EXPLORING FACTORS OF LEARNING EFFECTIVENESS IN 3D VIRTUAL ENVIRONMENTS

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Abstract

Virtual Reality (VR) application in education makes learning more engaging and knowledge-retentive, making learning more immersive and effective. As the 3D Virtual Learning Environments (3DVLEs) become more and more popular, it is essential to learn about the factors that affect the performance of students. This paper examines them by conducting a systematic literature review (SLR) and survey through a Web-based questionnaire of VR education practitioners. The findings determine that the significant issues are the low quality of teaching methods, language barrier, motivation, spatial learning, high prices, technological complexity, and health issues. Other barriers were COVID-19-related, and in specialized VR devices such as stereo vision, 3D object interaction, and bioprocessing training. HMDs were found to be very instructive in the development of practical and classification skills. Based on the literature, the barriers were overcome by identifying 43 best practices that confirmed that optimized 3DVLE design and well-organized VR-based curriculum are effective in improving the learning outcomes and student performance.

Keywords: Virtual Reality, Virtual Learning Environment, 3D Virtual Learning Environment, Students Learning, Performance Factors, Systemic Literature Review.

I.   INTRODUCTION

Virtual Reality (VR) is an advanced computer-generated environment that immerses users in realistic digital worlds, allowing them to interact dynamically with virtual objects and spaces that closely replicate real-world experiences [1]. Collaborative 3D virtual worlds offer learners a chance to work together, enhancing their cooperation, ability to interact, motivation, and skills [2]. The formation of a 3D environment where users can feel present within the virtual world is called virtual reality technology, and it is also a methodology of producing an innovative process of education, providing an interactive, immersive, and adaptive experience that can transform the way people learn and interact with the content [4]. 3D virtual learning environments are a method of creating a 3D environment that allows users to feel like they are a part of it, and the virtual space can be claimed to be an interactive, immersive, and flexible environment that can change the way people learn and approach the content [4]. The virtual learning environments (VLEs) are an area where students are able to study through electronic or any other Network devices in order to study anywhere with

the help of videos, quizzes, interactive lessons, and so on [5].

Application of Virtual Reality: VR improves learning, work, and problem-solving by providing useful and interactive experiences at low costs. It is commonly applied in the educational, medical, art, and engineering sectors to enhance visualization, training of skills, design generation, and practice learning with the use of 3D simulation and realistic virtual environments [6, 7, 8].

Problem Statement: Technology is growing rapidly, thereby facilitating the adoption of 3D Virtual Learning Environments (VLEs) in learning to foster practical and interactive learning. Nevertheless, issues such as usability, teacher preparedness, and affordability still exist. This paper fills this gap by determining the factors that improve learning to match education with the current and future skills needs.

Aim and Objectives: The primary aim of this research study is to determine and examine the factors that positively and negatively impact student performance in 3D Virtual Learning Environments. The study aims to achieve the following goals, including the determination of factors that can affect student performance in 3D virtual learning environments. The literature will be used to identify practices that can be used to address the identified factors. The identified factors will be practically validated. And Practical confirmation of the identified practices/solutions.

II. BACKGROUND: Representations of data in a three-dimensional space enable users to interact with virtual objects as if in the real world. Virtual Environments (VEs) are classified into three main categories based on their interface type and level of immersion.

NON-IMMERSIVE VIRTUAL ENVIRONMENT (NIVE): It involves interacting with a three-dimensional scene displayed on a computer monitor. Common VR input devices include keyboards, data gloves, stereo display monitors, space balls, and specialized headsets or glasses [9].

SEMI-IMMERSIVE VIRTUAL ENVIRONMENT (SIVE): People using the system put on eye goggles and are tracked by sensors, allowing them to see the virtual world in 3D while still seeing themselves [9]

FULLY IMMERSIVE VIRTUAL ENVIRONMENT (FIVE): It employs advanced technologies such as HMDs, data gloves, and tracking systems to fully immerse users in a virtual environment. For instance, using FIVE, one can create a virtual building tour [9].

