A Study on the Users' Experience in Learning Using a Virtual Reality Laboratory for Medical Sciences

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Abstract: As a result of the worldwide dissemination of COVID-19, educational institutions across the globe, particularly those that serve students in the field of science, have been mandated to close their doors. Consequently, educators and students have increasingly relied on educational technology to obtain a diverse array of resources. This research aims to construct a science laboratory in virtual reality by employing the ADDIE Methodology, a well-established structure for designing instructional programs. Additionally, the study aims to evaluate the impact of the virtual reality laboratory on the level of immersion that 37 science students experienced during the learning process. This evaluation will compare the students' sense of presence before and after utilizing the facility. The concept of presence within the context of virtual reality (VR) pertains to the experience of being fully immersed in a digital environment, such that the user's cognitive processes interpret it as being authentic. The degree of immersion users perceive substantially impacts their engagement, conduct, and affective responses while engaging with virtual reality. For this experimental investigation, the participants were segregated into two distinct cohorts. Group 1 consisted of twenty participants who viewed scientific films in two dimensions, whereas Group 2 comprised seventeen participants who engaged in science education through a virtual reality laboratory. The findings suggest a significant presence in both cohorts, with the virtual reality (VR) cohort exhibiting superior performance compared to the other group. The present study offers significant findings for educators and software developers engaged in creating virtual reality (VR) resources for science instruction. In forthcoming studies of instructional technology that utilize virtual reality, it is suggested that cognitive load be scrutinized as a variable. In general, this research adds to the increasing corpus of evidence that showcases the favorable and comprehensive impacts of immersive learning in education.

Keywords: Laboratory, Sciences, Virtual Reality, Presences, CAMIL.

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Introduction

In response to current conditions, educational institutions have promptly adopted efficient strategies for managing student interactions, delivering online courses, and assessing students. Institutions have recognized the need to adapt to the changing environment caused by COVID-19 (Mukhtar et al., 2020) despite initial concerns about the effects of investing in online education. This presents an opportunity to adopt technology that meets the requirements of contemporary education, especially for science students. Technology advancements have increased the desirability of online and web-based learning methods, mainly when traditional approaches are impractical. Such methods enable educational institutions to adapt their blended learning strategies quickly during a pandemic (Panchal et al., 2021). However, it is essential to ensure that online education operates efficiently.

Virtual reality (VR) is an interactive experience that immerses consumers in computer-generated environments (Fabris et al., 2019; Mokmin & Ridzuan, 2022). VR technology grants users access to interactive, three-dimensional virtual environments that enhance learning (Oigara, 2019). Users are transported to a 360-degree virtual environment by wearing a VR headset that monitors their movements, allowing them to explore, navigate, and interact with the content. This enables students to take charge of their learning process and choose content that corresponds to their abilities and requirements (Yin et al., 2021). However, virtual reality technology also raises ethical concerns and potential dangers, such as privacy, consent, representation, and bias issues.

This study has identified research voids regarding the long-term effects of VR exposure, including its effects on visual performance, visual fatigue, and cognitive aftereffects (Szpak et al., 2019). Additionally, when utilizing VR technology, ethical concerns regarding privacy, consent, representation, and bias must be addressed (Kenwright, 2018). Recent developments in the educational use of virtual reality include virtual field trips to historical and touristic landmarks, simulation-based learning for practicing psychomotor skills in preclinical dental students, immersive language learning for speaking and listening, VR integration in special needs education for social and life skills training, and iPad-based blended learning approaches (Crawford et al., 2022)(Jiao et al., 2021).

To facilitate this research, a Virtual Reality Biology Lab (VRBL) with virtual experiences for students was created. The VRBL combines Experiential Learning Theory (ELT) and the Cognitive Affective Model to generate the CAMIL model, an immersive learning environment. This instructional method integrates multimedia design and effective pedagogical techniques by utilizing the interactive capabilities of virtual reality. The study will assess pupil participation, engagement, and comprehension utilizing the Virtual Reality Laboratory (VRL) and conventional two-dimensional films on the same topics. The final prototype was designed and developed using the ADDIE Model, a recognized framework for VR-based technologies in scientific education. Educators and designers can use the findings of this study to create more engaging learning environments.

