

INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION

journal homepage: www.joiv.org/index.php/joiv

Virtual Reality (VR) in Superior Education Distance Learning: A Systematic Literature Review

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Abstract— Virtual Reality (VR) is one of the most popular contemporary technologies and it is widely used in the videogame industry, nonetheless, this does not restrict its use in other areas of science, such as medicine or education. Due to the large commotion caused by the appearance of Covid-19, long distance virtual education technologies (e-learning) are being used. With this context, virtual reality is the focus of this study, which had the objective of understanding the work done in superior education at a distance, through the use of VR, by doing a systematic literature review (SLR; LSR in Spanish). The results reveal that the use of VR in education can improve the experience, motivation and the comprehension of abstract concepts for the students, offering them an immersive environment in which they can interact and achieve effective learning. It was concluded that the works that were reviewed regarding the topic evidence a strong growth in the application of VR in education, which in their majority, employ experimental comparative methods between groups of students which use VR when compared to others who use the traditional method.

Keywords- Virtual reality; VR; virtual education; superior education; distance learning.

Manuscript received 26 Nov. 2020; revised 11 Jan. 2021; accepted 5 Mar. 2021. Date of publication 30 Sep. 2021. International Journal on Informatics Visualization is licensed under a Creative Commons Attribution-Share Alike 4.0 International License.



I. INTRODUCTION

Learning is the process of interaction between those that are learning and the educators, which takes place through the use of resources and environments, such as classrooms, in order to obtain the knowledge that one desires to transmit from the educator to the learner. The most frequently used method until now was traditional teaching, nonetheless, other methods exist, such as e-learning, which is a type of education based on the use of computers and the internet; it is used to improve the learning yield with the help of technology and the advantage that it offers is that one does not need to be physically present in the classroom. Another type of technology that can be taken advantage of in order to promote learning is virtual reality (VR), which according to M. D. Smith, S. Getchell, and M. Weatherly [1] is defined as an environment generated by computers which provides three dimensional images with which the users can interact; one of the principal tools of VR is Unity 3D. An important milestone in this area was the commercialization of the Oculus Rift, HTC VIVE VR, and Oculus Quest Standalone HMD devices, which entered into the mass market due to the fact that they offered a VR experience at a low cost. Generally, these

devices are used with the purpose of training, such as for videogames, though they have also been applied to areas of research such as engineering, medicine, education, and other areas.

The objective of this work was to identify the advances and learning activities of superior education students who used virtual reality technologies during the 2016 - 2021 period by doing a systematic literature review in order to obtain, classify, and analyze the relevant research that has been done regarding the use of VR as a means for learning. This study will be useful for keeping specialists up to date on the topic, by making known the methods, tools, areas of study, and limitations that are found for the use of VR in education. Due to the current context of the pandemic, which started at the end of 2019 and continues to this day in 2021, distance learning is taken into account as a form of teaching for this study. The research is structured in the following fashion: in section II the methodology that was used to do this work is presented, in section III the results from the finding are described, in section IV are the conclusions, and finally in section V you find the bibliographic references.

II. MATERIALS AND METHODS

According to the process for systematically reviewing literature, the following steps should be carried out in order to elaborate the study, taking into account the methodology of the work [2]:

A. Research Questions

With the purpose of understanding the focus of the study that is being done, research questions were created in order to obtain the necessary data.

- RQ1 Which methods were used in order to evaluate the learning of those who used VR?
- RQ2 Which types of VR technology were used for the research?
- RQ3 What limitations appear in the application of VR as a means for learning?
- RQ4 Which tools were used for the development of the research?
- RQ5 How was the experience of the VR users evaluated?
- RQ6 What areas of study were used in the research?

These research questions (RQ) were defined according to the context of the study. The purpose of the RQs was to respond to the questions regarding the methods used for the evaluation of the knowledge, the experience with the VR technology, the tools which were used for the studies, the limitations that were found in the studies, the types of technologies used, and the areas of study that were used in the research.

