The Opportunities and challenges in virtual reality for virtual laboratories

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ABSTRACT

The use of extended reality (XR) technologies, namely Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality(MR) in education, has attracted much attention in recent years. Since the middle of the 20th century, virtual reality (VR) has been a part of our lives. Today, technology has made virtual reality accessible to everyone. In the last ten years, virtual reality equipment has become suitable for individual use and has started to be used by large numbers of people. Virtual reality can now be used for educational purposes, including education virtual laboratories. The studies were carried out to reveal the advantages of virtual reality compared to traditional media tools, as well as the conclusion that a successful instructional design process plays a major role in the success of technology in education. In line with what has been mentioned, we review in this paper the historical development of virtual reality technologies, followed by the use of Extended reality technology in the field of education, including virtual laboratories. This paper is to argue and present evidence from extensive research that VR can be a valuable tool in engineering, such as virtual laboratories. As a result of the review we conducted, we were able to conclude that VR has a positive pedagogical and cognitive impact on engineering education, thus increasing students' understanding of the subjects, their grades and performance, and overall satisfaction with their education. Furthermore, VR, as a replacement for physical laboratories, can reduce university liability, infrastructure, and costs. It was also discovered that VR applications for education currently lack the integration of learning theories and objectives in engineering education. In this research, we aim to provide recommendations and guidelines for researchers who want to work in the field of virtual reality and to offer suggestions for virtual laboratories.

Keywords
Virtual reality technologies; engineering education, virtual laboratory, learning environment, educational technologies

Introduction

Extended reality has been an active research topic for decades; in the early days, a common term was artificial reality instead of extended reality (XR). There has been an increase in the use of the term 'extended reality (XR) as a blanket term for Virtual reality (VR), Mixed reality (MR), and Augmented reality(AR)technologies in recent years. Virtual Reality (VR) can simply be described as the ability to interact with and alter perception through computer-simulated environments, where the user participates in an experience through a mixture of sensory input, which is sent via computer to the human brain by means of a computer simulation. There have been many years of technological advancements and the development of microprocessors capable of high-level computation at an affordable price, resulting in modern VR as it exists today.

In the 1930s, different technologies and concepts emerged that led to the concept of VR. The first known VR technology, Sensorama, was developed by Morton Heilig in 1956 and patented on August 28, 1962, under the name Sensorama simulation, as shown in figure 1, which represented the features of the device. In 1962, Morton Heilig developed an immersive machine called Sensorama. It was a big bulky machine, which made a player experience riding a bike in the streets of Brooklyn. As a result of Sensorama, the user could sit down and experience an immersive motorcycle ride through the streets of New York(Morton L Heilig, 1962). Aside from providing the user with a visual experience, Sensorama also provides the user with the sensations of scent, vibration, and wind, as well as audio. Since the filmed route was static, Sensorama met all the characteristics of VR, with the exception of one: it had no interaction. In terms of VR, Sensorama lacked interactivity, which is a crucial component of the experience. During this experience, players can feel the vibration of a seat, a 3D view, the smell of a city and even the wind on their faces. In contrast, Morton Heilig published his paper "The cinema of the future" in 1955; he described a concept for a three-dimensional movie theatre that would provide a VR experience. The Sensorama was an interactive three-dimensional device based on Heilig's design, which was presented later on in 1962, providing the user with an immersive three-dimensional experience based on his design. It can be used in different fields such as relationships, education, psychology research and psychotherapy. In the early 1980s, NASA developed Virtual Visual Environment Display (VIVED), which enabled all characteristics of virtual reality: interaction, immersion, and imagination. A number of XR devices have been introduced as VR, including EyePhones, Data Gloves, and Data Suits. VR headsets such as EyePhone were among the first to be commercially available.