Background Study

Virtual reality encompasses four essential elements: virtual worlds, sensory feedback, immersion, and interactivity. Virtual worlds are computer-generated environments that permit real-time user interaction and simulate external sensations, providing a feeling of teleportation to the virtual world (Jiawei & Mokmin, 2023). Immersion enhances the authenticity of the experience by incorporating auditory and visual data, allowing users to become fully immersed using VR headsets and spatial audio. Sensory feedback replicates human perception, allowing VR equipment users to navigate, observe their on-screen movements, and interact with the virtual environment.VR can alter the perception of taste, scent, and force, in addition to audio and video. The fourth aspect is interactivity, which enables users to interact with the virtual world in real-time, fostering a sense of inclusion and immersion. Within the virtual world, users can perform actions such as slaying monsters, shooting, kicking, and selecting objects on the screen.

The technology seeks to simulate reality by utilizing VR equipment such as headsets, gloves, and goggles that transmit and receive data and display moving images and objects. When human motion is detected, the display alters in real-time, providing users with a realistic 3D experience. Explore the VR environment by walking, stepping, turning heads, and even touching 3D objects to experience them with their hands (Mokmin & Jamiat, 2021).

According to Heizenrader (2019) , there are two primary types of virtual reality: non-immersive and immersive. Non-immersive VR technology provides the user with a computer-generated virtual environment in which they remain. There are two types of immersive VR: semi-immersive and truly immersive. Semi-comprehensive virtual reality provides a more immersive experience than non-immersive virtual reality, but is not as immersive as fully immersive virtual reality. Completely immersing the user in a virtual environment provides the most authentic experience possible. Fully immersive experiences require a headset or other wearable device that covers the user's eyes, hearing, and sometimes other senses.This research focuses on fully immersive technology because it provides a more interactive and comprehensive virtual reality (VR) learning environment.

Using avatars, students can engage in various virtual reality simulations and engage in learning without fear of making errors. For instance, Shorey & Ng (2021) explain how the performance of nurses during clinical training can be monitored and recorded using VR, which provides an authentic and distinctive training environment that enhances their sense of presence. Additionally, VR can be used for challenging educational duties, such as assisting anxious patients receiving psychiatric care. Li et al. (2020) discovered that avatars in a virtual environment assist patients in identifying their emotions and practicing emotional responses.

Virtual Reality in Learning Science

The study of biology is essential to comprehending science, and it is included in the secondary school curriculum. Biology investigates the processes within living organisms, such as humans, plants, and animals, and forms the basis of medical science. It addresses questions concerning the origins of existence. However, pursuing biology at the secondary and bachelor's levels presents obstacles, particularly regarding teacher preparation and subject understanding. The psychosocial aspect relates to the student's interactions with the instructor, peers, and environment, whereas the physical aspect relates to the classroom's environment and resources. Effective interactions between instructors and students are crucial for educational success.

Due to the global proliferation of COVID-19, educational institutions have been forced to close their doors, particularly those training future medical professionals. Online education has filled the void and allowed students to continue their education. The course materials are delivered via online platforms in a manner that encourages student engagement and facilitates the evaluation of their progress. Virtual reality (VR) immerses users in a computer-generated environment, facilitating user interaction. Through sophisticated interaction techniques, VR technology provides educational applications with access to 3D simulated environments. By donning motion-sensing VR headsets (and sometimes portable controllers), individuals can experience a virtual 360-degree environment that completely replaces their immediate surroundings. This adaptability enables students to direct their own learning, selecting pertinent topics based on their own circumstances and receiving individualized instruction tailored to their specific skills.

The use of virtual reality in medical education and learning can be highly advantageous. Several studies have demonstrated the benefits of combining VR technology with conventional instructional methods in medical science education. Chen et al. (2020) discovered that virtual reality technology improved students' learning capacity, satisfaction levels, performance time, and confidence. Samadbeik et al. (2018) discovered in a review of studies on using virtual reality in medical science that 74% of the studies indicated enhanced learning outcomes, while 87% demonstrated that medical professionals trained with VR exhibited increased accuracy. Despite the many benefits of VR-based learning materials and environments in medical science education, Baniasadi et al., (2020) identified specific challenges and limitations that organizations and educators should consider prior to investing resources in the development of such materials and environments. To effectively utilize virtual reality, it is essential to meticulously align its educational purpose and consider it throughout the design and development phases.

