An Architectural Model for the Production of Virtual Reality Learning

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Abstract. Learning environments integrate multiple technology platforms allowing people to meet learning objectives through available content, resources, and integrated services. Learning environments allow users to cover learning objectives in different subject areas, such as social skills development, health, etc. This article presents a development model of Learning Environments through Virtual Reality (VR). This model incorporates new forms of interaction for learning, such as immersion in simulated scenarios that support users in attaining learning objectives. A VR tour of a university is presented as a case study, where distinct users, such as teachers, students, and general public interact with content, resources available and services to achieve the specific learning objectives.

Keywords: Virtual environments · Learning model · Immersive learning

1 Introduction

The design of learning environments involves a multidisciplinary work in which specialists participate in the generation of content, pedagogical design, in addition to technologists for the design and programming of digital platforms and content [1]. Learning environments allow to learner acquires knowledge through elements that are presented in the environment, these elements can be physical or cultural and involve the way in which people interact with the environment, other people and other organization ways towards achieving learning [2].

Supported by CONACYT.

K. O. Villalba-Condori et al. (Eds.): CISETC 2019, CCIS 1191, pp. 73–87, 2020.
https://doi.org/10.1007/978-3-030-45344-2_7

There are several ways to represent a learning environment, currently there is a wide variety of accessible devices to support the learning process, such as websites that offer courses at low cost, interactive books where the learner solves in a didactic way problems to reinforce knowledge and video games that allow a degree of interaction allowing the apprentice to meet goals.

This work proposes a model for the production of virtual reality learning environments, in the proposed model design and interaction artifacts are presented, also the inclusion of several available services and the existence of different user roles that can meet their learning objectives [3]. This work is composed of seven sections, in the following section related works to the proposal are presented, theoretical foundations section presents some conceptual elements of learning environments that are the basis for the proposed model. Next, problem outline section presents the challenges when producing learning environments in virtual reality. A production of virtual learning environments section shows the elements of model proposed, after, a case study section with a proposed solution in high education and finally conclusions a future works section are presented.

2 Related Work

This section presents a literary review of the state of the art of works that propose learning environments, these works refers to diverse approaches, platforms and several application contexts, as presented in the Table 1.

Table 1. Literature review of learning environments

Author	Approach	User centered	Feedback	Platform	Services	User roles	Interaction type
Yang et al. [4]	Physical interaction system	•	•	Video	•	-	Semi immersive
Pan et al. [5]	Game-based	•	•	VR	-	-	Immersive
James et al. [6]	Object recognition	-	-	VR	-	-	Immersive
Goulding et al. [7]	Game-based training	•	•	Web 3D	•	-	Semi-Immersive
Proposal	Game-based virtual map	•	•	VR	•	•	Immersive

As a first criterion, several approaches are presented such as video-games based [5,7], object recognition by the user [6] or even a combination of real elements with virtual approach is included [4]. A second criterion presented is the user-centered approach [8], that is, if the learning environment considers the facility to determine what actions are possible at any given time, besides being able to represent a conceptual model of the system and evaluate your state. A third criterion presented is the feedback provided by the learning environment, that is, it shows information of importance for the reinforcement of the learner

and educator. Goulding et al. [7] shows simulation scenarios for training in the industry. The platform is the criteria that help us to identify the devices used for the learning environment, among the literature, specialized devices for object recognition to web platforms and virtual reality. The user role is the criterion that allows the learning environment to offer content and services according to the user role, finally the type of interaction of the learning environment is presented, as you can see most of the works have a type of interaction immersive or semi-immersive [9], in the first one the users are completely isolated from the real environment and respond to the actions of the existing virtual elements in the scene presented to them, in the second the users perceive and can respond to both environments, real and virtual. Next section presents some conceptual elements of learning environments that are the basis for the proposed model.

3 Theoretical Foundations

Virtual reality is a technology that has become increasingly accessible to users and has begun to take part in various fields, science, health, education and entertainment. In the context of education it allows learning environments offer a range of possibilities in which the learner can interact with simulated elements that lead to the acquisition of knowledge. According to LaValle and Shin [10,11], virtual reality allows to induce the directed behavior of a person through the use of artificial sensory stimulation while the person has little or no awareness of interference.

