Evaluating Virtual Reality as a Learning Resource: An Insight into User Experience, Usability and Learning Experience

Katherina Gallardo
Tecnologico de Monterrey
School of Humanities and Education
Monterrey, Mexico
Email: katherina.gallardo@tec.mx

Nohemi Rivera
Tecnologico de Monterrey
School of Humanities and Education
Chihuahua, Mexico
Email: nohemi_rivera@tec.mx

***Abstract*—Information and Communication Technologies (ICT) are powerful tools that support teaching and the case of Virtual Reality (VR) is especially promising because of its unique characteristics. In this paper, we report on a project that aims to describe how variables such as usability, user experience and learner interface experience might affect learning results while using VR resources. We present the preliminary results of a mixed-methods study, including the students' perceptions collected in two focus groups. These undergraduate students were exposed to the use of VR resources for learning purposes. These preliminary results invite us to think about the inclusion of different indicators to strengthen the VR resources evaluation process in higher education.**

Keywords-Learning assessment; Learning interface experience; Usability; User experience; Virtual reality; Higher education; Educational innovation.

I. INTRODUCTION

Information and Communication Technologies (ICT) are powerful tools to support learning because they allow students to be reached at any place and time, reducing the costs of traditional learning methods. Digital technologies provide materials for active learning that more fully engage learners [1]. The case of Virtual Reality (VR) is especially promising because of its unique characteristics. VR is a term used to describe an absorbing, interactive, computer-generated 3D virtual experience in which a person interacts in real time with simulated objects that seem real [2], and it can be used as a learning environment for different levels and disciplines [3]. Most VR environments are primarily visual experiences, but they may also include auditory simulation, which is very useful because vision provides the most information, followed by hearing; probably 90% of our world perception is visual or auditory [2]. Furthermore, the VR content can be delivered in a variety of ways, including specially made VR headsets, smartphones and computers [1]. We can group the VR systems depending on the level of immersion they offer to the user. There are different kinds of immersions that can be achieved in a virtual environment [2]:

- Tactical immersion: Experienced when performing tactile operations.
- Strategic immersion: Related to mental challenge.
- Narrative immersion: When players become invested in a story (like reading a book).
- Spatial immersion: When the simulated world is perceptually convincing (feeling of being there).
- Psychological immersion: When a player confuses the game with real life.
- Sensory immersion: Experiencing a unity of time and space (fusing with the image medium).

VR headsets (immersive system) provide the greatest sense of immersion by completely replacing the real world with the virtual one, but they are also the most expensive way to deliver it [1]. This type of system provides a stereoscopic view of the scene according to the user's position and orientation [2]. Computers (non-immersive system), on the other hand, are the simplest and most readily available method for VR playback, but they greatly reduce the sense of immersion [1]. In this case, the user views a virtual environment through one or more computer screens and is able to interact with the environment without being immersed in it [2].

The rest of the paper is structured as follows. In Section II, we present the related work. Section III presents the structure of the project, as well as the research methods and instruments used in the gathering and analysis of the preliminary data. Section IV presents the most relevant results of the two focus groups, and Section V critically analyzes the main findings and the future work to be done.

II. RELATED WORK

The immersion, presence and interactivity are some of the features that make VR different from other traditional media. Furthermore, the autonomy, the free navigation in a 3D space, the intuitive and realistic interaction with virtual objects and the first-person point of view are some of the VR features that contribute to a sense of presence inside the virtual environment and make the users feel as being in a real laboratory [2][3]. Mikropoulos and Bellou [3] found that all these VR features play an important role for knowledge construction, and presence is the principal feature that contributes to positive learning outcomes. Thus, these features should be taken into consideration when designing virtual environments, in combination with the discipline and specific content under study. VR implementation is mainly found in high school, college and university; with healthcare and engineering being the most investigated subject areas, followed by computer sciences, culture, history and automotive. In addition, professional education domains are

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now incorporating VR technologies to train their employees [4].

The implementation of VR in education is based on constructivism, which emphasizes the dynamic aspect of learning. Experiential learning is constructivist, and it emphasizes the central role that experience plays in the learning process [5]. Unlike passive information transference methods (such as lectures), VR experiences allow the learner to control the pace of the process and make decisions that influence the outcome, making a virtual world feel real and increasing memory retention [1]. When the learning process involves learners' emotions and social life, they can better master the knowledge. Using VR allows learners to gain information from an experience that is not easily accessible or does not exist in real life, and encourages them to use their imagination when manipulating the environment, which eases the active construction of models and the skills development [2][6]. Also, creative learning and the ability to innovate can be stimulated and improved. Another advantage is that there is no risk in virtual training, learners can practice repeatedly until they master a skill [6]. For example, Tsai [7] found that using VR during training could reduce the anxiety caused by emergencies. In short, immersion in a virtual world allows us to construct knowledge from direct experience, not from descriptions of experience [8].