Experiential Learning in Virtual Reality

Lewin, Dewey, and Piaget all created significant experiential learning models that have influenced the growth of the notion of experiential learning. These opinions all emphasize the value of experience or hands-on training. Students acquire knowledge through actual experience and subsequent processing of that knowledge. The process of learning by actual experience is referred to as "experiential learning". Relearning should always be a part of the learning process since learning is a process, not a product, and learning itself inspires people to learn. When experience is taken in and transformed, knowledge is created.

Four experiential learning methodologies were presented using this just as the foundation. The Active Experimentation, Reflective Observation, and Abstract Conceptualization Cycle in Four Stages (David A. Kolb, 2015). The experiential learning paradigm is one of the most frequently cited rationales for employing virtual reality in the classroom (Falloon, 2019). The knowledge required for efficient learning can only be obtained through firsthand experience. Because it centers the learner at the center of relevant lessons, virtual Reality (VR) has a lot of potential as a teaching tool (Alrehaili & Al Osman, 2019). Virtual Reality (VR) has also been shown to increase student engagement in chemistry, engineering education (Chang et al., 2022)(Halabi, 2019), and STEM subjects (Sattar et al., 2020).

Virtual reality (VR) technology's application inthe medical sciences has been the focus of numerous studies that have looked at how to engage students' interest in learning. Virtual reality was used as a teaching tool for nurses to learn about childbirth throughout the trial. Their research indicates that when it comes to piquing students' interest in learning, employing virtual Reality (VR) to teach students is more effective than using more traditional methods. Students are significantly more engaged in virtual Reality (VR) learning than they are with video and text-based learning, according to research done by Sattar et al. (2020).

Cognitive Affective Model of Immersive Learning (CAMIL)

According to the Cognitive Affective Model of Immersive Learning (CAMIL), immersive media, such as virtual reality (VR), improve the learning experience. The function of multimedia design in enhancing immersive virtual learning environments is crucial (Makransky & Petersen, 2021). Visual, audio, and tactile feedback are used as virtual sensory inputs during immersive learning. This strategy is supported by motivation, curiosity, and multimedia learning, among others. Figure 1 depicts the six emotional and cognitive CAMIL components that can facilitate learning in immersive virtual reality (IVR) environments. These variables include interest, intrinsic motivation, self-efficacy, embodiment, cognitive burden, and self-regulation. Makransky & Mayer, (2022a) research indicates that effective instruction in virtual environments can improve learning outcomes. The hypothesis outlines six influences of presence and agency on the learning process. Figure 1 illustrates the relationships between CAMIL variables and factors such as cognitive burden, self-regulation, self-efficacy, and intrinsic motivation. Investigating the impact of the user presence scale and the VR Science Laboratory experience on learning will be the primary focus of this study.

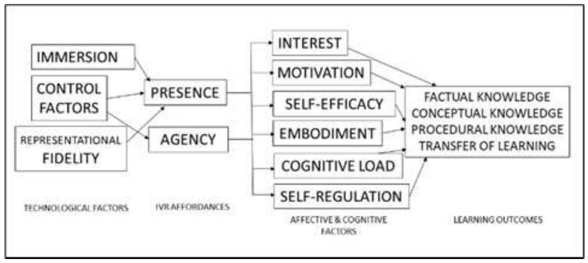

Figure 1. The Relations between the different variables in the CAMIL

Presences in Virtual Reality

Due to its requirement for user interaction within a virtual environment, virtual reality (VR) has received scant research attention despite its pervasive use. The feeling of presence is crucial for creating a more realistic virtual reality experience because it enables users to focus on the content rather than become distracted by illusionary flaws. Elements such as displaying actual constraints and equipment awareness can assist in reducing this subjective illusion. Moreover, social interactions with VR characters and internal factors such as personality traits and immersion propensity can influence a user's sense of presence while using VR (Servotte et al., 2020). After respondents have investigated the VR research facility, a questionnaire will be administered to determine their level of presence.