3.1 Reasons to Use Virtual Reality in Education

In the literature we can find that different authors present positively the use of virtual reality in education. Pantelidis [12] describes the use of virtual reality as a natural evolution of computer-assisted instruction (CAI) or computer-based training (CBT). Bowman et al. [13] and Wickens [14] agree that virtual reality gives increased learning and retention of the learner, since cognitive effort required load and activities related to the tasks and activities related to the system. Other authors such as Chen et al. [15] and Dede [16], propose strategies for the design and evaluation of virtual reality learning environments to determine in which situations it can be adopted or not. Pantelidis [12] mentions a series of advantages and disadvantages that we can take into account when adopting virtual reality in learning environments.

- Advantages
  - Virtual reality can more accurately illustrate some features, processes, and so forth than by other means.
  - VR allows extreme close-up examination of an object and gives the opportunity for insights based on new perspectives.
  - Virtual reality can change the way a learner interacts with the subject since active participation is required instead of passivity.

- VR allows a learner to learn by doing, a constructivist approach.
- VR provides a way for some objectives to be taught via distance education which were previously impossible to teach in that way.

– Disadvantages
- The costs associated with the adoption of virtual reality.
- The time required to learn how to use the hardware and software of virtual reality devices.
- Possible health effects that may be caused to the user, such as vertigo, dizziness, sickness virtual reality, etc. [17].

Como se puede observar, la realidad virtual puede ofrecer una gran aporte al contexto educativo, y es necesario indicar que su uso en el aprendizaje se debe ver como una herramienta y resaltar las ventajas de su uso.

3.2 Virtual Reality in Leaning Environments

Shin and Huang [11,18], agree that virtual reality oriented learning environments allow learners to interact with others while carrying out a set of tasks. [11] in his model presents key elements when designing virtual educational environments, as presented in Fig. 1.

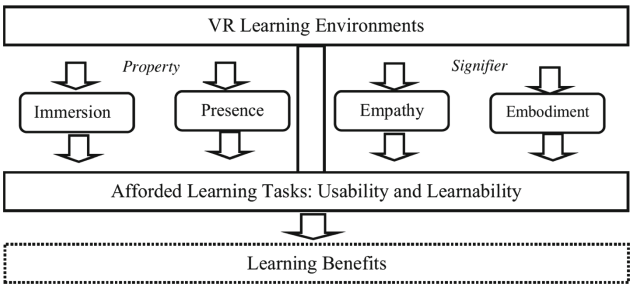

Fig. 1. Virtual learning environment approach by Shin et al. [11].

The model in Fig. 1 is based on the concept of affordance [11], for learning environments represents a characteristic of the environment that, when perceived, provides an opportunity for some action [19]. In the case of virtual reality learning environments affordances they are divided into technological and affective, technological represent how users perceive the technology and affective affordance of user's perceived technological property. In other hand signifiers help how people discover the possible actions that can be performed [20].

3.3 Virtual Reality in Constructivism Context

Virtual reality has a great adoption of the constructivist approach to learning since it allows learners to build their own knowledge from meaningful experiences [21].

This applied to a learning environment, allows the apprentice to control the way in which he acquires knowledge, in an exploratory way avoiding any possible consequences [22].

In general, the theory of constructivism mentions that humans generate knowledge by interacting with the environment and acquire knowledge by establishing a relationship between acquired experiences and ideas [23–25].

There are learning environments such as Edugames, dedicated to supporting collaboration and learning in education in a safe and meaningful way [26]. An example which may be mentioned of such learning environments with constructivist approach is Minecraft[1].

According to Schifter and Cipollone [27], Minecraft is seen as a tool that offers students (or players) the ability to gain knowledge through experimentation in the constructivist sense. Basically it is an open world construction game that allows the user the freedom to represent a world through the use of blocks that present various structures such as elements of nature, minerals, etc. It presents various game modes such as survival, adventure, creative, among others.

