# Chapter 10
# Virtual Reality Environments (VREs) for Training and Learning

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## 1 Introduction

The term Virtual Reality (VR) was first used by Jaron Lanier, founder of VPL Research, in 1989, when he began to develop goggles and gloves, which were needed to experience what he called VR. We live at a time where advances in the field of VR are moving rapidly. People in VR are immersed in an environment that is realized through computer-controlled display systems, and with the possibility to affect changes in that environment (Sanchez-Vives & Slater, 2005).

VR provides users the ability to experience realistic scenarios, environments and situations, and chances are they will likely react natural and realistically, so we could say that VR simulates reality. Examples of current uses of VR in real applications include simulations (Aristidou & Michael, 2014; Michael, Kleanthous, Savva, Christodoulou, Pampaka, & Gregoriades, 2014), training, learning (Christofi et al., 2018; Pappa, Ioannou, Christofi, & Lanitis, 2018) and phobias treatment (Christofi & Michael-Grigoriou, 2016).

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In the broad area of training, immersive VR and its power of interaction with virtual objects and visualization (Norrby, Grebner, Eriksson, & Bostrom, 2015) could be extremely helpful. People can be trained in a virtual environment alone or in a shared environment with others. Virtual environments have many advantages over real ones; they can be used to experiment safely, and they are controllable. Any environment can be created, realistic or fictional, for the purposes of the training. When using VR technology for training, it is possible to repeat training exercises as many times as required without additional cost. Interaction could vary as well, depending on the cause and the specific field of training. VR has also the advantage of the three-dimensional representation of objects, which is really important for understanding and learning.

An area that VR training is being used is in sports and physical training in general. What makes VR ideal for this area is that when an HMD is combined with the body tracking of the user, or at least hand or foot tracking, it could be utilized to train athletes (Miles, Pop, Watt, Lawrence, & John, 2012) or normal people to play sports or even just for exercising without having the need to go to an actual gym. It can be also used to understand perception and action in sports (Craig, 2013) and even analysing sports performance (Bideau et al., 2010). VR has the potential to make exercise more fun for people. One example could be to connect an exercise bike to a display, so the user can view a landscape while biking, and the scenery would change accordingly to his actions. Similarly, it is possible to connect a treadmill to a VR display, so that the user could walk on the moon for example, or a forest or an imaginary setting. This is the power of VR, it allows us to go beyond our reality, and make people feel like they are exercising on another planet, or walk on another place rather than the gym, and this could motivate them to exercise more.

Often, experts coming from a variety of fields like doctors, lawyers or even psychologists are required to make decisions with multiple results for the recipients. VR environments can provide those experts an ideal space to replicate situations similar to those that they face, providing them the opportunity to be trained as many times as necessary and experiment on the proper course of action but within a safe three-dimensional environment. For instance, VREs could provide medical students a virtual setting like a hospital, for example, allowing them to interact with the human body or with virtual patients minimizing the risk of harming a real patience (Cendan & Lok, 2012; Cook, Erwin, & Triola, 2010; Kleinsmith, Rivera-Gutierrez, Finney, Cendan, & Lok, 2015; Michael-Grigoriou, Yiannakou, & Christofi, 2017).

A more specific area that VR has been used and researched thoroughly is training surgeons and medical students (Alaraj et al., 2011). VR simulations are being used for training, teaching and planning for surgeries. It is an area that the advantages of virtual environments are most visible, because it is easier and better to train on virtual bodies than real ones. These simulations have visual displays combined with haptic devices that are important for the user to apply forces to the virtual object and at the same time feel back the resistance from the object. Reviews and meta-analyses regarding the effectiveness of VR training simulations used in training have been conducted as well (Al-Kadi et al., 2012; Zendejas, Brydges, Hamstra, & Cook, 2013).