The sensation of being tangibly present within a virtual environment. It requires the user to feel truly present, interacting naturally with avatars, objects, and the surrounding environment. The objective is to create sensory experiences that closely mimic "being there." User characteristics and media attributes determine their presence in mediated contexts, according to Riva et al. (2003) classifications. Individual component perception plays a significant influence on presence (Bachmann et al., 2021). As it involves the subjective experience of the learner, different individuals may have varying levels of presence in response to the same experience. As our brain perceives all sensory information as a unified entity rather than discrete channels, developing multisensory experiences is essential for creating impactful moments. However, most VR research has primarily focused on enhancing image fidelity.

The term "immersion" is used to describe both the objective measure of creating a visually and aurally engaging virtual environment and the subjective impression of believability in that environment (Cummings & Bailenson, 2016). "Presence" refers to the mental perception of being physically present in a simulated environment, resulting in a "presence illusion." Contrary to prevalent belief, the primary objective of virtual reality is not to make users feel physically present in a virtual environment (Samur, 2016). Instead, "presence" refers to the sensation of being fully immersed in a digital world, predominantly on a visual level, despite the brain and body's response to environmental stimuli. In the VR industry, "presence" can be subjective and sometimes used interchangeably. "Presence" can also refer to the sensory realism of a virtual reality (VR) system (Slater & Sanchez-Vives, 2016).

Immersive VR experiences require tactile feedback, minimal latency, and the full integration of visual and auditory elements (Slater & Sanchez-Vives, 2016). High-fidelity visuals, immersive audio, and natural interaction flow create an immersive experience (Jung & Lindeman, 2021). Virtual reality (VR) technology aims to thoroughly immerse users in a virtual environment by providing visual, auditory, and sometimes tactile sensory feedback. VR headsets, motion controllers, and other specialized technologies aim to make the virtual world appear, hear, and feel astonishingly natural (Witmer & Singer, 1998). In the development of virtual reality (VR) experiences, it is essential to prioritize a high level of presence because it increases user engagement and facilitates prolonged interaction within the virtual environment. A high level of presence can enhance immersion and engagement, thereby enhancing the efficacy of scientific learning in a VR environment. Considering factors such as realism, engagement, and multisensory integration, additional research is necessary to fully comprehend the impact of presence on learning outcomes.

Design and Development

Virtual Reality Science Laboratory

Throughout the design and development phases, the ADDIE (Analysis, Design, Development, and Evaluation) methodology is applied. Using cutting-edge interactive technologies, the virtual reality (VR) laboratory develops highly engaging 3D virtual worlds for scientific study. Under the supervision of an instructor, students are able to navigate a fully immersive virtual laboratory using motion-sensing VR headsets and portable controllers. Students can investigate in-depth information about pathological elements such as cancer cells, germs, and bacteria via interactive 3D models and informative instructional videos. Consequently, students have more control over their academic journey and can tailor their education to their specific requirements and interests.

Hardware

Individuals can entirely immerse themselves in computer-generated virtual reality environments using various sensing devices, allowing them to experience and feel as if they are physically present in that location. Examples of such virtual environments include airplane cockpits and operating rooms. We increased participant engagement using the HTC Vive, a virtual reality headgear manufactured in the United States by HTC Corporation. With a field of view of 100 degrees and a resolution of 1,080 by 1,200 pixels per eye, the HTC Vive provides users with a high-quality visual experience. It also has a refresh rate of 90 Hz. The HTC Vive's built-in wireless adapter allows users to explore virtual environments without being physically tethered to a computer. To further facilitate interaction within the virtual world, we used a set of HTC controllers with two Vive trackers affixed to the feet and one Vive tracker placed on the torso (see Figure 2). Two lighthouse cameras continuously surveyed the 3x3 meter playing area, allowing precise tracking and movement within the virtual environment.