Durrani and Pita [4] found that VR has a very positive effect on learning. 92% of the studies they analyzed showed a positive impact of integrating VR, and the other 8% of the studies showed a neutral effect. In line with this, Marks [9] found that the exploration of a 3D model really helped students to understand the spatial structure. In addition, the VR application promoted discussions among the students and, when compared with the group using traditional materials, they showed a higher cooperation. Moreover, the VR group showed the most significant difference in the question about stimulating interest in the topic. This is where VR seems to show more promise [9]. Hence, VR can enhance the learning process, but it is not appropriate for every instructional objective or learning content. Therefore, to decide if using VR is the best option, it is necessary to evaluate the type of contents that will be taught and identify the experiences that would be difficult, dangerous or impossible to provide in formal education. Strategic and descriptive knowledge can often achieve good results without using a virtual experience. Furthermore, it is crucial to consider if creating a simulated environment is relevant to the learning objective [6][10]. Creating a pedagogical foundation when designing VR modules is an important step in their development. This process requires script writing and expert content evaluation before the modules can be recorded. Students may benefit greatly if provided with safe and effective experiential learning opportunities through VR [1].

Besides the pedagogical foundation, the application of VR technology to education requires students to be autonomous learners and to have learning initiative. This learning way is student-centered, emphasizing that students need to demonstrate their enthusiasm and initiative in the learning process [6]. However, it is important to consider that a purely exploratory tool, such as a VR application, is not sufficient to guide the students through the whole learning process. Marks [9] discovered that even though the 3D model they used in the VR tool presented all the necessary information, not all of it was discovered or remembered correctly by the students. Therefore, teachers should not think that using VR can be enough for students to finish learning. On the contrary, the use of VR in education has high requirements for teachers, who play a guiding role in the entire process and must constantly improve themselves and adapt to the needs of future teaching [6]. It is also helpful to have some guidance in the VR application besides previous oral indications delivered by teachers, such as a list of items to work through or an audio or textual narrative. Regarding this, the majority of the participants in Marks' [9] study requested a guidance mechanism for the exploration process and short comprehension tests of the content before unlocking the next part of the tour. In conclusion, VR is a promising tool for educators, presenting important advantages like the ease of use, the increased motivation and the non-symbolic, first-person experience. However, to maximize the benefits, it is important to consider the whole context of the education process in the design of any VR application [8][9] as well as the instructional decisions teachers take to insert this kind of material for learning purposes.

As mentioned previously, many authors have evaluated the usability of VR technology [9] and the students' experience when using it as a learning tool [11], but there is very little research on its instructional usability, which is the degree in which the tool is really motivating and helping students to achieve the learning objective. In this sense, the objective of this paper is constructing an evaluation process for VR resources that considers all the aspects of the learning process.

III. METHODOLOGY

A. Design

This is a mixed-methods study [11]. The objective is to describe how variables such as usability, user experience and learner interface experience might affect learning results while using VR resources.

B. Context and participants

This study took place in a private university located in northeastern Mexico. Undergraduate students from different programs such as engineering, medicine and business were exposed to the use of VR resources for learning purposes. The results presented in this paper focus on a VR resource that was designed to collect, calculate and estimate data from a daily activity: going to buy groceries at a supermarket. This VR tool attempted to achieve spatial immersion (a simulated world that is perceptually convincing).

In sum, 268 students from engineering and business that were taking the course "Mathematics and Data Science" used the VR tool in Monterrey; 76 students were studying at the campus in a presence-based modality and the rest were online students. The students used the VR tool for about an

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hour and, during this time, they had to choose 5 foods, trying to get the smallest number of calories possible. The objective of the VR tool was to help students to calculate their caloric intake and stimulate their interest in the nutritional value of the food they choose.

C. Instruments

Two instruments were adapted for responding to research questions: The first instrument was a questionnaire with 21 items using Likert scale (1= completely disagree, 2= disagree, 3=somewhat disagree , 4=somewhat agree, 5= agree, and 6= completely agree) divided into two sections: usability and user experience statements [9][12]–[15]. The quantitative results obtained from this questionnaire will be presented in future work. The second instrument was a mixed questionnaire [9], [12]–[16]. In this case, this instrument was applied in a focus group technique. The instrument was divided into four sections.