VR can be a powerful tool in the research of empathy for learning and education. VR technologies have been used for inducing empathy towards groups of people that are stigmatized by society (Christofi & Michael-Grigoriou, 2017). Empathy in this context was induced into student learning about international studies. Stover (2007) described a computer simulation that allowed students to participate in the emotional effect of the Cold War, developing a sense of empathy with decision-makers and having a better appreciation about the risk, danger and fear associated with the Cold War.

## 2 Literature Review

### *2.1 Introduction*

The last few years, the use of Virtual Reality Environments (VREs) in the field of education has attracted the interest of the scientific community that seeks new ways to bring technology into the learning process. The use of VR as a teaching and learning instrument demands taking into consideration several pedagogical principles to guide the implementation of activities. From an educational perspective, VR approaches can be used to support constructivist learning theory, offering users engaging learning activities allowing them to conquer knowledge on their own and connect it to their previous knowledge (Aiello, D'Elia, Di Tore, & Sibilio, 2012; Eschenbrenner, Nah, & Siau, 2008).

### *2.2 The Significance of Virtual Reality in the Learning Process*

Research revealed numerous benefits of using VR-based approach in the field of education. Most importantly, VR technology allows the development of virtual worlds that mimic the real world, simulating real-based incidents and situations, providing the users a space that suits their needs for training and learning through experimentation (Eschenbrenner et al., 2008). Thus, within VREs, users are able to experience authentic and realistic scenarios and situations closely connected to real life, within which they can behave and respond as they would do in the real world (Parsons, Bowerly, Buckwalter, & Rizzo, 2007). Moreover, the VR situations are easily controllable making VREs a valuable training tool (Rizzo et al., 2009). Another significant issue is that learners could potentially feel more psychologically present in virtual environments compared to the traditional learning methods (Bailenson et al., 2008). That fact makes VREs an extremely useful therapeutic tool for the treatment of anxiety disorders (Powers & Emmelkamp, 2008), social phobia (Klinger et al., 2005), public speaking anxiety (Harris, Kemmerling, & North, 2002), fear of spiders (Garcia-Palacios, Hoffman, Carlin, Furness Iii, & Botella, 2002) or even fear of flying (Rothbaum, Hodges, Smith, Lee, & Price, 2000).

Apart from the fact that VR allows the design of virtual spaces that are identical to the real ones, more importantly within those environments the performance of the user can be measured and be used for multiple purposes including training (Rizzo et al., 2009). Of great value is also the fact that not only the knowledge gained within the VRE can be transferred to the real world but also the knowledge from the real world can be used within the VR environment (Eschenbrenner et al., 2008; Huang, Backman, Chang, Backman, & McGuire, 2013; Parsons et al., 2007). As an illustration, VREs have been used for job interview training in order to enhance interview skills and self-confidence for individuals, so as to have greater odds of receiving a job and weed out their anxiety (Smith et al., 2015). Equally important is the fact that VREs allow the users to experience a scenario from multiple different perspectives, understanding the different aspects of a situation (Bailenson et al., 2008). Therefore, the users can experiment in a risk-free environment and learn by trial and error (Freina & Ott, 2015; Rizzo et al., 2009). For example, in the past, we could read a book and try to enter the position of the character, but within a VRE it is possible for genders to swap bodies, so a woman could feel as being inside of the body of a man and vice versa (Bertrand, Gonzalez-Franco, Cherene, Pointeau, 2014; Kuchera, 2014; Rutherford-Morrison, 2015).