Figure 1. The Sensorama Simulator of Morton Heilig (M L Heilig, 1962)

According to Martn-Gutiérrez et al. (2017) and Radianti et al. (2020), virtual reality (VR) refers to a simulated reality created with computer systems and digital formats to produce a realistic, immersive experience. VR is defined as hardware and software systems that aim to produce an all-encompassing sensory illusion of being present in the virtual environment. the virtual reality (VR) simulation of a 3D image or environment that uses specialised VR equipment, such as VR Headsets, to allow interaction that appears real or physical. Since the 1960s, this technology has been in trouble. However, with the current advent of VR technology, the road to success for virtual reality (VR) in education and training has recently been paved. Academics anticipate that interest in virtual reality will last a long time given its benefits over traditional learning environments. This circumstance thus highlights the necessity for resources to fully address VR technology. The technology of Virtual Reality (VR) has evolved dramatically over the years by reducing its form factor while increasing its features and power. Moreover, The social distancing rules that were put in place during the COVID-19 pandemic (2020-2022) forced people to study and work from the comfort of their own homes, causing them to feel isolated. Current technology has the capacity to afford a virtual experience that challenges the notion of a teaching laboratory for undergraduate science and engineering students. A result of this fatigue is an increase in demand for reduced digital distances between people, as well as richer visual environments for online communications, which emerging technologies, including extended reality (XR), promise to achieve.

In the professional education and training sector, there has been a dramatic rise in interest in VR over the past few decades, which was followed by the introduction of VR in higher education in the 1990s with projects such as ScienceSpace Worlds, Safety Worlds, Atom Worlds, etc. (Soliman et al., 2021). Even though the technology was developed in the 1960s and numerous scientists worked to create various versions of VR since then, none of them could be used for practical reasons at an accessible price, unlike the Oculus VR gear. The goals of this study will be able to describe VR and explain the evolution of XR technology historically in this way. The usage of VR in classrooms and research facilities during pandemics will then be covered.

Virtual Reality in Education

Since the 1980s, VR has been used for educational purposes, and this technology has been used as flight simulator, particularly for aviation instruction. Early in the 1990s, VR technology was used in formal educational settings, including primary and secondary schools. Unfortunately, for a variety of reasons, virtual reality was not widely used in classrooms at that time (Fransson et al., 2020).

Aside from being more widely available, VR gadgets now have more distinguishing characteristics, such as interactivity, artificial sensory stimulation, physical and mental seclusion, and communication tools. In addition, VRE consists of interactive computer simulations that recognise the user's position and activities, alter or amp up the feedback sent to one or more senses, and offer a mental enclosure or sensation of being (Sherman & Craig, 2019). Immersion, a term used to describe the experience of being in a virtual environment, is now used to describe VR (VE). The goal of sensory containment is to use technology to artificially excite the body's senses. The concept of telepresence, which aims to give one the impression that they are in their environment, is comparable to the idea of mental containment. For consumers to feel encircled, sensory feedback must be present in VR equipment. Simulation methods are used to build virtual environments. Users are submerged in virtual worlds while using simulation techniques, which trick their senses into creating an impression of an alternate reality in the brain. Perceptual signals come in a variety of forms, including audio, visual, tactile, scent, and motion stimuli. Since then, a lot of authors have utilised VR as a platform to serve a range of industries, including training and education (Bogusevschi et al., 2020; Mulders et al., 2020).

Although virtual reality (VR) is not a new technology, academic interest in it has grown recently as a result of the advancement of virtual reality equipment in terms of interaction and perception. In other words, technology is now acceptable for both extensive civilian use and instructional reasons (Kugler, 2021). Virtual reality (VR) is a computer-based technology that can help professionals in training put their theoretical knowledge to the test. Trainers and vocational school teachers will need to develop appropriate training modules for trainees so they can learn with VR. With the help of existing VR training courses, the participants should also learn how to use them in the classroom and practical instructions. The integration of the 3D simulations is intended to expand the possibilities for the trainees to acquire technical skills. It costs a lot of money and space to build up learning sets for various courses or subjects. This gap has been filled by using virtual reality to develop customised course material that is tailored to each learning environment. The technical capabilities and accessibility of VR equipment have significantly improved nowadays. The barriers to using VR for education have also been eliminated as a result of this situation.

Nowadays, VR has used for educational purposes in many different disciplines, such as preschool education (Bailey & Bailenson, 2017), higher education (Radianti et al., 2020), science education (Radianti et al., 2020), social skills development training programs (Howard & Gutworth, 2020), primary education (Innocenti et al., 2019), and special education (Nuguri et al., 2021) are some of these areas. VREs for educational purposes have gained popularity due to their advantages over traditional learning environments. For example, the advantage of a virtual laboratory is that creating a VE is generally less costly (A. J. A. Alnagrat et al., 2021). We can simulate a variety of studies using VR. Additionally, multiple students can collaborate in the same VE at once. In terms of safety, VE damages are also virtual and do not result in any monetary loss. Users can therefore make mistakes in these environments and learn from them without running the danger of getting hurt. In order to execute tasks that are challenging or unsafe to perform in a regular classroom setting and to visualise the learning process, VR has the potential to facilitate learning (A. J. A. Alnagrat et al., 2022d).

