning scenario, the activities are structured as the interaction of avatars with 3DVs elements: synthetic environment, 3D objects, NPCs and other avatars. They are designed to develop and practice the skills involved in learning a foreign language.

- **Reading skills**: Reading skills are promoted through information tagged to 3D objects included in the scenario. When one of these objects is selected, its name appears along with practical information (reading comprehension). For instance, associated with the street names are written anecdotes about events that occurred there in the time of Velázquez.

- **Listening skills**: Listening skills are encouraged through interaction with 3D objects and NPCs. Some 3D objects have associated audio that is triggered when learner approaches the object. For instance, associated with the statue of Velázquez is a speech about his major paintings. Learners can also hear pre-recorded conversations between NPCs (see Figure 1). Simple conversations allow illustrating the use of grammar patterns and more complex conversations, related to cultural aspects of the lesson topic, allow the development of more advanced listening skills.

- **Writing skills**: Learners will develop basic writing skills using the vocabulary and grammar of the lesson to ask and give information to NPCs that understand simple constructions. This is done by using natural language processing chatbots. For instance, at Figure 2 David is asking a female chatbot for an address.
• **Speaking skills**: The activities previously described are achieved primarily through the exploration of the virtual environment. All the learners can discover the same vocabulary and language patterns, but not all of them receive the same information about Velázquez. Learners are divided into groups and each group will hear only some of the dialogs played by the NPCs. Learners should exchange the information received among their pairs in order to pass collaboratively a final test. See the back of Figure 2, where two learners are talking.
Implications for an architecture to deploy 3DVWs to learn foreign languages

The deployment of any learning environment over 3DVWs, and in particular those based on situated learning, requires a 3D scenery filled with meaningful 3D elements: 3D objects relating to the context of the application, and NPCs to simulate real-life situations in the learning environment. It is expected that these graphical elements in a 3D medium provide visual immersion to learners and thus engage them in the learning experience. Visual immersion can be fostered by using hardware devices providing the stereoscopic vision, 360 degree immersive virtual reality.

Avatars are the mediums learners have to interact with the virtual world, communicate with other avatars, and navigate through the world. To cover the interaction capabilities, our application requires multimodal information attached to 3D elements that can be viewed or heard when a learner selects or approaches them. These scripting possibilities will support the reading and listening skills. A more sophisticated way of interaction that is especially useful in our application is through NPCs provided with Artificial Intelligence tools that allow them to understand simple written sentences. By including this capability, the application supports the development of writing skills.

None of the above is possible without an adequate means of navigation through the world. Usually this is done via the mouse or the keyboard. Nevertheless, it is also desirable to have software elements to overcome the orientation problems in 3D.

The collaboration activity designed to develop speaking skills, requires students to work in groups and the possibility to give different information to each group. Thus, the system must provide capabilities to group students and security mechanisms that allow restricted access to information.

Architecture

We have built our 3D virtual learning environment with Open Wonderland (Open Wonderland Foundation, 2010), a cross-platform, free and open source software. The toolkit is written entirely in Java, it supports audio conferencing, desktop application
sharing, and integration with external data sources. This platform has been chosen by the “Immersive Education Initiative” (Immersive Education, 2009) to integrate an ecosystem of platforms in which learning objects can be exchanged.

Open Wonderland has a distributed client-server architecture. We have extended its functionality by plugging in several modules required in our learning environment (see Figure 3). Although each module has three components executed in the client, the server and both client and server respectively, a module is identified as a client’s module when its primary functionality is executed on the client, otherwise is identified as a server’s module.

**Open Wonderland server**

A 3DVWs is a composition of 3D scenes filled with NPCs, chatbots and smart objects that are installed by the administrator into the Snapshot Engine. In Open Wonderland, these graphical objects must be in the COLLADA (Arnaud, Barnes, 2006) format and are stored as XML files. In order to simplify the building of our 3D virtual learning worlds, we use the application Google SketchUp (Google, 2010) to create (or import) the 3D models required.

One advantage of Open Wonderland over other platforms is that it can be used to build collaborative 3D environments with spatial sound capabilities. These capabilities are provided by its Audio Engine and are particularly relevant for our Spanish learning
environment because they provide full audio immersion. The audio immersion is achieved by attaching each audio treatment to a point in the 3D scene. The point can be, for instance, an NPC that identifies the source of audio, when an avatar approaches to that point, the user can hear the sound louder. The audio data used to reproduce the NPCs conversations was obtained using a Text To Speech (TTS) technology that provides an acceptable quality. The audio files were created with TTS Reader (SpheNet, 2009) freeware software. As a future work, we are planning to use TTS technology to get the audio in real time, instead of using prerecorded files.

A key aspect of our instructional design is the social interaction among students; this is implemented by grouping them in small units managed by the Group Management plug in. Finally, each learning sequence must be orchestrated, it takes place in a scene and when the learning goals have been achieved, the avatar may be teleported to another learning sequence; this is done by the Portal Engine.