Adaptive approaches enable 3D-VLEs to personalize content, tasks, and interactions based on each student's needs, learning style, and performance, creating customized, effective, and continuously optimized learning experiences [10] Navigation aids in 3D virtual learning environments use menus, maps, and cues to support seamless exploration, content access, object interaction, and collaborative manipulation, enhancing immersion and effective learning experiences [11].Immersion permits students to experiment in cooperative environments, acquire first-hand experience, and also actively interact with the learning process without having to be bound by the real world [12]. 3D MUVEs enhance education by enabling realistic, interactive learning with advanced spatial visualization, higher motivation, contextual understanding, and collaborative design, supporting experiential and engaging learning across diverse fields from science to art [13].

III.RESEARCH METHODOLOGY: The research employed a two-phase methodology: an SLR to identify performance factors in 3D VLEs, followed by a survey to validate and uncover additional influencing variables.

SYSTEMATIC LITERATURE REVIEW: This research employed a Systematic Literature Review (SLR) to ensure a comprehensive, unbiased, and replicable analysis of factors influencing student performance in 3D virtual learning environments.

Following established SLR protocols, the organized process enhances clarity, reliability, and credibility. [14. 15].

Resources search string

(Student OR Learner OR Scholar OR Trainee OR Apprentices) AND ("3D Virtual Learning" OR "Virtual Reality Education" OR "Interactive 3D Education" OR "3D virtual education" OR "Digital Immersive Instruction") AND (Performance OR achievement OR Display OR Production) AND ("Success factor" OR" Key Factor" OR "Positive Factor" OR barrier OR occupied OR constraint OR Potential OR attribute OR issue)

Information Resources

Checking the available resources and the given time, the search string mentioned above was used on eight popular social networks. Digital venues: IEEE Explore, ACM, Wiley Online Library, Springer Link, Science Direct, Scholar Space, PubMed, and SPIE Digital.

Research Questions

RQ1. What are the success factors, as determined in literature, that have a positive influence on the performance of students in a 3D virtual learning environment?

RQ2. What are the barriers determined in the literature that affect the performance of students negatively in a 3D virtual learning environment?

RQ3. What practices are identified in the literature that deal with the factors that negatively affect the performance of students in a 3D learning environment?

STUDY SELECTION PROCESS: An extensive search was done to find out pertinent published works. In the first instance, a specified range of search terms was used to obtain 1,358 papers (see Table 1). The shortlisting of papers was performed based on reviewing titles and abstracts and resulted in the shortlisting of 413 papers. After a full-text analysis and the usage of inclusion and exclusion criteria, 42 articles were selected for extraction.

Table1: finally selected papers

Name of the libraries	Ph-1	Ph-2	Ph-3	Ph-4	Ph-5
Scholar Space	37	23	19	14	2
ACM	151	70	32	26	1
Springer	367	89	61	52	15
IEEEXplore	221	45	23	11	8
Wiley Online Library	134	67	41	29	4
Science Direct	132	45	34	10	2
PubMed	236	40	28	25	7
SPIE digital library	79	34	13	4	2
Snow Balling	1	0	0	00	1
Total	1358	413	251	171	42

Table 2: List of the identified factors through SLR

Table 2 List of Identified Factors through SLR

S. No	Factors	No. of Occurrence in Papers	Frequency (n=42)	Percentage
1	Potential Challenges of using VR in education and training	9,10,10,11,11,16,16,17,17,18,18,19,24,27,29,33,34,36,41	19	45%
2	Educational challenges during COVID 19	6,6,14,14,15,15,17,21,28,28,36,40,40,42	14	33%
3	Cost and complexity of VR tools	5,14,16,16,26,34,35,36,36,41,41	11	26%
4	Lack of interest and motivation	3,3,5,13,13,19,32,34,40	9	14%
5	Inappropriate teaching methodology	2,9,20,22,22,25,34,36,37	9	14%
6	Effective use of HMD in education	16,16,16,16,23,23,34,34	9	14%
7	Inappropriate design of learning activities	3,8,25,28,33,35	6	21%
8	Lack of spatial instructions	4,31,31,37,40	5	18%
9	Bridging the Gap Between theory and practice in education	12,12,26,30,32	5	18%
10	Challenges of stereoscopic vision of VR acceptance in education	25,25,25,30,41	5	14%
11	Challenges of bioprocessing training and 3D object production	18,18,32,39,39	5	12%
12	Health challenges of VR in education	16,18,25,41	4	12%
13	Teaching in non-native language	1,1,23,42	4	11%

DISTRIBUTION OF FACTORS: Table 3 represents the success factors and barriers influencing students' performance in 3D Virtual Learning Environments (3DVLEs), highlighting both the positive and negative impacts of using 3D Virtual Environments in education. Success factors are those factors F1, F2, F4, F5, F7, F8, F9, and F10, which improve the students' performance in 3D virtual learning environments and also improve the use of virtual reality for education. The challenges refer to those factors, F3, F6, F12, and F13, which do not improve the performance of students in Virtual Reality.