In this digitally advanced era, virtual reality is considered to be a critical learning aid that enhances learning (Leong et al., 2018). It is essential to analyse the key factors behind the learning paradigms and VR in order to authenticate the connection between them. Some of the most important factors include behaviourism, cognitivism, constructivism (Schunk, 2012), connectivism (Siemens, 2014), and experientialism (Kolb & Kolb, 2012).

Virtual Laboratories

The use of distance learning and open universities in education is now becoming more widespread. As a result of the subject domain nature of Science, Technology, and Engineering, the teaching of these subjects remains somewhat behind when it comes to utilising new technological approaches, especially online distance learning. There is a discrepancy between these two fields because these fields often require laboratory exercises to acquire skills and provide hands-on experience. These laboratories are often hard to access online. The real lab has to be made accessible from a distance by enabling remote access, or it has to be replicated as a software-based virtual lab that can be accessed remotely.

We have seen a number of new ideas appearing in the literature recently regarding the future of education, especially the teaching of Science, Technology, and Engineering (STEM). Several of these notions are new, while others are reimagined ideas that were previously thought of in a different way. There are a number of technological examples relevant to this study, including distance learning, e-learning, virtual labs, VR and virtual worlds, avatars, dynamics-based virtual systems, as well as an overall new concept of immersive education that integrates many of these ideas together. ICT advances and the current pandemic caused by COVID-19 have profoundly changed society and the economy in most parts of the world. In response to this technological change, virtual laboratories (VLs) that use VR have emerged and are used in a variety of academic and professional training programs to facilitate the teaching-learning process. There are a number of advantages that are offered by this type of virtual learning environment, of which the main advantages are listed in this article, which has made its use increasingly common as a support for engineering classes at universities.

Nowadays, engineering laboratory courses play a very important role in building practical knowledge on the part of the students and enhancing skills on the part of the students. A student's experience in an engineering laboratory is one of the most crucial elements in their understanding of concepts and strengthening them through the practice of these theories. There is no doubt that laboratory experience plays a significant role in the development of the student's knowledge and abilities (Kapici et al., 2019).

The student is required to operate sophisticated hardware and software tools in engineering laboratories in order to perform practical experiments. Since engineering institutes maintain busy academic schedules, students have limited access to laboratory equipment. Students are limited from working on laboratory hardware because of the cost of purchasing and maintaining the complex hardware(Angulo et al., 2018). It is possible to engage students through virtual laboratories and give them a similar experience to visiting a laboratory facility. Furthermore, traditional teaching methods lack interactivity, which prevents students from actively participating in their learning. Indirectly, this influences the student's performance, thinking level, technical skills, and expertise (Akçayır et al., 2016).

Some authors have also suggested that immersive and interactive learning experiences can be provided by VR. In addition to offering a technologically supported instructional approach, VR techniques have a great impact on student engagement. Transformer operations can be visualised and understood using a VR-based learning tool. Engineering students are trained in virtual maintenance and operations of an electric power substation transformer using a VR-based system. In addition to demonstrating how the equipment works, VR systems provide more clarity on theoretical concepts as well. As a result of the virtual laboratory, students have been able to visualise molecular symmetry concepts more clearly and have improved their spatial abilities. Chemical engineering students can practice using an interactive three-dimensional (3D) virtual practice system developed by (Ouyang et al., 2018). By using the virtual practice system, the user can take a virtual walk through a chemical plant, engaging with the equipment in the environment and virtually walking through it. There is a wide range of applications for the system, which can be provided to students in order to provide them with perceptual training about the production plants without allowing them to go inside and operate or handle the equipment.