Another significant issue is that VREs allow training in situations where it is impossible to do it in a physical space due to the cost or possible danger (Bailenson et al., 2008; Freina & Ott, 2015). However, within a simulated virtual environment that represents real-life dangerous situations, learners can experience crises situations but within a safe environment with room for error and no danger (Bailenson et al., 2008; Freina & Ott, 2015). For this reason, VR is often used in vocational training providing practical experiences to workers of areas in which real-life training is not an option due to lack of access or because the danger is very high (Freina & Ott, 2015). To illustrate, it is not possible to train in real scenarios firefighters or bioterrorist response units as those dangerous situations cannot be created in reality. However, within VREs that represent real-life dangerous crisis, the users can experience such chaotic and stressful crisis and through continuous training be prepared to act accordingly if needed (Bailenson et al., 2008). For instance, VR can be used as an educational tool to train young people face and survive against natural disasters such as fire and earthquakes. Using VR technology allows the users to step inside the disaster and thus, experience a remarkably realistic experience while they are trained to avoid dangerous actions like going near windows or touching flames aiming to reduce their fear during the disaster (Dumol, Lascano, Magno, & Tiongson, 2014).

Another important aspect is that VREs can support knowledge acquisition by supporting different learning styles such as visual, auditory or kinesthetic (Lee & Wong, 2014; Freina & Ott, 2015). In this way, the virtual worlds match the needs of the trainees leading to knowledge mastering (Rizzo et al., 2009). Apart from visual capabilities, VR can offer the users haptic and auditory capabilities, maximizing their experience in the virtual world and more importantly their learning. Those capabilities provide a multisensory immersive journey maximizing the user experience and level of realism of the VRE supporting in that way highly demanding training activities such as training for medical doctors (Bailenson et al., 2008).

VR allows the visualization of the educational content, allowing the users to better understand concepts that are difficult to present dynamically in the traditional classroom (Eschenbrenner et al., 2008). Hence, the users gain deeper understanding and sense of caring for the topic leading to increased enthusiasm for learning (Freina & Ott, 2015). Moreover, the users are offered instant feedback allowing reflection and maximization of learning and performance (McComas, Pivik, & Laflamme, 1998). The fact that VR can increase learner's involvement, motivation and engagement of the users in the simulated activities (Freina & Ott, 2015; Huang et al., 2013) can support supplementary to traditional teaching methods allowing teachers to spend the classroom time in more effective activities for the students such as discussions and group work (Eschenbrenner et al., 2008). Furthermore, instructors can develop cooperative activities with VREs promoting communication, collaboration and social skills of the users (Bailenson et al., 2008; Eschenbrenner et al., 2008; McComas et al., 1998). Using VREs is an innovative approach that can promote creativity skills allowing users to develop their own VRE, which results in idea generation, while offering new educational opportunities (Eschenbrenner et al., 2008).

Research regarding the use of VR in education sector is still at its infancy and there is limited yet growing body of research indicating the potential of using such an approach. Freina and Ott (2015) conducted a literature research related to the use of virtual reality in education and the results revealed that most of the papers are related to the subjects of computer science, engineering, social sciences and medicine. Moreover, most virtual reality research papers have to do with university or pre-university while VR appears to be used in adult training in areas in which practice in the real setting is impossible due to lack of access or danger. Despite the limited body of research, the results indicate significant positive effects on teaching and learning in many different thematic areas. For example, VR environments have been used for pedestrian safety training (Schwebel, Combs, Rodriguez, Severson, & Sisiopiku, 2016); children with attention-deficit/hyperactivity disorder (ADHD) (Rizzo et al., 2009), children with disabilities (McComas et al., 1998) and children with Autism Spectrum Disorder (ASD) (Parsons et al., 2007).

## *2.3 Limitations of VR*

Despite the several positive aspects of using VR in education, there are several limitations and challenges that need to be addressed. One of the more significant challenges is to ensure that the designed activities of VR applications developed for educational purposes meet the pedagogical objectives that must be achieved, providing the necessary educational added value to learners (Eschenbrenner et al., 2008). VREs have the potential to enhance teaching and learning; however, it is essential to establish the theoretical framework that will guide the design and development of the VR system aiming to promote effective learning (Chen, 2006).