B. Review of the Reach

The reach is determined by using the PICOC rule (Population, Intervention, Comparison, Outcomes, Context):

- **Population:** University or Superior Education Students
- Intervention: Virtual Reality as a learning tool.
- Comparison: There is no comparison of technologies.
- **Outcomes:** Evaluation of the VR experience; evaluation of knowledge and the technologies.
- **Context:** How is the experience of those who use VR evaluated?

C. Doing the Search

The strategy for doing the search of the studies consisted in identifying the terms mentioned and applied in the studies, which were: "higher education," "university education," "virtual reality," "VR," "education," "educational," "learning," and "distance education." These were created using the research questions as a reference. The selection of the database was done using digital sources, since these possess an advanced search engine, which is needed in order to carry out the research. The sources are: ACM, IEEE, SCOPUS, and SCIENCEDIRECT, and the search was done from the year 2016 to 2021. The base chain in Table I was the most used search chain for each database, with the goal of obtaining a search which was adequate, based upon the title, keywords, and abstract.

TABLE I Search Chain by Database

Source	Search String
ACM	(Title:(("virtual reality" OR "VR") AND (educat*
Digital	OR "learning")) OR Abstract:(("virtual reality" OR
Library	"VR") AND (educat* OR "learning")) OR
	Keyword:(("virtual reality") AND (educat* OR
	"learning"))) AND Fulltext:(("higher education" OR
	"university education")) AND Fulltext:(("distance
	education"))
IEEE	(((("Document Title":"virtual reality" OR
	"Document Title":"VR") AND ("Document
	Title":educat* OR "Document Title":learning)) OR
	(("Abstract":"virtual reality" OR "Abstract":"VR")
	AND ("Abstract":educat* OR "Abstract":learning))
	OR (("Author Keywords":"virtual reality" OR
	"Author Keywords":"VR") AND ("Author
	Keywords":learning OR "Author
	Keywords":educat*)) OR (("Index Terms":"virtual
	reality" OR "Index Terms":"VR") AND ("Index
	Terms":learning OR "Index Terms":educat*))) AND
	("Full Text Only":"higher education" OR "Full Text
	Only":"university education") AND "Full Text
	Only":"distance education") NOT ("Publication
	Title":"augmented reality") NOT ("Publication
	Title":"AR") NOT ("Abstract":"augmented reality")
	NOT ("Abstract":"AR") NOT ("Index
	Terms":"augmented reality") NOT ("Index
	Terms":"AR") NOT ("Author
	Keywords":"augmented reality") NOT ("Author
	Keywords":"AR") NOT ("Publication Title":"mixed
	reality")
Science	("higher education" OR "university education")
Direct	AND ("virtual reality" OR "VR") AND
	("Education" OR "Educational" OR "Learning")
	AND ("distance education")
Scopus	(((TITLE("virtual reality") OR TITLE("VR")) AND
1	(TITLE(educat*) OR TITLE("Learning"))) OR
	(ABS("virtual reality") OR ABS("VR")) AND
	(ABS(educat*) OR ABS("Learning")) OR ((KEY
	("virtual reality") OR KEY("VR")) AND (KEY
	(educat*) OR KEY("Learning"))) AND
	(ALL("higher education") OR ALL("university
	education"))) AND ALL ("distance education")
	AND (LIMIT-TO (PUBYEAR 2021) OR LIMIT-
	TO (PUBYEAR.2020) OR LIMIT-TO
	(PUBYEAR.2019) OR LIMIT-TO
	(PUBYEAR.2018) OR LIMIT-TO
	(PUBYEAR.2017) OR LIMIT-TO
	(PUBYEAR, 2016))
	(10010,000))

Table II shows the results that were found when the search chains were applied, with there being a total of 227 articles related to the topic in study.

TABLE II	
SEARCH RESULTS	

Number of Studies					
1					
11					
50					
165					
227					
	Number of Studies 1 11 50 165 227				

D. Selection of the Studies

Table III shows the inclusion/exclusion criteria that was formulated for the process of selecting the articles related to the topic in study.