Virtual laboratories (VLs) are generally accepted and demanded by students, who consider real laboratories (RLs) to be essential for face-to-face teaching. As a result of COVID-19, hybrid teaching and learning models combine face-to-face teaching and online learning. Online teaching and learning are expected to coexist in education post-COVID-19. It has been several decades since VR-based resources were introduced into the teaching and learning process. However, some studies suggest that this type of technology is not being fully utilised. There have been countless articles analysing the advantages VLs present from an educational perspective(Vergara et al., 2017). It is a very inexpensive investment compared to the cost of setting up a real laboratory, and they do not require any maintenance costs to keep them running, although they do require periodic updating(Balali et al., 2020).

Prevent potential damage that can arise from the misuse of a real machine. There is a need to reduce the amount of space occupied by large equipment installed in real laboratories. Taking care to avoid problems or accidents that may occur in training conducted in real-life settings, such as for example chemical reactions and firefighter training (Achuthan et al., 2018; Narciso et al., 2020). Students are encouraged to watch the instructor's explanation at their own pace so that they become familiar with the explanation at their own pace. As a result of their interactivity features, zone transparency, zooming in to see more details, changing the execution speed of a task to examine certain details or obtain related insights, and so on, they provide a variety of options that facilitate the teaching and learning process (Vergara et al., 2018).

Some argue that VR labs provide a better learning experience than traditional classrooms (Winkelmann et al., 2020), while others believe that the learning experience is at least equal. In addition, the universities will gain an edge in terms of their international offerings and use of technology by being affordable and as good as the physical laboratory. Due to its cognitive and learning benefits, VR is an effective tool for engineering education via blended learning rather than a traditional approach.

Virtual laboratories should be assessed in terms of their impact on the effectiveness of the studied science. In addition to taking into account the structure of the assignments and the delivery method of training materials, it also takes into account the availability of methods for finding and monitoring the needed information, as well as the organisational features of the learning process generally. The use of multimedia e-pedagogical software is known to enable automated graphic, and complex design works to be performed(Soliman et al., 2021). The benefit of using pedagogical software is expected to make teachers' teaching ideas more effective by formulating, analysing, applying, and evaluating them in relation to the curriculum they are teaching.

A great deal of emphasis is placed on the importance of laboratories in science education because of the rich benefits of laboratory learning. In science education, lab sessions are critical because students are actively engaged in the process of inquiry and investigation (Hofstein & Lunetta, 2004). It has been shown by Baldock and Chanson that combining problem-based and project-based learning through lab work has resulted in students being able to prepare high-quality professional reports in the area of fluid mechanics through the use of problem-based and project-based learning techniques.

There are a number of drawbacks for an institution when it comes to physical activities such as lab experiments, such as safety (liability), infrastructure, and capital when it comes to those activities. In order to ensure that lab experiments are conducted in a safe manner, each institution must place a high priority on the safety of its students. As a matter of fact, lab activities are limited by the availability of infrastructure at the university, which means that universities that do not have adequate tools, space, or budgets will not be able to offer their students enough laboratory time. There is a consensus within the United Nations Task Force on Habitat III that student learning at universities is undermined due to: "safety factors, inappropriate infrastructure and equipment, and restrictions in terms of time and space availability."

In the article (AlAwadhi et al., 2017), it is stated that dangerous mistakes in “chemical interactions and electrical experiments” can result in serious injuries, as well as the fact that expensive materials can pose a barrier for some institutions. As a way to overcome these obstacles, (Alnagrat, A. J. A., Ismail, R. C., & Idrus, 2021)suggest that VR can be employed in the creation of Virtual Laboratories in order to enhance the learning experience and knowledge for students. Additionally, in order to provide the best possible learning experience for students when space and resources are limited, it is imperative that education providers continue to explore new methods of teaching in order to provide the best possible learning experience. It is possible to use VR to provide full-time on-campus students with an education and learning experience that is as close as possible to that of distance learning students(Makransky et al., 2021). Furthermore, this can give a university that adopts a VR lab an edge over its competitors and attract more distance-learning students. Distance learning students face additional financial obstacles due to the cost of high-end VR equipment and the setup process. Students learning experience, cognition, and pedagogy are enhanced by VR labs, not only for the university or institution. Several research papers using VR applications/labs demonstrate the potential and excellence of this technology.