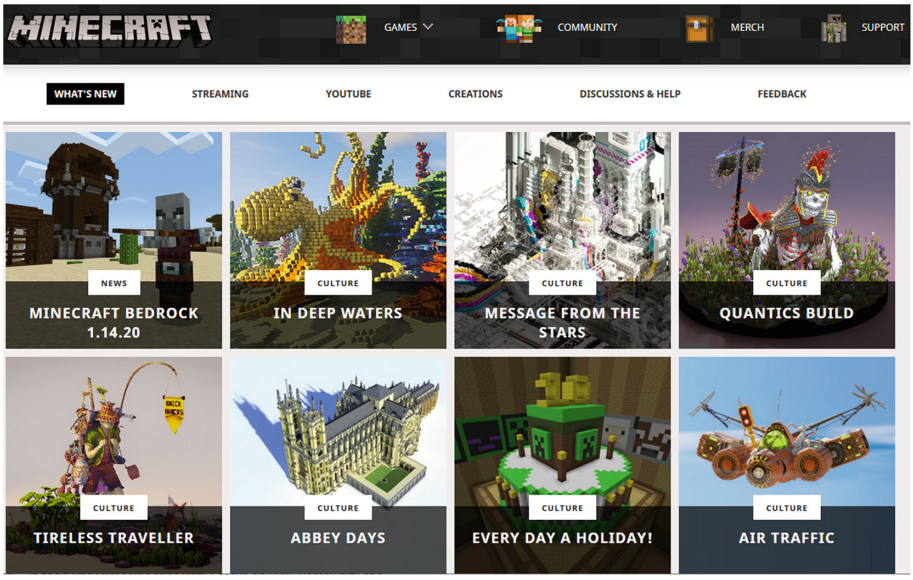

Fig. 2. Minecraft community website, with many resources available

[1] https://www.minecraft.net.

As shown in Fig. 2, Minecraft[2] has a large community in which various types of contents are provided, ranging from representations of historic sites, vehicles, buildings, etc.

In addition, Minecraft has an educational version, this presents a safe environment where the teacher can have control without losing the essence of the game is creativity and freedom. In addition to offering specific functionality for teachers and ready scenarios for specific activities and adapted for classroom use.

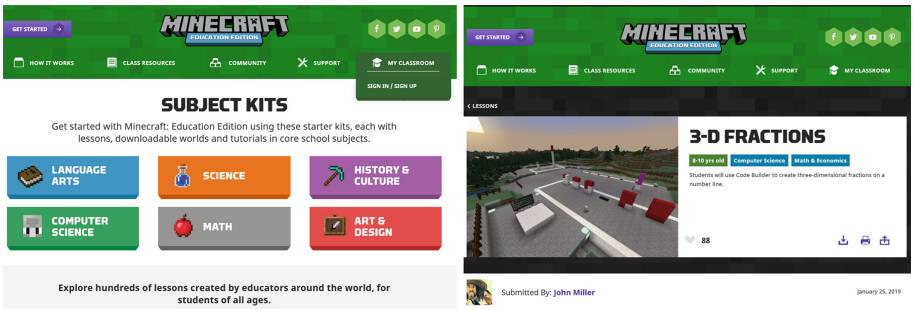

Fig. 3. Minecraft education edition; main page with some lessons *(left)* and math lesson example about 3D fractions *(right)*

Figure 3 presents the Minecraft educational platform, where you can find various resources that can be support for teachers and apprentices. These resources range from lessons, science, math, programming, etc. Tools for learners and teachers to adapt, edit and create content.

The use of such virtual environments under the constructive approach allows trainees to acquire knowledge themselves to interact with the virtual environment [26].

4 Problem Outline

This work proposes a model for the production of virtual reality learning environments that considers a user-centered design, virtual reality aspects, learning strategies and the incorporation of educational services. The proposed model allows the generation of content for various user roles, under a constructivist [28] learning approach, in which the learner (user) can select and transform the information for their decision-making, in addition to this can build their own processes to solve situations to various problems within a virtual reality environment [29–31]. Therefore, developing a learning environment that can solve these points is a complicated task that requires consider the following:

[2] https://www.minecraft.net/en-us/community.

- Establish a user-centered design for the creation of software oriented to learning needs and thus achieve the highest satisfaction and user experience.
- Develop digital scenarios based on a virtual reality-based learning strategies.
- Allow the adaptability of virtual reality learning environments to multiple contexts of use, platforms, available services and ways to acquire knowledge.
- Identify and define the various user roles within the virtual reality learning environment.
- Provide feedback information to the various user roles.

The following section presents in detail the design of the proposed model.

5 Production of Virtual Learning Environments

Virtual reality is a technology that has recently entered the field of education and is currently accessible at low cost [32]. In the educational context it can be used so that trainees can have an inverse experience in the learning process, this generates the need to propose models that help integrate virtual reality to produce applications according to learning needs [28]. Figure 2 shows a production model of learning environments is presented, this model shows elements comprising virtual reality and using educational services to produce applications that can be a support for learners, educators and other roles associated with the educational process. This model is based on the constructivist [30,33] approach and includes basic principles for understanding learning, these principles involve the exploration and discovery of artificial worlds and technological features that support learning [28]. Next, elements of model proposed in Fig. 4 are described.