- Section 1: contains 6 items about usability and 5 items about user experience. All of them are open-ended questions.
- Section 2: contains 12 items related to instructional issues and learning experience. These items use a six-point Likert scale (1= little 6= a lot), open-ended questions and statements that need to be qualified according to a scale in consensus.
- Section 3: Contains one open-ended question to make a global appreciation of students' perception of the learning experience using VR and how to improve it.
- Section 4: Contains a single-word multiple choice question that asks to select the word that best represents how they felt about the learning experience with VR. There are eight possible options that go from positive to negative emotions or feelings. A mode value is obtained after voting.

Five educational experts in tertiary education and educational technology usage made a first validation procedure for both instruments before application.

D. Procedures

At the time this contribution has been written, we had some partial results, as this research project is still in progress. Thus, two focus groups were formed. 13 students were randomly chosen to participate in the two focus groups. The application of the questionnaire using Likert scale is still open for collecting data and two other focus groups are pending.

The steps corresponding to the methodology procedures of this study are the following:

- Design of the instruments.
- Validation of each instrument by experts.
- Adjustment of the instruments according to expert's opinion and suggestions.
- Application of the questionnaire using an electronic format for collecting data.
- Application of focus group, with the participation of at least 7 students in each one.
- Transcription of focus group dialogues using the Amberscript online service.
- Ensure transcription in verbatim format corresponding to the content of each audio files.
- Analysis of data using IBM SPSS and ATLAS.ti software respectively.

IV. RESULTS

The preliminary qualitative results of the study are presented in this section. The expected and emergent categories are presented, along with the most representative students' comments, which invite us to think about the inclusion of different indicators to strengthen the evaluation process of these resources, considering three dimensions: usability, user experience and learning experience.

Usability: The majority of the students said that adapting to the VR was a trial and error process because people guiding them could not know for sure what they were going to do; but they felt this adaptation process was pretty fast; they agreed that the interface was very simple and easy to use. Even though the interface was perceived as very simple, students agreed they needed someone to tell them how to use it, and some of them faced some issues at the beginning and at the end of the activity and needed further instructions. They mentioned the end of the activity was confusing because it was not well defined. Students who saw their classmates do the activity first or had previous experience using VR technology were more comfortable with the environment from the beginning, but all of them would have preferred to have more instructions included directly in the VR.

With respect to the complexity of the environment, the students mentioned it was comfortable and practical. Some students perceived this simple interface as an advantage. They said supermarkets are a lot bigger compared to the one in the VR, so, this simplified things for people that do not know how to use it because they could easily reach and count everything. However, other students perceived this simplicity as a disadvantage because they felt it limited their options or made it less realistic.

User experience: Students agreed that it was an attractive experience that excited them. They were glad to have the opportunity to do something new and go out of the regular classroom activities. Some of them said the VR exceeded their expectations and they never imagined being able to have something like this in a class. They felt having VR tools is an advantage and the school should invest more in this technology. A few students said they even took some extra time after finishing the activity to explore the environment.

Regarding immersion, students said they were not conscious of what was happening around them, just the VR, so they felt they were the character they were controlling. They liked the 360 degrees view because they could turn their head anywhere, which made them feel immersed in the environment. The students also mentioned it was important not being told what to do, in order to feel free to experiment in the environment; they liked to have a feeling of control.

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One of the issues that affected their sense of presence was that they could not find everything they were looking for, which made the experience less real. Also, they mentioned they would have felt more immersed if they had been able to walk and listen to the kind of music you find in a supermarket. Not being able to walk also made some students feel dizzy after the experience. Furthermore, they mentioned that the quality of the graphics is a key element to experience inside the game; as well as being able to do all the normal activities one can do in the real environment and interacting with the objects in a natural way, like placing the products in a shopping cart and paying for them at the cashier, in this case.

Learning experience: In general, students thought that using VR is a good way to learn because it takes them out of their routine. They also thought the learning objective was clear, the activity was related to their class and the VR complexity was adequate for the purpose of the activity. About the effort they had to do to learn, they said they did not have to focus a lot because the objective was clear, they were familiar with the context and they were comfortable with the use of technology. They added that the mental effort would have been a lot greater if they had not had any instructions. In relation to the physical effort, they said no effort is needed and anyone can do it, even a person with a physical impairment can enjoy it.