Researchers (AlAwadhi et al., 2017) examined multiple research papers on virtual labs in engineering education and developed an interactive virtual lab that allows students to interact with the equipment in a safe virtual environment and conduct experiments. As a supplement to traditional classroom instruction, the prototype was called Virtual Electric Manual (VEMA). Electrical Circuit Theory was practised in a safe environment, where mistakes did not harm students or assets. Various learning theories were used by (AlAwadhi et al., 2017) including inquiry-based, passive, active, synchronous, and asynchronous approaches. As a result, VEMA can be used in distance learning to close the gap in education quality for distance learning students in a very cost-effective manner.

Virtual Laboratory during the Covid-19 Pandemic

Engineering students are able to effectively understand engineering concepts when they conduct experiments in the laboratory as part of their studies. As a consequence, the laboratory is just as important as theory; however, the ill-equipped laboratory facilities negatively affect the student's ability to learn. Having virtual laboratories may prove helpful to the students in overcoming the problems that they face when they are working in a conventional laboratory. As a result of the COVID-19 pandemic, colleges are closing for students, which inevitably causes a problem in completing laboratory experiments due to the closure of colleges due to the teaching of theory classes online. The feedback received by the participants of this virtual laboratory training programme has been analysed based on the feedback given by them. It has been found that, on the basis of the analysis, more than 90 per cent of the participants were satisfied with the virtual laboratory and expressed an opinion that the virtual laboratory experiments enabled them to improve their learning process. In addition, they felt that the virtual laboratories could be used until the COVID-19 pandemic issue was resolved. It is important that students understand science topics effectively by performing laboratory experiments, which is one of the reasons why laboratory experiments are integral to the science curriculum. This program teaches students practical problem-solving skills, improves students' working habits, enhances their ability to understand practical problems, and improves their attitudes toward education through the use of concrete materials.

Traditionally, the laboratory is a procedure where students conduct experiments as per the laboratory protocol, prepare reports, analyse data, and interpret the results of their experiments. The students are able to improve their observation skills and their ability to analyse results as a result of this practice. A laboratory is one of the most important elements of engineering education and plays a key role in allowing students to understand theoretical concepts, teamwork, observation capability, communication, and analytical skills, among many other things (Alnagrat, A. J. A., Ismail, R. C., & Idrus, 2021). In addition, it is helpful for the students to understand how hazardous materials are stored and handled, safety guidelines and safety labels(A. J. A. Alnagrat et al., 2022a; Artdej, 2012). There is evidence that students are more likely to conduct experiments effectively if they have knowledge of the experimental procedure and setup (Attanasi et al., 2022). Consequently, the use of virtual laboratories is considered an effective method to conduct experiments during the period of complete closure caused by Covid-19. It is important to highlight the fact that VR technology can be used to operate virtual laboratories in order to conduct experiments safely.

Virtual Reality Learning Environment for Enhancing Laboratory Experience

Students enrolled in engineering programs face many challenges as they seek to gain the necessary practical experience. In the past few years, the shortage of resources (capital and operational), the increase in engineering students, and the need for safe, up-to-date laboratory experiences have become global concerns. Virtual laboratories (VLs) have the potential to provide some relief, but more pedagogical research needs to be conducted within the engineering curriculum in order to provide some benefit.

In higher education within engineering, students will be required to undertake extensive laboratory experience in order to acquire technical competencies, apply practical knowledge to new concepts about the processes and techniques involved, and acquire technical competencies. In spite of this, due to economic and logistical constraints. In many cases, laboratories are treated as isolated exercises with limited variables, but the development of concepts requires exposure to a wide range of variables in order to be fully developed. In addition, the COVID-19 pandemic has had the unfortunate consequence of causing 87.9% of educational institutions worldwide to close, which in turn has made it even more urgent to offer online education. The positive impacts of using VR in education are undivided attention in learning, enhanced creativity of students, teachers' skill level improvement, and easy retrieval of learned theories.

There is nothing wrong with traditional classroom learning. However, in the old-fashioned classrooms, students get bored and tired of learning the theory content of the books, as the same method of black-and-white learning is followed throughout the year. The introduction of a novel virtual learning environment, such as VR, into classroom learning would bring students' undivided attention to the subject in the classroom (Elkoubaiti & Mrabet, 2018). Previous studies have shown the use of VR in the classroom enhances students' creativity (Elmqaddem, 2019). Students are able to explore and apply new ideas in several domains through applied learning, which promotes their learning and increases their creativity.