**Open Wonderland client**

The visual component in a virtual world is essential to involve users in the virtual experience, therefore any platform to build 3DVWs provides a Rendering Engine to handle 3D graphics. In Open Wonderland 0.5 this engine is allocated in the client component and requires from the server’s Snapshot Engine the XML files representing the virtual world. We extended Open Wonderland’s Rendering Engine to provide visual immersion through the integration of a virtual-reality headgear as display. The new functionality allows the learner to switch into the full screen mode and set a 360° camera in order to watch through the world from any angle. The learner may also include new objects into the world; the easiest way to do so is by importing objects from Google SketchUp.

As avatars are users’ representation in the virtual world, it is crucial that learners customize their avatars according to their preferences. As Open Wonderland 0.5 provides limited capabilities for this, thus we suggest using the Evolver 3D Avatar Generator (Darwin Dimensions, 2009) to create avatars and then import them into Open Wonderland’s Avatar Engine.

To ease the movement of avatars in the virtual world, we have
developed the OSC Engine, an avatar manipulation engine that allows students to move their avatars through a SunSPOT
(Smith et al., 2006), besides the keyboard and the mouse. The SunSPOT communication with the Open Wonderland client is achieved with the OSC protocol (Wright, 2005), an Open Sound Control protocol optimized for modern networking technology. Any virtual world platform provides mechanisms to add functionality to smart objects through Scripting Engines. Our platform customized programming object behaviors as reaction to mouse and key events. In this regard, the cursor’s shape change when the mouse is over an object with information to the learner and text appears once the student clicks on a smart object. The changes made on the Scripting Engine promote reading skills and help students acquire vocabulary. We distinguish among two types of characters controlled by our system: NPCs and chatbots. The first are synthetic characters which drive cyclical story line that perform dialogues depending on the student who approaches them. The last are used to transmit information to the students by simulating typical Spanish people conversations. Chatbots encourage students to approach them when their avatars are in their surroundings, once done chatbots perform interactive dialogues with students. These behaviors contribute to the acquisition of listening and writing skills in our Spanish learning environment. ProgramD (Program D, 2009) an extended open source AIML platform was used to program the chatbots. As AIML (Artificial Intelligence Mark-up Language) is a XML-based programming language, it was necessary storing linguistic patterns and their possible answers related to the learning topic.
Finally, GPS Engine was developed to manipulate NPCs with an external device, a mobile phone with Symbian Operating System. The mobile phone uses the GPS technology to detect movement and send the NPC’s new position to the GPS client’s module via socket. In the future, we intend to use this technology to move the user’s avatar.

**WebDav server**

Data common to all clients are stored in a WebDav-based content repository hosted by the Open Wonderland Server. With this content repository, the client can access these data via the HTTP protocol.
AIML data and Script data needed by AIML Engine and Scripting Engine respectively are stored in the content repository. AIML data are the XML files that hold patterns that can be introduced by clients along with their associated answers. The Script data are JavaScript files holding the behavior associated with keyboard and mouse events.

Preliminary evaluation of the learning environment

We conducted a preliminary evaluation to determine the usefulness of our learning environment in terms of motivation, immersion into a situated learning experience, and participation in collaborative activities.

The participants were twelve non-native Spanish speakers and six foreign language teachers grouped in six different experiences located in the virtual world. Only one participant had previous experience in virtual worlds. Participants did not have initial training using our system.

In the study, we observed the participants interacting with the 3DVW and we used interview evaluation techniques with open questions to identify strengths and weaknesses of the learning environment. Participants felt unsure when the tour began but they soon gained self-confidence. Collaboration emerged naturally to overcome initial difficulties participants had in understanding what to do and how to do it.

“At the beginning, I didn’t know where to go. I asked my friend and he told me what to do.”

“It is weird to walk through the middle of the street.”

Activities were perceived as games, participants were seen really engaged, and most of them continued the discussion after the experience had finished. In terms of communication, 3D audio provided a strong feeling of immersion, text chat was perceived as useful to establish communication with partners physically distant in the virtual world and most of users asked for tools for writing notes. Those who came from outside Madrid reported it was useful to be into a 3D scenery where the city’s cultural activity could be observed.
“Although I understood the dialogues, I would like to have a block of notes.”
“It was fun to chat with the actors (chatbots).”
“Are you sure that Velázquez was a friend of Quevedo?”
“Good, we are at Madrid!”
“I liked it, it is very visual.”

Despite features deployed to support orientation within the world, participants had difficulties to find locations. Furthermore, hardware devices provided to improve 3D visualization (Z800 3DVisor) and 3D interaction (SunSPOT), proved to be more a problem than a solution.