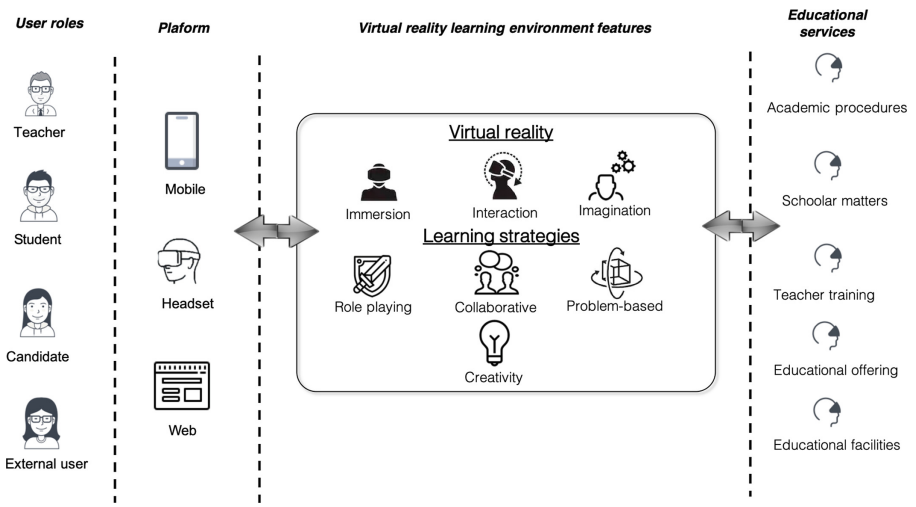

Fig. 4. Proposed architectural model for virtual reality learning environments

5.1 User Roles

The model proposes support for several roles within the learning environment, these roles define the actions of the user and their learning process, in the reverse part of virtual reality determines the type of interaction and content available and its associated educational services [34–36]. Table 2 describes each of these user roles.

Table 2. User roles description in virtual reality learning environment model.

User	Description
Teacher	- Provide student orientation services - Provide content for pedagogical activities - He is an expert who dominates the contents - Share learning experiences with students - Encourage student participation - Facilitate the understanding of the basic contents and encourage self-learning
Student	- It generates its own knowledge - It is characterized by being interactive - It is related to the learning process - Guided by the teacher while building their own knowledge - Plans the learning activities
Candidate	- It has access to educational offering services - Interact with the contents academic procedures and educational facilities - It has access to some school matters
External user	- It has access to content public, and limited access to content and services

5.2 Platform

Virtual reality learning environments produced can be built on different platforms according to the needs of the user, the available platforms ranging from mobile devices, web applications and desktop applications that require a virtual reality headset such as Oculus Rift[3] or HTC Vive[4]. The platform selection also determines the degree of interaction and content that can be presented to the user within in virtual reality learning environments.

5.3 Virtual Reality Learning Environment Features

The objective in virtual reality learning environments is that users achieve their learning objectives through a transfer of immersive learning based on virtual reality to the real world with real situations through practice by interacting with objects and events in the simulated world [28,37]. The following describes two important features for the design of virtual reality learning environments under the proposed model.

[3] https://www.oculus.com/.
[4] https://www.vive.com/us/product/vive-virtual-reality-system/.

Virtual Reality

- Immersion technology aspects are considered to offer the user the feeling of presence in an artificial environment as if he were in a daily learning situation [10].
- According to Huang and Burdea [28,38], interaction considers the strategies for the user to interact with the virtual reality learning environment, user inputs and feedback with the system are defined. Also it refers to strategies to take into account that the user is engaged in the virtual environment [39].
- Imagination refers to how the learner uses his problem solving skills and his ability to perceive and creative sense to interact with simulated elements [28].

Learning Strategies

- Role-playing allows the learner representation or simulation of roles for a given situation or event that occurs within the virtual environment, which encourages the learner to think creatively and solve situations [28,40].
- Collaborative refers to the strategy where users exchange ideas and experiences to gain knowledge within the virtual reality environment [28].
- Problem-based is based on the methodology of problem-based learning where the user faces real situations using their own strategies using the tools offered by the virtual environment [41].
- Creativity refers to strategies for the user through new ideas and concepts develop their ability to solve problems [28].