Technological problems must be taken into consideration as the continuous technological advancements have not yet eliminated all the technical difficulties, while the design of the VREs is also a complex issue (Huang & Alessi, 1998). Another important limitation is that the acquisition of high-fidelity VR technology by many educational institutions such as schools is difficult due to the cost in combination with the lack of resources devoted to education. As a result, in many cases where perishable groups such as students with severe disabilities will require such an equipment the cost for the families will be unreachable (Eschenbrenner et al., 2008; McComas et al., 1998). Health and safety issues in the form of dizziness and risk of accidents associated with the use of the VR equipment cannot be neglected; hence, safety measures need to be taken into serious consideration when using VR for education (Eschenbrenner et al., 2008).

Additionally, the lack of experience in the use of such technology by teachers and students can cause problems (Eschenbrenner et al., 2008). Thus, training for familiarization to this technology is essential so as for the learning purposes not to be downgraded, which is time-consuming (Pantelidis, 2010). Additionally, due to this unfamiliarity with this technology, developing VR applications by teachers to meet the needs of the students is difficult, and thus teachers need to rely on already existing material that not only is extremely limited but probably does not meet their needs. Ideally, teachers should have at their disposals tools that would allow them to create VR applications customized to their teaching needs. Furthermore, there is a lack of research related to primary and secondary education; however, several factors must be taken into consideration including the demands of conducting research in a school setting and the recommendations related to the use of the 3D glasses by children (Freina & Ott, 2015).

It is also worth mentioning that there are several researchers related to the use of VR in education including the use of three-dimensional environments. However, most of those researches refer to the use of second life and similar virtual worlds consider 3D computer visualization as VR, yet they do not include the use of special electronic equipment, such as HMD glasses, that support the immersion of users.

## *2.4 Opportunities: VR Capabilities, Immersion, Presence and Embodiment*

### 2.4.1 VR Technical Capabilities

The typical VR system we would recognize until a few years ago focused around vision and sound. The latest developments in VR are experimenting with the use of specialized suits and gloves to provide the users with tactile and force feedback as well. Most rarely smell and taste are included in a VR system.

The goal is to substitute the users' real sensory data with the virtual ones so that to immerse users into a virtual world and make them believe that they have a highly realistic experience. More technically, VRs' goal is to replace the users' real sense perceptions with the virtual ones. Many researchers in the 90s have found some of the factors that are fundamental to achieve this sensory substitution (Heeter, 1992; Held & Durlach, 1992; Slater & Wilbur, 1997; Steuer, 1992) which include head tracking, high-resolution displays, wide field-of-view vision, stereo and low latency. Nowadays, new factors arose including body tracking. VR systems like the Oculus Rift and especially the newest Vive Pro (Vive, 2018) include dual-OLED displays with an industry leading resolution of 2880 × 1600 pixels, up to 10 × 10 m room-scale tracking, Hi-Res headphones, 3D spatial in integration and environmental noise cancellation and controllers for the interaction of the user inside of the virtual world.

### 2.4.2 Immersion, Presence and Embodiment

Three important concepts in the field of VR are immersion, presence and embodiment. A VR system that is considered as immersive is the one that can deliver the ability to perceive through natural sensorimotor contingencies. How immersive a VR system is is determined by the technology (Slater & Sanchez-Vives, 2016). Comparisons can also be done, and classifications of systems as being more immersive from one another. We could say that one VR system is "more immersive" than another one when it can simulate a perception the other system cannot. For example, a VR system containing an HMD with head tracking and real-time body tracking of the user could be considered "more immersive" than a Cave, because when using an HMD, you view a virtual body in the same place with your real one. You cannot accomplish this using a Cave.

A subjective correlate of immersion is the concept of presence. If a participant in VR perceives using his body in a natural way, then the simplest inference for her brain's perceptual system to make is that what is being perceived is the participant's actual surroundings. Presence then is the subjective illusion of "being there" in the environment you are viewing through the VR displays (Slater & Sanchez-Vives, 2016). Slater in 2009, deconstructed the concept of presence into two independent concepts: (i) Place Illusion (PI) and (ii) Plausibility Illusion (Psi). He refers to PI as the original idea of the illusion of being in the virtual place and to Psi as the illusion that the events experienced in VR are really happening (even though the participant knows that they are not). He mentions that Psi requires that the virtual environment responds to actions of the participant and when both PI and Psi exist then the participants will more likely behave realistically in VR. This fundamental aspect of VR to deliver experience that gives rise to illusory sense of place and an illusory sense of reality is what distinguishes it fundamentally from all other types of media.