	INCLUSION AND EXCLUSION CRITERIA					
Criteria	ID	Criteria Description				
	I1	Articles from journals or relevant				
Inclusion		conferences according to "Explore				
		the GII–GRIN-SCI (GGS)				
		Conference Rating."				
	I2	Articles with content in the English				
		language.				
	13	Articles which make use of virtual				
		reality in superior education in their				
		research.				
	E1	Articles prior to 2016.				
	E2	Articles from secondary sources.				
F 1 ·	E3	Articles duplicated in other				
Exclusion		databases.				
	E4	Articles which were not done about				
	56	distance learning.				
	ES	Articles which do not have a				
		relationship with virtual reality nor				
	EC	learning.				
	E0	Articles which are locused on Augmented Beality (AB) on Miyed				
		Augmented Reality (AR) of Mixed				
		Reality (MR).				
	E7	Articles which only mention the				
	L7	terms "virtual reality" and				
		"education" without applying it to the				
		research.				
	E8	Studies that do not focus on superior				
		or university level education.				

TABLE III Inclusion and Exclusion Criteria

Table IV shows the three phases of how the inclusion and exclusion criteria were applied for the process of filtering the studies, during which 191 studies were discarded. At the end of the process, a total of thirty six potential articles was obtained.

TABLE IV PHASES OF FILTERING THE STUDIES

Phase	Criteria ID	
1	I2, E3, E1	
2	I1, E6, E2, E5	
3	I3, E7, E8. E4	

E. Evaluation of the Quality

In order to do an evaluation of the quality of the articles, the following questions regarding the quality were created:

- Are the objectives of the study related to virtual reality and distance learning?
- Is the research method appropriately described in order to reach the objective of the study?
- Are the results of the study clearly expressed?
- Is the article about an experimental study?

Of the thirty six articles that were evaluated using these questions regarding quality, twenty seven were chosen in order to carry out this study.

F. Data Extraction

In order to obtain the study data, the following extraction indicators were established:

- Instruments for Learning Evaluation
- VR Devices
- Research Topic
- · Tools for Carrying Out the Study
- Instruments for the Evaluation of the User Experience
- Limitation in the Application of VR Technology in the Study



Fig. 1 Article Selection Process

III. RESULTS AND DISCUSSION

From the results obtained after the previous processes, studies were accepted from three principal databases: SCOPUS (74%) [1], [3] - [21], IEEE (19%) [22] - [26] and ScienceDirect (7%) [27] [28]. Figure 2 shows studies

obtained from different locations, of which, in two countries more studies of this type are done: The United States (29%) and China (15%), while in the rest of the countries these types of studies are hardly carried out.

I ABLE V Assessment Tools that were Identified						
Assessment			Re	ference	s	
tools	2016	2017	2018	2019	2020	2021
Questionnaires	[28]	[15] [18] [20]	[16] [1]	[3] [5] [6] [7] [9]	[8] [10] [12] [23]	[11]
Polls	[4]	[15] [19]	[26]			
Feedback to the students		[24]			[8]	
Problem solving using VR		[18]		[5] [6]	[27] [8] [12]	



Next, the results from the data extraction are described,

with which the research questions are answered:

RQ1: Which methods were used in order to evaluate the learning of those who used VR?

Four principal tools for the evaluation of learning were identified, as shown in Fig. 3, below. Table V shows the evaluation tools, where the majority of the works that were reviewed were evaluated using questionnaires or tests (57%), which were made up of open and closed-ended questions. Notwithstanding, problem solving through the use of VR (22%) is the second way to evaluate learning through the use of simulation exercises or by doing activities with the device. The second method is based on surveys (14%) which were done in order to evaluate the opinion of the students with respect to their assimilation of learning. In the feedback to the students 7% indicated that the questions were asked during classes. Nonetheless, studies were also identified in which learning evaluations were not carried out [13] [14] [22] [17] [21] [25].