**Conclusions and future work**

3DVWs open the door to a new way of learning. Setting up realistic environments enhanced with a powerful set of learning oriented tools, these platforms allow for the implementation of sophisticated instructional models within a framework of richer information and cooperation.

In this paper, we have taken a step forward in the deployment of 3D virtual learning environments that fully exploit the immersive, interactive, and collaborative possibilities of 3DVWs. Technical and pedagogical features enrich our environments to provide students with formal and informal learning following less rigid curricula where a teacher is not always present. From the technical point of view, we included the use of haptic devices and natural chatting with NPCs. From the pedagogical point of view, we provide a collaborative environment where students will acquire and practice the necessary communication skills under the constructivist principles of situated learning and cooperative/collaborative learning.

We have conducted a preliminary evaluation to test the usefulness of our learning environment in terms of motivation, immersion into a situated learning experience, and participation in collaborative activities. The results were encouraging. There is much more to improve in order to really convert a 3DVW environment into a learning platform. Another very important milestone will be the introduction of assessment procedures into 3DVWs, which is the challenge we are tackling now.
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Sintesi

Il successo nell'apprendimento di una lingua straniera richiede la full immersion del discente e il suo coinvolgimento in una esperienza collaborativa che gli permetta di esercitare le abilità linguistiche fondamentali (reading/listening/writing/speaking) in situazione reale. L’utilizzo di ambienti virtuali multi-user in 3D nel settore dell’apprendimento presenta straordinarie potenzialità in quanto garantisce l’immersione senza richiedere onerosi spostamenti e permette agli studenti di esercitarsi in autonomia, anche indipendentemente dalla presenza dell’insegnante. La virtualità favorisce un approccio articolato alla lingua, alla cultura e all’arte di
un paese, approccio che i ricercatori del dipartimento di ingegneria informatica dell’Università di Madrid, in collaborazione con la School of Arts and Communications (K3) di Malmö, hanno concretizzato nella realizzazione di un prototipo di ambiente virtuale, navigabile a 360°, che riproduce la città stessa e culmina con la visita del museo del Prado. Gli studenti, mediante l’interazione tra pari, con smart objects e NPC (non-player characters), sono coinvolti in un “gioco” in cui devono raccogliere una serie di informazioni, riguardanti il pittore Velasquez, disseminate all’interno dell’ambiente virtuale, prima di poter accedere alla visita del museo. La dinamica ludica che si instaura tra i partecipanti all’interno dell’ambiente 3D stimola la curiosità e favorisce il coinvolgimento emotivo, un elemento importante per promuovere l’apprendimento. La tecnologia Avatar è il medium della comunicazione e dell’interazione con l’ambiente e tra pari; una strategia didattica che mira a contemperare le istanze teorico-pedagogiche di matrice costruttivista con la pratica educativa tradotta in termini tecnologici. In particolare, la piattaforma realizzata è orientata a potenziare il situated learning e il cooperative learning, in una prospettiva ispirata al modello vygotskyano dell’apprendimento in funzione sociale.

Dal punto di vista tecnologico, il prototipo realizzato parte dalla piattaforma free e open source Open Wonderland, adottata dalla Immersive Education Initiative, una associazione internazionale di enti universitari e di ricerca impegnati con modalità collaborative alla definizione di standard e best practice [per l’apprendimento] mediante la virtualità e il game-based. Le funzionalità della piattaforma sono state ampliate e adattate alle esigenze del corso, potenziando la possibilità di personalizzare gli avatar, facilitandone la manipolazione all’interno dell’ambiente virtuale e l’interazione tra studenti in gruppi.

La valutazione del prototipo su un gruppo di venti studenti e sei docenti ha prodotto esiti incoraggianti, decisivi anche per definire future migliorie al sistema, come la possibilità di prendere appunti - esigenza segnalata da diversi studenti - l’utilizzo del sistema GPS per muovere gli avatar mediante cellulari e mobile device, e la necessità di potenziare gli strumenti per l’orientamento all’interno della città virtuale. Le attività, percepite in maniera ludica, hanno stimolato l’interesse degli studenti e il loro coinvolgimento; la collaborazione tra pari si è instaurata in maniera naturale, fin dall’inizio dell’esperimento, poiché gli studenti, per superare le difficoltà iniziali dovute alla non familiarità con l’ambiente e al suo funzionamento hanno problematizzato la situazione consultandosi vicendevolmente.

Dal punto di vista strettamente didattico, infine, la funzionalità su cui il team sta attualmente lavorando riguarda l’inserimento di procedure di valutazione dell’apprendimento all’interno dell’ambiente; l’applicazione ai corsi di lingua della virtualità degli strumenti in 3D multi-user, in cui si valorizza infatti l’interazione su due livelli 1) utente - ambiente 2) utenti tra loro e 3) utente-istruttore, un passaggio decisivo per trasformare un mondo virtuale in una piattaforma di apprendimento e verifica delle conoscenze.