If we require for the user to have a virtual representation in the virtual world, we would replace his real body with a virtual one. This process is called embodiment. Spanlang et al. (2014) described a technical setup to achieve embodiment. A typical setup would require an HMD with a wide field-of-view, head and body tracking in real time using devices like the Kinect or a motion capture suit or sensors.

## 3 VR for Training Teachers

Traditional teacher preparation programmes focus primarily on pedagogical issues and only in some cases include in-field practical experiences (Andreasen & Haciomeroglu, 2009; Dieker, Hynes, Hughes, & Smith, 2008; Katsarou & Dedouli, 2008; Ting, 2013). This results in the question of whether there should be an alternative training method that could provide teachers the in-field training that they need. Teaching practice in schools with real students is becoming more difficult to accomplish nowadays. Nonetheless, beginning teachers are expected to be of highly professional quality and practice.

Technology might give the answer to the request for a strong training tool in teacher preparation, enabling pre-service but also in-service teachers to improve the quality of their teaching performance. VR environments can be used for the development of highly effective and professional future teachers that will be successful in the classroom. Moreover, constant training within a virtual school environment will better prepare teachers and ensure their survival in today's digital and multicultural classrooms. The significance of using immersive VR environments in teacher training lies on the fact that the scenarios can simulate real-life-based phenomena and situations, while the knowledge gained within the VE can be transferred to the real world (Eschenbrenner et al., 2008; Huang et al., 2013; Parsons, 2016). Another key point is that VEs provide teachers a safe environment within which they can make mistakes but without influencing learning of real students and they can repeat the experience to work on their mistakes and no matter how many times teachers may want to experiment, the virtual students have no memory of the process (Dieker et al., 2008; Freina & Ott, 2015). By the same token, virtual classroom environments aim to provide an innovative training tool that can be used for constant professional development and update of teachers' skills so that teachers can remain productive (Dieker et al., 2008). Furthermore, the use of virtual environments will allow teachers to take control of their own learning, monitor their progress and thus learn more. Equally important is that the virtual environment will provide immediate feedback and data that in an actual classroom would be difficulty to identify (Dieker et al., 2008).

Despite the extensive use of VR in fields such as medicine and military, in the field of teacher education, its use is extremely limited. In the last few years, some attempts have been made in the preparation of teachers via virtual training environments. However, it should be noted that many of those attempts do not include the use of the VR equipment such as HMD glasses but provide the user a virtual classroom for experimentation through large screen displays. For instance, a prototype virtual environment named STAR Simulator was developed aiming to identify, recruit and train the best teachers by providing them rich experiences through interactions with the virtual students (Dieker et al., 2008). The results of the research revealed that it is possible to develop a virtual environment that can provide teachers with realistic and compelling experiences as if they were in a real classroom with real students (Dieker et al., 2008). Another mixed-reality environment called TeachMe was developed to train beginning teachers (Andreasen & Haciomeroglu, 2009). The prototype focused on behaviour and classroom management aspects and was to train beginning teachers before entering the classroom for the first time. The results of the research indicated the potential in training teachers via a simulated classroom environment helping them gain in-depth knowledge of their domain and assist the development of behaviour management strategies.