Table 3: Distribution of factor success or challenges

DISTRIBUTION OF FACTORS

S. No	Success Factors / Positive factors	S. No	Challenge/Barriers / Negative factors
1	Teaching in non-native language	3	Inappropriate design of learning activities
2	Inappropriate teaching methodology	6	Cost and complexity of VR tools
4	Lack of interest and motivation		
5	Lack of spatial instructions	11	Challenges of stereoscopic vision of VR acceptance in education
7	Educational challenges during COVID 19	12	Challenges of bioprocessing training and 3D object production
8	Potential Challenges of using VR in education and training		
9	Bridging the Gap Between theory and practice in education	13	Health challenges of VR in education
10	Effective use of HMD in education		

Empirical study: The study was approached through a survey that was administered in the form of a questionnaire to determine and confirm factors affecting 3D Virtual Learning Environments, and the quantitative data obtained were from 93 qualified global respondents. The responses were classified with a five-point Likert scale into Optimistic, Pessimistic, or Impartial, and valid or invalid responses were filtered out. The experience level of the participants was analyzed, and the factors of optimism and the percentage distributions were presented in Table 4.

Table 4: List of the responded

S. No	Factors	Total Response=93							
		Optimistic			Pessimistic			Impartial	
		E/Agre	Agree	%	E/Agre	Agree	%	Neutral	%
1	**F1** Teaching in non-native language	42	45	90	1	1	2	4	4
2	**F2** Inappropriate teaching methodology	38	45	89	1	1	2	8	8
3	**F3** Inappropriate design of learning activities	32	38	73	0	8	9	15	16
4	**F4** Lack of interest and motivation	34	39	73	0	8	9	12	13
5	**F5** Lack of spatial instructions	30	45	77	0	2	2	16	17
6	**F6** Cost and complexity of VR tools	59	26	87	0	2	2	6	7
7	**F7** Educational challenges during COVID 19	44	35	82	0	8	9	6	7
8	**F8** Potential Challenges of using VR in education and training	22	43	68	0	14	15	14	15
9	**F9** Bridging the Gap Between theory and practice in education	46	29	77	0	8	9	10	11
10	**F10** Effective use of HMD in education	40	37	80	0	4	4	12	13
11	**F11** Challenges of stereoscopic vision of VR acceptance in education	24	42	70	0	6	7	20	22
12	**F12** Challenges of bioprocessing training and 3D object production	35	42	80	0	8	9	8	9
13	**F13** Health challenges of VR in education	36	45	84	0	6	7	6	7

Limitations:

This research study used a Systematic Literature Review (SLR) and a questionnaire survey across the world to determine the factors that affected student performance in 3D Virtual Learning Environments. Nevertheless, it was restricted by such limitations as limited access to all literature in English only, limited database coverage, and the exclusion of all studies older than 2024, as well as the possible omission of other important works. The survey of 93 participants verified SLR results but had the potential for bias in self-report, non-response, and the lack of representation of the real views of learners and educators.

Future Work:

This research provides an understanding of the thirteen most important factors affecting student performance in 3D Virtual Learning Environments, which is important to software developers as VR becomes significant in the education sphere. Future research will be extended to other areas such as healthcare, engineering, architecture, and corporate training to determine the effectiveness of VR in improving learning, performance, and decision-making, as well as give useful recommendations to maximize the experience of learning in 3D virtual worlds.

Conclusion:

The majority of factors have positive effects on the performance of students in 3D Virtual Environments, which confirms the usage of VR in education. VR increases immersion, interest, and real-world knowledge through immersive devices, such as Head-Mounted Displays (HMDs). Although cost and health issues are considered to be complications, the advantages of VR in education are remarkably stronger than the disadvantages, which proves the value of VR in education.

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