5.4 Educational Services

Educational services within the virtual reality learning environment complement the virtual content offering support to academic institutions processes. Educational services of the proposed model are described below.

- **Academic Procedures:** Service available for users to perform management or diligence management or diligence that is performed to obtain a result regarding an academic process.
- **Scholar Matters:** Service responsible for administrative tasks and validation of study programs also register and validate information derived from the educational process of students and provide academic and administrative support to the teaching staff.
- **Teacher Training:** Service responsible for policies and procedures to prepare teachers in the field of knowledge, attitudes and skills [42].
- **Educational Offering:** Service refers to the different opportunities of education degrees, these are offered by the university to future students.
- **Educational Facilities:** Service to find out the educational infrastructure.

6 Case Study

This section presents a virtual reality learning environment called "UAA Virtual tour and services", is designed to be used to offer learning content and educational services for the Autonomous University of Aguascalientes (UAA). The UAA is an institution of higher education that has an approximate of 20,128 students distributed in postgraduate, undergraduate and high school. Currently, the UAA has 89 plans and programs of study, 25 of which are postgraduate programs in masters and doctorates, 64 undergraduate 1 and a high school plan [43].

6.1 Virtual Learning Environments in Higher Education

According to Cuadro et al. [44], learning environments represent a series of steps towards teaching allowing a reduction in time and space making it possible for a large number of people to have access to content while attending their daily activities. The "UAA Virtual tour and services" (VRUAA) is intended to people who attend a higher education institution can cover their learning needs in an immersed way where the user interacts with 3D elements and make use of simulated educational content, In addition to having available services offered by institutions of higher education, such as, consulting kardex, class content, teachers information, etc. Among the advantages that we can mention when incorporating VRUAA are [45]: Provide elements for learning in an understandable way that is not limited to the classroom or the educational institution; having a platform accessible from a mobile device to a virtual reality device; Allow interaction of different types of roles such as students, academics, etc. Integrate different resources and services to enhance the way of teaching.

6.2 Collaborative Work

Figure 4 shows a model of a virtual reality based learning environment, which in other words, is a scenario of consumers of educational services based on virtual reality learning strategies. However, for the case study, it is also necessary to describe the model of collaborative work that has been carried out to describe the process of creating educational services. In other words, there cannot be a service consumption scenario without a scenario where those services are being produced. For this reason, Table 3 describes the roles involved in the design and production of educational services in the virtual reality model.

In Fig. 5, the collaborative work carried out by the different roles to create the virtual reality environment is shown through a use case diagram. According to Fig. 5, the RV-UX Designer is responsible for designing the user research strategy, where he uses quantitative and qualitative user research methods to discover the insights that will become the inputs to define the virtual reality experiences. The RV-UI Designer is responsible for transforming the insights into Virtual Reality based user interfaces. When the RV-UI-Designer finishes the UI designs, the RV-QA takes care of applying various usability tests.

Table 3. Role description for design and development of virtual reality learning environments.

Role	Description
RV-UX Designer	- Applies quantitative and qualitative methods of User Research to detect features (insights) - Analyze the usability tests and proposes improvements - Design learning strategies based on VR services
RV-UI Designer	- Define low and high level VR wireframes - Design the prototypes of educational services UI - Design the prototypes of 3D objects
RV-Developer	- Develop the objects in 3D - Develop the scenarios based on VR Services
RV-QA (quality assurance)	- Define the instruments and metrics of Usability - Applies the Usability tests - Generate the reports of the Learning Analysis