Using VR in teacher preparation and training is still at its infancy given the fact that this technology has still several limitations and high cost. Nevertheless, the first attempts seem promising and indicate the usability of such a tool in the field of teacher education. As part of our ongoing work in this field, several experiments with different scenarios took place aiming to give an innovative VR-based approach to teacher education and the related training methodology (Manouchou et al., 2016; Stavroulia et al., 2016, 2018a). For all the experiments HMD (Oculus Rift and VIVE) were used, in an effort to create an immersive experience to the users. Moreover, the design of the VR prototype followed a five-phase model—Analysis, Design, Development, Implementation and Evaluation—based on ADDIE model (Stavroulia et al., 2018a). Furthermore, to simulate real-life situations within the VR environment, apart from an extensive literature review research, data regarding teacher's real training needs were collected through survey and interviews with education experts (Stavroulia et al., 2018b). Examples of related work include the following: Experiencing Vision Disorders of Students: The objective was to raise teacher's awareness and maximize their skills in identifying similar vision problems by placing them to the position of a visually impaired student (Manouchou et al., 2016) (see Fig. 1). The results identified the potential of training teachers in student's vision disorders, while it is highly important the fact that many of the participants after the end of the experiment stated that they might have confused possible student's vision problems when looking at the blackboard that they were unaware of with indifference during the lesson.

Identifying Bullying: The aim of this experiment was to help teachers identify bullying issues and distinguish them from simple teasing between the students (Stavroulia et al., 2016). The results indicated that in-service teachers who participated felt extremely comfortable regarding their skills to identify bullying due to their experience and prof posed the use of VR only for pre-service teachers, yet what is interesting is the fact that they failed to distinguish bullying from simple teasing incident.

Dealing with multiculturalism and verbal bullying: This experiment had to do with multiculturalism and verbal bullying, to help teachers deal with today's multicul-

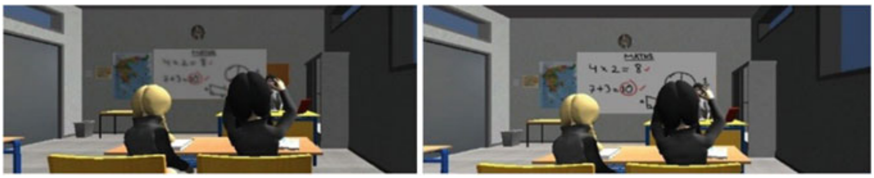

**Fig. 1** The virtual environment showing blur (left) and clear (right) vision

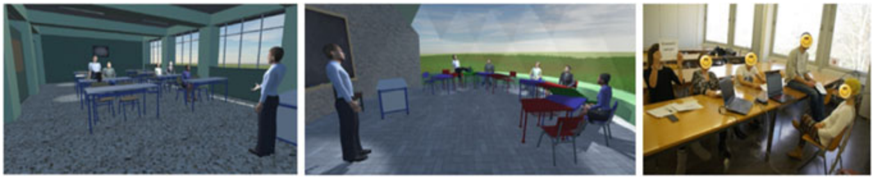

**Fig. 2** The three different environments: Real-life based VRE (left), imaginary VRE (middle), real classroom setting (right)

tural classrooms and cultivate their empathy and reflection skills (Baka, Stavroulia, Magnenat-Thalmann, & Lanitis, 2018; Stavroulia & Lanitis, 2018; Stavroulia et al., 2018b). Another aim of the experiment was to investigate whether the participants would prefer training within a VR or in a physical classroom space (see Fig. 2). In this scenario, the participants were able to experience two different perspectives that allowed them to enter the position of a foreign student and experience verbal bullying by the classmates, while they were also able to see the incident through the eyes of the teacher. The results indicated that participants preferred training with the use of VR technology. Moreover, there were strong indications that training using VR helped the participants cultivate their empathy and reflection skills, while the experience provoked to them many emotions and mood states. Equally important is the fact that there are strong indications that the VR experience helped the participants to change the way they will attend to the needs of foreign students and the way they will react on disruptive behaviour among the students. Finally, it should be noted that there were participants coming from a different country who admitted that the scenario they experienced within the virtual world reminded them of a similar situation they experienced when they moved from their country to another for work obligations.