Figure 2. HTC headset and hand controller
Taken from: HTC VIVE (n.d.). Gadgets to Use. Retrieved June 17, 2023, from https://gadgetstouse.com/blog/2017/08/23/htc-vive-price-cut-india/

Virtual Reality Science Laboratory Development Platform

The Virtual Reality component of the Virtual Medical System was created using the Unity platform. Creating a digital representation of the healthcare system was the initial step. Utilizing Blender and Photoshop, a detailed 3D model and texture were created for the virtual medical environment. This procedure required considerable time and effort. After creating the 3D model in Blender, it was imported into Unity and scaled accordingly. The roaming module functionality was implemented by encoding the required functions based on the predetermined design to facilitate user movement within the virtual laboratory scene. Individuals can immerse themselves in a computer-generated virtual reality environment using various sensing devices, providing an immediate sensation of presence and realistic experiences, such as being in the cockpit of an aeroplane or an operating site.

We employed the HTC Vive, a sophisticated virtual reality headset developed by HTC Corporation in the United States, to increase participant engagement. The HTC Vive features a 100-degree field of view and a display resolution of 1,080 by 1,200 pixels per eye. In addition, it has a refresh rate of 90 hertz, which ensures fluid and immersive visuals. The HTC Vive's wireless adapter enables users to freely investigate virtual worlds without requiring physical connections to a computer. To further facilitate user interaction within the virtual environment, we used a set of HTC controllers with two Vive trackers affixed to the feet and one Vive tracker placed on the torso (refer to Figure 2). Two lighthouse cameras continuously scanned a 3x3 meter area to accurately monitor user movements and interactions within the virtual environment.

Virtual Reality Science Laboratory

In the Virtual Reality Science Laboratory, there are six distinct sections, each featuring labeled 3D objects, movies, and infographics. One of these sections is dedicated to the study of animal, plant, and fungal cells, allowing students to explore their structures and understand the importance of precise labeling in a laboratory setting.

Figure 3. General view of VR science Lab

In the Virtual Reality Science Laboratory, viewers have the opportunity to observe 3D objects, such as Amoeba and Chlamydomonas, with their corresponding descriptions. This interactive experience enhances the understanding of the bacterial structures and their characteristics.

Figure 4. Cell and bacteria section

In the Virtual Reality Science Laboratory, the second area is dedicated to the exploration of cancer, tumors, and inflammatory diseases. Within this section, there are various three-dimensional objects, a movie, and interactive discussions that provide insights into inflammation, tumors, and the different stages of cancer.

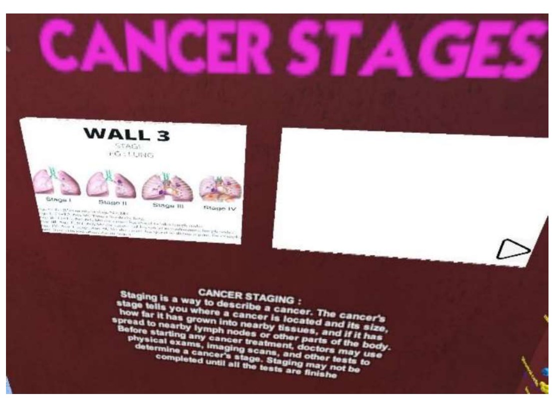

Figure 5. Cancer and inflammationsSection

The VR Science Laboratory features a Human and Skeleton wall where every part of the human skeleton is categorized and labeled. This setup aims to enhance visitors' comprehension of human anatomy by providing them with a comprehensive overview of each component of the skeletal system.

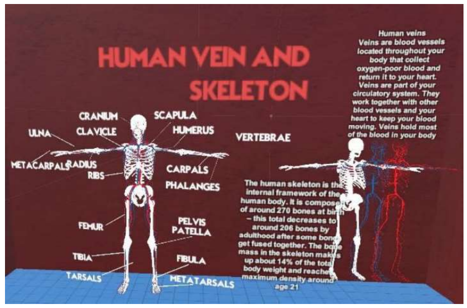

Figure 6. Human vein and skeleton section

In the next section, the VR Science Laboratory showcases a three-dimensional infographic wall that visually presents the progression of tumors, highlighting their significance within the study of cells. This interactive display aims to provide a comprehensive understanding of tumor development and its relevance in scientific research.