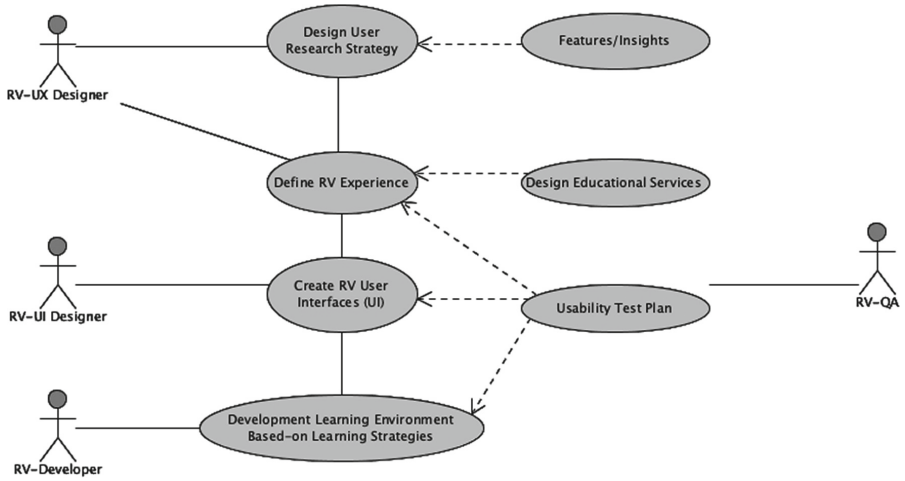

Fig. 5. Use case diagram of collaborative work.

The results obtained are analyzed by the RV-UX-Designer with the purpose of finding improvements in the UI features. When all UIs have been validated, they are sent to the RV-Developer who is responsible for transforming the UI-RV into the VR Educational Services. The VR-UX-Designer and the VR-Development work together so that the development process is adjusted to the creation of the learning environment and the strategies.

6.3 Participants

The launch of the VRUAA includes the participation of 20 students on average graduate aged 25 to 30 years, of which 15 are men and 5 women. The procedure for launch was that each participant used a virtual reality headset (HTC Vive System) in which the VRUAA presents content and the user has an immersive experience, as shown in Fig. 6. The following subsection the results of the information obtained from the launch of the VRUAA are presented.

Fig. 6. VRUAA environment learning launching.

6.4 Results

The data for this study were gathered by means of an online survey based on Davis et al. [46]. The survey is divided into two sections with six questions and answers on a scale of 1 (unlikely) to 7 (likely). The purpose of the survey is to measure in user experience in terms of perceived usefulness and ease of use of VRUAA. The chart in Fig. 5 presents the result of the survey of perception of utility and ease of use applied to the group of participants that used the VRUAA. The objective is to know the degree of perceived usefulness, that is, to what extent the user believes that using the VRUAA can improve their performance and take advantage of their learning activities. Perceived ease of use, refers to degree to which a person believes that using the VRUAA can be free of

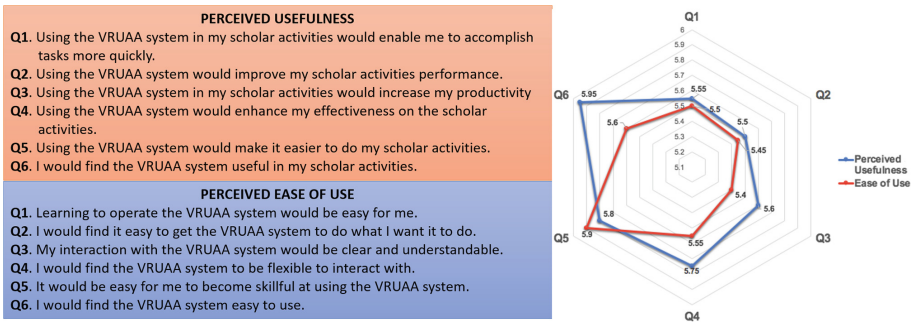

Fig. 7. Perceived usefulness and ease of use survey (left) and results chart (right) of VRUAA launching.

effort into their learning activities [46]. As shown in the chart in Fig. 7 for both aspects greater value 5 is obtained, indicating that there is a good acceptance in perception generates usefulness and ease of use of the learning environment VRUAA.

7 Conclusions and Future Works

The work presented in this article proposes a method to produce virtual reality learning environments. The main objective is to integrate multiple technological platforms that allow people to meet learning objectives through available content, resources, service integration and various user roles. In the proposed model, each of its elements is described in order to have a base and design to produce virtual reality learning environments to support the needs of higher education institutions.

The case study presents the implementation of VRUAA, which is an immersive virtual reality system composed of 3D simulated content and services associated with the purpose of offering support to various users who attend a higher education institution. An evaluation is also presented showing the degree of perception of utility and ease of use of the system, allowing users to know the acceptance in general. The future work of this research includes new strategies for the design and production of virtual reality educational environments, new forms of interaction, new usability evaluation techniques and user experience focused on supporting new learning needs through virtual reality.

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