The virtual system is a cost-effective way for schools and universities to organise high-quality laboratory work in Science, Technology, Engineering, and Mathematics (STEM). The ability to create different virtual (simulation) experiments using a variety of components (virtual apparatus) that are easily customisable. There is a possibility of multiple users accessing the same virtual equipment at the same time. An example of this is the possibility of changing the configuration of the system: it is possible to modify details that are often not changeable in a real system.

In virtual worlds, "damage" is allowed, which allows for mistakes to be learned from. In most real lab devices, there is a cover to protect them from dust, etc., and the covers cannot be removed easily, at least in most cases. In virtual equipment, covers can be removed or made transparent to reveal the inner structure. When it comes to education, the implementation of a Virtual Laboratory has some advantages over a real laboratory installation since the latter could have a limited amount of materials that can be used for practice, while occasionally the teacher is the one who is working, and students do not have much opportunity to interact with the tools and the equipment other than observing. Furthermore, depending on the risks associated with laboratory practice, feedback may be required, which is not needed for a virtual laboratory. Therefore, the Virtual Laboratory could be considered a cost-effective and fully controllable educational tool that would allow students to practice repetitively and in an easier way, leading to self-learning, understanding of real-life challenges, and the development of engineering skills as a result of this practice. As a result, Virtual Laboratories become fascinating and attract students' attention and participation.

In VR, teachers can practice time management, student management, and engagement in the classroom before they attend real-life classroom sessions, and it's evident in the studies using VR to avoid the mishaps which occur in the regular classroom while handling the subject and preparing themselves to handle such calamities (Dong, 2016). A study conducted by Dong (2016) found that 90% of information is stored in the human mind through physical movements, not hearing and listening. There are various applications of VR available today, including the ability to interact with virtual 3D objects and the ability to store knowledge in the human mind and retrieve it at a later time.

Virtual Reality Increases Learning

In the learning and instruction field, it is important to examine whether VR can be used to enhance the motivating effects of simulated labs. In particular, one area in which immersive VR may be of particular value is in the design of virtual learning simulators, a field where immersive VR can be of great benefit. By allowing users to manipulate objects and parameters in a virtual environment, virtual learning simulations are able to replace or amplify real-world learning environments by replacing or amplifying real-world learning environments. There has been a long history of science labs being used in science education for many decades. In light of this, it is reasonable that advances in computer-based learning will include the development of computer-based simulations of science labs and learning experiences(Al-Amri et al., 2021; A. J. A. Alnagrat et al., 2021). In the context of science learning, computer-based simulations can be used to promote procedural knowledge for performing lab procedures as well as conceptual knowledge for understanding and explaining demonstrations in a way that can enhance procedural knowledge. However, the effectiveness of simulated scientific environments as a tool for teaching science is yet to be determined, which means that further research is necessary (A. Alnagrat et al., 2022; Council, 2011).

Numerous studies have been conducted on the application of VR in various learning settings. These studies assess the impact of VR on learning outcomes as well as affective elements like motivation and fun (Albus et al., 2021; Makransky & Petersen, 2021). Research has discovered that the usage of VR boosts students' levels of motivation and significantly affects learning. However, it may be said that this predicament applies to all modern technology. No single piece of technology is anticipated to boost learning on its own. A proper instructional design process is a requirement for technology to have a good impact on learning outcomes.

Human-computer interaction (HCI) has been transformed in recent years by VR technologies, offering new and unique perspectives on training and education. VR provides a sense of immediacy and control through its immersive display allowing the user to enter a simulated environment that looks and feels, in a sense, to a certain extent, like the real world, giving the user a sense of immediacy and control. The rapid advancement of technology in the last decade has had a significant impact on HCI. There have been a number of attempts by the education sector to make use of it to its advantage since it, too, has realised its significance. In turn, this immersion engages the user in the experience in a way that enables them to focus on the subject to its fullest extent, therefore improving their learning outcomes. The advantage of this approach is that students are able to observe phenomena that may otherwise be unobservable, reduce the amount of time required for experiments, and receive adaptive guidance in a virtual world where they can feel a sense of physical, environmental, and social presence(A. J. A. Alnagrat et al., 2022a; Makransky et al., 2017). In order to enrich the quality of education, various technologies have been introduced to enhance the learning, engagement, and assessments of students (Rehan et al., 2016). As one of the key priorities for educational systems across the world, motivating students to learn effectively plays a critical role in ensuring that learning takes place effectively. It has been shown that some empirical studies and meta-analyses have shown that low-immersion simulations have a positive impact on cognitive outcomes and attitudes toward learning in comparison with more traditional teaching methods (A. J. A. Alnagrat, 2022).