Drugs in School Environment: This application (see Fig. 3) relates to the problem of drug use in schools, a real and common problem that is underestimated and not properly addressed within the school setting, partially due to teachers' lack of training regarding how to address this issue (Stavroulia et al., 2018a). The scenario provided the users the ability to experience the problem from three different perspectives: through the eyes of the teacher, a healthy student and a student under drug use, to cultivate empathy. The results indicated differences after the use of the VR environment regarding empathy towards students facing drug-related disorders, while the scenario affected their emotions and mood states as there were significant differences after the experiment.

Overall, the first experiments indicate that VR can be a potential alternative paradigm for teacher education, offering teachers the possibility to be trained in real-life scenarios and situations. Additionally, with VR, it is possible to provide teachers the opportunity to live the life of someone else getting an idea of what someone else's life might be like. Hence, VR technology can allow teachers to live their students' life and experience different viewpoints, helping them to understand their students and their problems. Thus, VR can enhance significantly teacher's skills including empathy or reflection allowing them to establish strong communication channels with their students. Undoubtedly, further research is required regarding the use of VR in teacher training and there are many questions yet to be answered; however, it seems that it is only a matter of time for VR to become a new paradigm in teacher education and in the field of education in general.

## 4 VR for Training Students: Toolkit

In order to realize the many benefits that VR technology might report for education, it is necessary to facilitate the process of designing and developing VR environments. Due to the variety of skills and specialist knowledge required in their design and development, the production of this type of artefacts is still a challenging task, which usually entails high costs. In addition, it is necessary to consider the difficulty to guarantee on beforehand the effectiveness of the educational artefact produced. Investing in developing one VR environment without having the possibility to quickly modify it, adapt it or to develop more might result too expensive (Klopfer & Squire, 2008). Moreover, it will be necessary to put the design and development of these artefacts into the hands of those that experience problems that could be improved with it, that is, the end users (Von Hippel, 2005). In our case, these are the teachers and instructors, who have the knowledge and expertise required to create valuable educational experiences. For this to be done, it is necessary to provide this type of users–designers with adequate tools that take into account the specific requirements derived from their profile and do not impose an excessive cognitive workload. At that moment, most VR applications are created ad hoc, and there is little chance to reuse and adapt them without having a specialized technical background (Shih & Yang, 2008; Virvou & Katsionis, 2008).

During the last few years, the DEI Interactive System Group of the University Carlos III of Madrid has investigated the use of End User Development (EUD) techniques to empower educators to create educational technology. EUD is defined as "a set of methods, techniques and tools that allow users of software systems, who are acting as non-professional software developers, at some point to create, modify, or extend a software artefact" (Lieberman, Paternò, Klann, & Wulf, 2006). In this section, we present a EUD tool called VR-GREP (Virtual Reality Game Rules scEnario Platform) (Zarraonandia, Díaz, Montero, & Aedo, 2016), which aims to empower educators to create a specific type of VR educational artefact, VR seri-

**Fig. 3** The three different perspectives: teacher (left), student drug user (middle), health student (right)

ous games, without requiring technical assistance. VR serious games will give the opportunity of combining many benefits that videogames can report in the context of education, as increasing the learner's motivation (Druckman, 1995) or self-regulated learning (Kim, Park, & Baek, 2009), with the opportunity that VR technology offers to live a realistic experience in the first-person perspective.

To empower educators to create VR serious games, without requiring technical assistance in the process, the VR-GREP uses two techniques: an immersive design of the game level and a definition of game rules as combinations of simpler games.