Figure 4 shows the number of learning assessment tools that were used to evaluate those who utilized VR, with questionnaires being the most widely used; having exponential growth in recent years.



Fig. 3 Learning Assessment Tools Which Utilized VR



Fig. 4 Number of Learning Assessment Tools that were Utilized by VR from 2016-2021

RQ2: Which types of VR technology were used for the research?

In Table VI it can be observed that the studies were generally done through the use of Google Cardboard (19%), Desktop VR technology (25%), Oculus Rift technology (19%), HTC VIVE technology (9%), Samsung GearVR technology (6%), and other Mobile Client technologies (16%).

RQ3 What limitations appear in the application of VR as a means for learning?

On the other hand, Table VII shows the limitations that are presented in the studies that were reviewed, where the following data was obtained: these limitations were the small number of participants (20%) with which the experiments were done, the problems in equipment use (13%), the time that is required to learn to use a device (9%), the budget for equipment acquisition (7%), VR sickness (7%) which is the sensation of dizziness experienced when using the devices, the lack of communication between students and teachers (6%), the lack of maturity in the VR technology (4%), the internet connection (4%), the participants quitting (2%), and the hardware and software problems (2%).

VR DEVICES THAT WERE FOUND							
Daviasa			Refe	rences			
Devices	2016	2017	2018	2019	2020	2021	
Desktop	[4]	[15] [24]		[5]	[23]	[13]	
VR	[28]			[9]			
Google				[3]	[8]	[11]	
CardBoard				[6]	[14]		
					[25]		
Oculus Rift	[21]	[18] [19]	[16]		[12]		
		[20]					
Samsung		[20]			[10]		
GearVR							
HTC VIVE		[20]	[26]		[27]		
Other	[21]		[17]		[22]	[13]	
Mobile			_		_	_	
Clients							

TABLE VI R Devices that were Founi

TABLE VII LIMITATIONS ON STUDIES

T :			Refe	ences		
Limitations	2016	2017	2018	2019	2020	2021
Few Participants	[28]		[16]	[5] [9]	[27] [8] [14] [25]	[11]
Problems in Equipment Use	[4]			[5]	[8] [12] [14]	[11]
Learning Time	[4]				[12] [8]	[11]
Equipment Budget	[21]				[8] [23]	
VR Sickness			[26]		[12]	[11]
Lack of Communication				[5]	[23]	[11]
VR Technological Immaturity			[17]			[13]
Internet Connection		[24] [18]				
Participants Leaving					[14]	
Hardware / Software Problems			[17]			
Homogeneous Participants					[8] [14]	
Late Equipment Delivery					[14]	

RQ4 Which tools were used for the development of the research?

Table VIII shows the studies that were reviewed, where it was identified that distinct tools were used in order to carry out the research; these were categorized into programming language, services, development software, apps, and others. In the review it was found that Unity3D is the most used tool in most of the research due to the fact that it is specialized for the development of VR content.

RQ5 How was the experience of the VR users evaluated?

According to studies that were reviewed, Table IX and Fig. 5 show that there were three principal tools used in order to evaluate the user experience with a VR device, which are surveys (54%) that mainly references the students' opinions, questionnaires that also grant results of the students' perceptions, and cognitive interaction (8%) which are done in experimental sessions. On the other hand, studies are found which do not carry out this type of evaluation of the user

experience [10] [7] [21] [22]. Figure 6 shows that the assessment tools for user experience were the surveys and that they have had exponential growth in recent years.