Because traditional teaching methods won't be adequate for this generation's education, the utilisation of cutting-edge technology like virtual reality in the classroom is essential (Chan et al., 2022; Jamah et al., 2022). Although the needs for learning today are the same as those of earlier generations, it is fair to conclude that students' expectations and interests have changed. For this reason, especially in light of the benefits of VR compared to conventional learning tools and the fact that motivation is one of the most significant determinants of learning. Utilising cutting-edge technologies in educational settings, like virtual reality, will also improve students' motivation and learning outcomes (Georgiou & Kyza, 2018). The literature review then looks at the software and extras that could be required to create a VR application, as well as the instructional design approach that VR needs in order to deliver the desired educational outcomes.

Virtual Reality Environment for virtual laboratories Opportunity and Challenges

Despite all the great possibilities, there are some negative impacts of using VR in education, such as Cost, Device, Teacher Readiness, and Sickness. In VR technology, the cost is an influencing factor, where the implementation of complete VR hardware is not affordable for most people. The stakeholders have to invest a lot of money in transforming an education laboratory into a VR lab. The fact that such a huge sum of capital has been invested does not mean it can be operated by experts with deep technical knowledge.

There are several VR devices on the market; finding the right VR device for each tailored learning environment remains a challenge. Both hardware and software have limitations. Hardware and software may not meet all the needs and requirements of one classroom (Samadbeik et al., 2018). Due to the fact that the technology has not grown to its fullest potential, where there are changes in the hardware and software of VR, it is still troublesome for teachers when it comes to adapting to one specific device and software. In order to integrate VR into classroom learning, trainers need to be trained in the hardware and software necessary to convert traditional classrooms and labs into VR-enabled classrooms. It is quite challenging to train teachers from non-IT backgrounds who have no prior experience in IT.

One of the major drawbacks of VR devices is visual fatigue. During and after virtual learning, students and learners have experienced motion sickness. There is a difference between the visual display of the real world and the virtual world that causes this visual discomfort. It is due to visual fatigue that problems with focusing, far vision, and near vision are created. As a result of motion sickness, you may feel sleepy, nauseated, or dizzy (Nolin et al., 2016).

Furthermore, VR technology is new and constantly evolving, and there has not yet been a saturation point reached. In fact, there are so many opportunities that researchers can explore to work in the field of virtual reality and, more specifically, virtual laboratories in education.

Immersion and Presence

It is one of the most important features of a VR experience, and it is often referred to as Spatial Immersion and is essentially a sense of being or presence in the virtual world which is achieved by disconnecting the user from the physical world and giving them a sense of presence in the virtual world. It is important to note that immersion and presence are two different things, contrary to popular belief. It has been explained (Slater, 2003) that the difference can be explained through a human's perception of colour, where colour perception differs from human to human (presence), but that a particular colour has a wavelength that identifies it (immersion). During a VR experience, people may be able to experience a variety of levels of presence based on the same immersive experience, similar to the colour example described earlier, and this is called "human reaction to immersion".

The level of presence is therefore related to how much of the five sensory modalities are active, which are activated by the physical properties of the virtual environment as well as how closely it resembles the real world, commonly referred to as immersion. In contrast, immersion cannot be defined by a system's physical dimensions or properties; rather, it is defined by the user's response to a narrative or event; instead, it is based on the interaction between the user and that event. In other words, immersion is the result of the brain's indulgence in the narrative to such an extent that it transports us from the physical environment to the virtual environment due to our brain's focus on it (Murray, 2017). It has been shown that there are different levels of immersion and that the system does not have to possess a perfect level of photo- and audio-realism in order to be immersive; rather, the narratives have been developed to align the user's expectations and actions to the conventions of the virtual world to ensure that the user experiences an immersive experience. It has been found that the term presence is often misunderstood, and its meaning depends on the academic discipline in which it is used (Wirth et al., 2007).