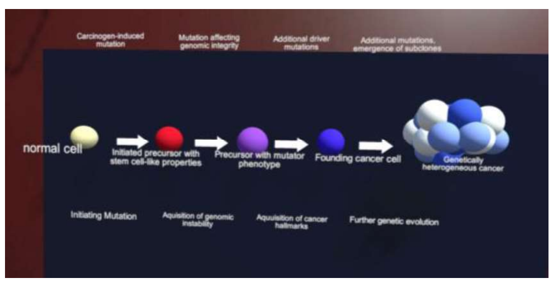

Figure 7. Infographic of tumor genesis

Within this section, users are granted unrestricted exploration, allowing them to navigate freely while accessing informative movies that provide a comprehensive overview of the activities within a pathology lab. Additionally, users have the opportunity to examine virtual microscope slides and interact with 3D models of various laboratory equipment, enhancing their understanding and engagement with the subject matter.

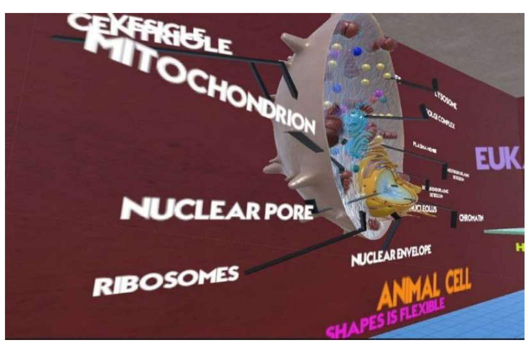

Figure 8. Pathology section

Methodology

Research Approach

A descriptive quantitative methodology is used to address the study's research subjects. Students are asked to voluntarily participate in the study using a Google form, a pre-posttest, and open-ended questions as research tools.

Sample size and population

In this study, we assess participants' proficiency with the VR scientific lab and their presence experience about application when studying sciences. Two separate groups of 37 science students were given a set of questions as part of the study. Twenty kids will be in Group 1, studying Science through 2D movies, and 17 students will be in Group 2, studying Science using a Virtual Reality Science Lab. Both groups will get a set of questions following each session.

Instrument

An online questionnaire was utilized as the instrument to gather data for this study because it is a quick and easy process. There are two sections to the questionnaire: Part A and Part B. The information about respondents' backgrounds, including name, student number, and course, is gathered in Part A of the survey. In Part B of the survey, participants are asked to score their replies on a Likert scale that spans from strongly disagree to strongly agree in response to six questions (three for each group) concerning their presences experiences while learning in a virtual reality science lab and 2D video. The layout of the questionnaire is shown in Table 1.

Table 1: Students' Feedback- Questıonnaıre Part B (Lıkert Scale)

Questions
Group 1 (Video)
1. The "Cell Structure and Function" video seems to help me to visualize the cell itself better
2. My experience learning with "Cell Structure and Function" video similar as learning in the actual classroom
3. The "Cell Structure and Function" video attracts my attention for learning about topics
Group 2 (Virtual Reality)
1. The virtual science laboratory seems real to me
2. The virtual science laboratory gave me the feeling of being there myself
3. My experience in the virtual science laboratory seemed as though I was there in the real world

Data Analysis and Findings

Results

There are 3 outliers for this data collection. Therefore, the total collected is 37. Group 1 is 20, and group 2 is 17.

H_0: There is no significant Different between Group 1(Video) and Group 2(VR) in the median mark score.

A non-parametric Mann-Whitney U test was performed to compare the mark scores between Group 1 (Video) and Group 2 (VR) in a data collection containing 37 observations, with 20 in Group 1 and 17 in Group 2. Since the data was not normally distributed, this test was chosen.

The results of the Mann-Whitney U test indicate that there is a statistically significant difference in the mark score distributions between Group 1 and Group 2. The test statistics show a U-value of 238.5, a z-value of 2.141, and a p-value of 0.036.

Based on the p-value being below the common significance level of 0.05, the null hypothesis, which states that there is no significant difference in the median mark scores between the two groups, is rejected.

Further analysis reveals that the median mark score in Group 2 (VR) is significantly higher (93.3) than in Group 1 (Video) (83.4).

In summary, the statistical analysis using the Mann-Whitney U test suggests that there is a significant difference in the median mark scores between Group 1 and Group 2, indicating that Group 2 (VR) has a higher median mark score compared to Group 1 (Video).