 TABLE VIII

 TOOLS USE FOR DEVELOPMENT THE RESEARCH

Programming Language	C#, JAVA
Services	Labster Service, Veer.tv, OpenCV, Poll Everywhere, Morph 3D, High Fidelity.
Development Software	Unity 3D, Voice Macro, MatLab, MaxWhere, Photon, ROSA, CADIX, CADENCE SUIT (CAD), AutoDesk 3D
Apps	VRNature, VRChat, Microsoft's Cortona, Qlone, VitrinasXR, VR180 App, Socket.io, SecondLife, SCOPE, Open Stack
Others	LeapMotion, SpaceConnextion 3D, Nod BackSpin, GoPro Hero 5, Kinnect, iSocial, Digilent Analgo Discovery Kit (ADK), Arduino IOT, Adobe Flash Player, 3D Muve

TABLE IX LIMITATIONS ON STUDIES

Assessment			Refe	ences		
tools	2016	2017	2018	2019	2020	2021
Questionnaires	[28]	[15] [24] [20]	[16] [1]	[3] [5]	[23]	[13]
Polls	[4]	[15] [19]	[16] [17] [26]	[6] [9]	[8] [12] [14] [25] [27]	[11]
Cognitive Interaction		[18]	[1]			





Fig. 6 Number of Assessment Tools for User Experience from 2016-2021

RQ6 What areas of study were used in the research that was done?

From the data extraction, Table X shows that in the engineering branch, studies have been done in the areas of environmental, electrical, industrial, and computer engineering. Later new areas of application were identified, which were anthropology, biology, physical education, legal education, physics, and geophysics. Also, an area of teaching foreign language was identified, which was TEFL. Later other types of study such as chemistry, medicine, MLIS, psychology, silviculture, social work and zoology were identified. Nonetheless, studies were also identified which had no relation to an area of science [3] [5] [24] [17] [25] [26].

TABLE X	
RESULTS FOR THE RESEARCH TOPICS	

No	Science	Areas of Study	References
1	Anthropology	Anthropology	[16]
2	Biology	Biology	[9] [16]
3	Physical education	Physical education	[22]
4	Legal education	Legal education	[8]
5	Physical	Physical	[20]
6	Geophysics	Geophysics	[15]
7		Environmental	[23]
		engineering	
8	En sin sonin s	Electric engineering	[6]
9	Engineering	Industrial engineering	[7]
10		informatics	[28] [18] [21]
		engineering	
11	Language teaching	TEFL	[11] [12]
12		Chemistry	[27] [10]
13		Medicine	[19]
14		MLIS	[14]
15	Others	Psychology	[1]
16		Forestry	[1]
17		Social work	[4]
18		Zoology	[13]

IV. CONCLUSIONS

From the study it was concluded that for the evaluation of student learning through the use of VR devices, questionnaires are one of the principal tools for measuring this indicator, which is denoted from the years 2016 - 2021; nonetheless, since the year 2020, the resolution of VR problems is being taken into account as another indicator of learning. It was observed that the Desktop VR technology is one of the most frequently used technologies in order to carry out experimental studies in VR, nonetheless, since the year 2019 the Google Cardboard technology has been growing, together with Desktop VR, due to the low costs of these technologies because they are HMD technologies. On the other hand, other technologies such as Oculus Rift, Samsung GearVR and HTC VIVE are not the principal tools for the studies, but it was found that these technologies are used in studies with greater complexity and which have the need for a more robust devices due to the study type. Among the limitations of the studies, it was concluded that a large part of the experiments were done with a low number of participants; an imbalance in the number of participants and the number of control groups was also found. Another principal problem that was identified was that the VR equipment can be difficult to manipulate for a large majority of the users, due to the fact that it is a technology that is being tried for the first time. The tool Unity3D is a software that is largely used for studies that

are carried out in a 3D environment, however, it was identified that in some studies a decision was made to contract services that are specialized in this area in order to create the experimental environments, thus, technologies other than Unity3D, such as AutoDesk, were used for developing the environments. For the evaluation of the user experience regarding the VR device, surveys were the principal tool which were used to measure this indicator. The greatest number of studies were done in the area of engineering, together with the area of teaching languages, in comparison to the other areas that were found in the revision process.

ACKNOWLEDGMENT

The authors wish to thank all of the participants who were part of this research work.

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