**Immersive-level design**. An essential part of designing a video game is the composition of the virtual scenario in which the play takes places. The scenario contributes to set the mood of the game, and its definition includes the specification of the game elements the player can interact with, as well as the background non-interactive elements, lighting, music and other ambient effects. In the case of a VR video game, the scenario of the game is a 3D virtual environment. Tools like Unity, Unreal or Blender allow to model this type of environments using a GUI and different views of the 3D virtual space. Although these tools are adequate for users with expertise in 3D modelling, having to control and modify the camera's viewpoint and viewing direction of the scene can be difficult for non-expert users. To avoid these issues, the VR-GREP platform supports modelling the virtual world immersively, from within the environment itself. This way the designer acts upon the player's experience of the environment, and not over a 2D representation of it. The designer navigates and interacts with the virtual scenario in a similar way as the player, testing the user's view even from an early stage of the design process. Moreover, this approach allows to carry out the modelling tasks using natural interaction techniques. The designer selects, places and modifies the objects in the scenario using her own hands. This saves from having to master new commands usually required to control and change between the different views and perspectives of the modelling tools.

**Combinatorial rules design**. To simplify the definition of the games rules, the VR-GREP tool implements the combinatorial approach described in (Zarraonandia, Diaz, & Aedo, 2017). This way, the rules of the game are described by selecting and combining the rules of simple archetypical games, such as treasure hunts, adventures or races. The designer links the elements in the virtual scenario with behaviours taken from those games, such as treasures to collect, enemies to avoid or goals to reach. As these behaviours and rules are well known, the designer is not required to learn a new design language for describing the game.

The VR-GREP Platform provides two applications: the edition tool and the runtime environment. The edition tool allows to create game designs following the approach described previously. The tool provides access to the Assets Repository, which contains graphical resources to model the virtual scenario of the game. The designs produced can be exported as XML files and stored in the platform's Games Repository. The runtime environment allows to select and retrieve game designs from the repository. It processes the game designs and automatically generates a virtual environment for the game by instantiating the assets specified in it.


**Fig. 4** Screenshot of the VR-GREP editor: Entities menu (left) and rules menu (right)

The process of creating a game using the edition tool is as follows: First, the designer selects an initial setting, or background, for the game scene. The Assets Repository provides several predefined backgrounds that might range from simple empty terrains to more elaborated representations of environments, as rooms or forests, which already include trees, bushes, etc. Once the background of the scene has been selected, the author puts the HMD and starts exploring and transforming the virtual scene. This process is supported by the entities and edition menus (Fig. 4, left). The entities menu allows to select assets (entities) from the Assets Repository and add them to the scene. The edition menu allows to edit an entity in the scene to adjust its size, position and orientation. It is also possible to add entry points to other scenes so that more complex VR game scenarios can be created.

Once the game scenes have been defined, the next step is to specify the rules of the game. This process is supported by the rules menu (Fig. 4, right). Using this menu, the designer can select behaviours from archetypical games and link them to the entities in the scene. For example, the author can select the behaviour tool from the archetypical game adventure. This behaviour specifies that certain entity is a tool that when combined with some other specific entity, transforms the latter into something else. For example, a key can be set to be a tool for a closed door and to transform it into an open door.

Currently, the tool allows to link entities to behaviours taken from four archetypical games: treasure hunts, avoid enemies, race and adventures. These simple behaviours can be used to design games with an educational purpose. For example, the behaviour treasure to collect can be used in games in which the player has to identify elements or objects that satisfy certain condition. In a similar way, it could be used in a game for teaching basic biology to kids, in which the player has to identify the animals that are mammals. As another example, the behaviour tool from the adventure game can be used in games in which the player needs to establish relationships between objects or to learn the steps to follow to complete a procedure.

## 5 Conclusion

In this paper, we summarized some of the opportunities and challenges that the integration of VR in educational faces. We also presented two works that exemplify the vast possibilities of application of this technology. The potential of VR technology has just started to be explored, and more research needs to be done in order to understand how to exploit the benefits of VR in education. Educators need to be informed on the contexts and applications in which immersive learning experiences will improve the outcomes of traditional practices. Also, it is not only necessary to reduce the cost of the technology, but the design and development of the activity and educational content need to be facilitated. It is necessary to provide the teachers with the means to create VR application customized to their teaching needs.

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