Table 2: Hypothesıs test summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Mark is the same across categories of Group.	Independent-Samples Mann-Whitney U Test	0.036[a]	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is 0.050.

a. Exact significance is displayed for this test.

Table 3: Independent-samples Mann-Whıtney U Test summary

Total N	37
Mann-Whitney U	238.500
Wilcoxon W	391.500
Test Statistic	238.500
Standard Error	31.997
Standardized Test Statistic	2.141
Asymptotic Sig.(2-sided test)	0.032
Exact Sig.(2-sided test)	0.036

Table 4 :Dıstrıbutıons of the two group İndependent-Samples Mann-Whitney U Test

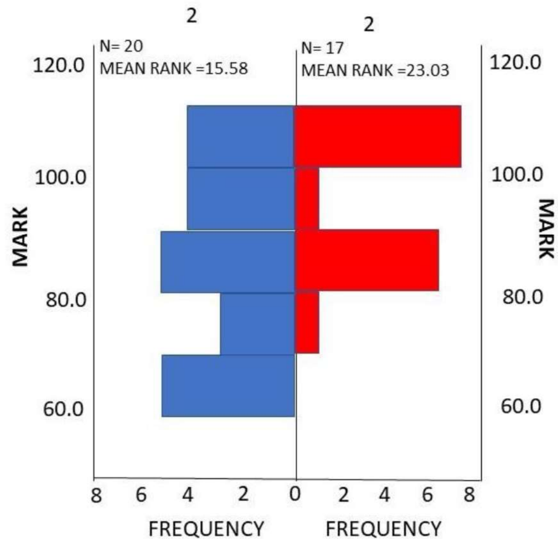

Table 5: The Mean, Std. Devıatıon and Medıan Report

Report				
Mark				
Group	Mean	N	Std. Deviation	Median
1	83.000	20	13.4060	83.350
2	92.165	17	8.5712	93.300
Total	87.211	37	12.2042	86.700

Discussion

The study results indicate that the group taught science using 2D film demonstrated lower levels of presence than the group taught using virtual reality. This outcome is consistent with the immersion principle of multimedia learning, which suggests that immersive experiences foster increased engagement and presence. Makransky & Mayer (2022b) also supports this idea, stating that increased immersion in learning environments results in greater levels of presence. These findings support previous research demonstrating that less immersive mediums like video provide less virtual presence than high-end VR systems (Riva et al., 2003).

This study's primary objective was to comprehensively investigate the impact of the immersion principle on multimedia learning and to comprehend how virtual reality influences a learner's sense of presence when engaging with science. Presence is vital in virtual reality experiences, as it profoundly influences user engagement, behavior, and emotions. When users feel physically present in the virtual environment, they become more engaged with the content. Numerous studies have demonstrated that students in virtual reality environments retain information better and perform better on related tasks. The concept of presence in virtual reality has numerous practical applications, ranging from therapeutic interventions to medical training and simulations. Virtual reality enables users to acquire and practice skills in a safe and controlled environment by fostering a sense of presence.

Conclusion

This research aimed to determine the efficacy of virtual reality (VR) applications incorporating the immersion principle in multimedia learning. The study compared the level of presence of two groups of students during scientific education, one using virtual reality and the other using conventional methods. The results revealed a significant difference between the two groups' levels of presence, with the VR group exhibiting higher levels of presence and performing better overall. These findings have significant implications for educators and developers, demonstrating the potential of virtual reality (VR) tools to improve scientific learning experiences.
It is recommended that future research investigate additional variables, such as cognitive load, in conjunction with VR learning aids. This will provide a deeper comprehension of the impact of virtual reality on learning outcomes and guide the development of effective VR interventions.

Virtual reality is not a permanent solution but a highly effective instructional instrument, especially for specialized learning applications. Its use in medical science, particularly in pathology education, has been thoroughly investigated. Virtual reality's future depends on its continuous incorporation into educational curricula and technological advancements that enable shared simulations of therapeutic encounters. This will enable the extensive and location-independent delivery of high-quality interprofessional education, thereby altering the educational landscape of the future.

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