Although students thought the VR experience was related to their class, the majority expected a more analytic experience, in which they could see graphics and interpret information. Considering this, the majority of the students agreed this experience is more relevant as an introductory activity, to learn a new concept, rather than a practice. In addition, they thought having more products in the supermarket would have also enhanced their learning experience because they would have been able to analyze more data. They also emphasized having the right calorie values is important in order to use those values in their analysis.

With respect to the time they had for the learning experience, students in the two groups had different opinions. In one of the groups there were more students, so they felt they did not have enough time to interact with the VR tool. The other group had very few students and they felt they had a lot of time for the activity, they even mentioned the activity should have a limited amount of time in order to be more like a game and compete with their classmates. In addition to the competition, students also mentioned they would like this tool to allow a more social learning. They said they would like to have more people connected in the same virtual environment, including the teacher.

Students concluded this tool should be used in more subjects at the university, and they should be able to use it more frequently. They even mentioned they would be able to learn more and benefit more from the tool if they could access it at any time, using it as a reference material. Students say they can not really learn anything if they only use the tool once.

Table 1 summarizes the most relevant students' comments for each dimension.

TABLE I. STUDENTS' PERCEPTIONS

Dimensions	Students' comments	
	Features appreciated in the VR	***Missing features in the VR***
Usability	"I adapted very fast, it was really easy to use and simple" "I had seen others do it, so it was easier" "I feel that if more things are added, people who don't know how to use the VR will start to get confused"	"If there had not been a professor explaining everything, I wouldn't have known what to do" "I finished and I did not know what to do next" "The game does not have a lot of food options, so it is easy to repeat other's actions"
User experience	"I really liked the experience, and when I finished, I wandered around to see the products" "It is a new experience for many of us and you go out of the classroom, because it is very tedious to be in the classroom all the time" "What made me feel immersed is the fact I could turn my head anywhere freely, see everything, and move anywhere I wanted to"	"I could not find meat, chicken or something more similar to what I really eat" "I would have preferred to walk instead of teleporting" "The music of a normal supermarket, or hearing people talking would have made me feel inside a supermarket" "To be like a supermarket, we should have been able to pay for the products, having a shopping cart and going to the cash register"
Learning experience	"The program was simple, but we did not need a lot more detail for the learning objective we had" "It meets the objective and it's very simple" "The way to use it was so simple and clear that it did not require a lot of mental effort to understand what you were doing, maybe you need a little bit more effort to apply it in class"	"We understood the data collection, but not its analysis, which is the focus of the course" "I would prefer to have this activity starting the semester and build on this experience to do further activities" "I did not like to feel pressured by the time" "I would like it to be more competitive" "I imagine having a digital class with everyone connected; like an interactive classroom" "We should be able to access the resource freely"

This preliminary qualitative analysis allows us to rethink about the indicators that should be considered to evaluate a VR didactic resource for learning processes in higher education.

V. CONCLUSION AND FUTURE WORK

These preliminary results seem to confirm that the features proposed by Mikropoulos and Bellou [3] strongly contribute to a sense of presence when using a VR tool. Students agreed that the free navigation, the autonomy, the 360 degrees view and the interaction with the objects made their experience more realistic. They also mentioned they would have appreciated involving more senses in the

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experience, for example listening to the type of music they would hear if they were really in the place.

However, VR tools should be used carefully because they are not appropriate for every instructional objective. The students in this study said that they would have preferred to have this experience at the beginning of the semester and build on it for further activities. In addition, they felt that the resource objective was limited; they would have appreciated analyzing the data they collected during the experience. This supports Pantelidis [10] suggestions about creating a pedagogical foundation when designing VR modules; the interaction with 3D objects by itself will not be enough to achieve better learning outcomes.

Furthermore, this study corroborated that teachers play an essential role when using this technology [6]. Teachers should clarify the learning objective of the resource before using it, and they should also define the steps students should follow and what is expected from them. After the experience, it is also important for teachers to engage students into a discussion about what they learned and how they can apply it to further class activities and to their daily life.

This study presents qualitative preliminary results, but the three dimensions will be evaluated using quantitative data, and interviews with teachers will be done. VR resources have demonstrated to have a great potential to enhance the learning process, but we must carefully define the learning objective and guide the students' experience. It is important to continue evaluating the characteristics that must be considered when using VR tools in higher education.

In this respect, future work must consider students' characteristics, analyzing any differences in the VR experience related to their gender, the program they are studying, their previous experience using VR, and their learning styles. In order to generalize results, it is important to include larger samples of students in different disciplines and with different characteristics. This could also allow measuring other variables such as acceptability of VR tools and user satisfaction.

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