The term spatial presence is more appropriate to them because it closely matches the experience of being present in the virtual world that is closely associated with VR. Furthermore, they argue that spatial presence can also be achieved by closely replicating the real environment visually as well as auditorily, as well as by psychologically involving the users through the activation of their senses modalities to create a sense of presence.

Taking into account all of these arguments, we can conclude that the VR application needs to utilise a variety of sensory modalities in order to engage the user, such as stereo sound, stereoscopic vision, realism, a large field of view, a high frame rate (FPS), and head tracking, so that they can become immersed in the virtual world as well as transport themselves from the real world to the virtual world. The narrative elements should also be designed to set users' expectations and align them with their actions, as well as the conventions of the virtual world, to maximise the immersion of the user.

Design Model

When designed and built with an effective strategy, VREs are more efficient. The appropriate design model must be chosen in order for the VRE to function effectively. According to many studies, choosing the appropriate design model is the most crucial step in producing successful VREs (Sattar et al., 2020; Vergara et al., 2017). Designing virtual reality environments requires researchers to use a variety of techniques or models. Because VREs may totally disconnect the learners from their environment, they are more dynamic and inclusive than desktop learning environments, distant learning environments, or traditional educational environments (Chen & Teh, 2013; Ip & Li, 2015).

In this context, the instructional design models may be insufficient in the process of designing these environments (Vergara et al., 2017). In this regrade, researchers have developed design models that have been addressed from many different perspectives (Chen & Teh, 2013; Geris & Özdener, 2020). The right model that can be used to design suitable VREs is shaped following the design-based research methodology within the scope of their studies on VREs. As a result of this, researchers who revised the analysis and design steps of the ADDIE instructional design model tried to address the initial stage of the model development process with new questions they added to these steps (Castronovo et al., 2019).

The ability of the human body to appropriately grasp the equipment to be used and to give the most engagement and learning through this equipment is crucial for the design of VREs (Goodwin et al., 2015). Researchers proposed a five-stage design method that included an appraisal of the lesson plan. Publication and evaluation of the learning environment, implementation of instruction, analysis, evaluation, and revision of learning outcomes, including the selection of tools, technologies, and settings, inclusiveness of the learning environment, use of artificial tutorials, and facilitation of active learning (Ou et al., 2019; Radianti et al., 2020). The developed design models also had a number of design-related technical problems. Indeed, they are addressed from various angles and emphasise various steps.

The researchers' models' least discussed problems are that the environment's development process does not devote enough attention to technical problems and ancillary units. According to the design models in the literature from an educational, design, and technical perspective, design models are based on students and learning activities, and technical difficulties and ancillary components are not given enough importance (Balzerkiewitz & Stechert, 2020; Geris & zdener, 2020). These concerns should be taken into account, though, because VR, by its very nature, has a surrounding feature that can be enhanced with the correct peripherals and technical research.

Development and Applications

During the development phase of the VRE, modelling and coding studies should be performed correctly to get an effective model. Researchers emphasised the importance of titles such as reality, fidelity, presence, enclosure and interaction when they discussed VREs from a technical point of view (Grajewski et al., 2015; Makransky et al., 2019). It is stated that the first of the indispensable elements of an effective VRE is a real level of the environment (Cho et al., 2021). Learning can be done in the virtual world, and the VRE has a greater impact on the learner, the more realistic it is. The similarity of the objects to their originals is a further factor to take into account. How true to the originals the artefacts are is another crucial consideration. When an object closely resembles the genuine thing both physically, and in terms of response and interaction, this is known as fidelity. The efficiency of the learning process will be positively impacted in this regard more realistically, and faithfully the learners engage with the VRE's aspects.

The state of existence means that individuals detach from real life and find themselves in completely virtual states of feeling in real environments. Although the peripheral devices currently in use are equally crucial, the created platform's advantages in terms of fluency and error-freeness also come into play. The effectiveness of the environment is also significantly influenced by how the participants engage in the VRE. One aspect that can directly impact a VRE's success is its capacity to offer character-object and character interactions. Using the appropriate software that can combine these components is the key to giving crucial elements like realism, authenticity, existence, and interaction in the VRE. With the proliferation of VREs, more platforms are being developed to construct these environments in addition to the appropriate software. For researchers and designers looking to create a VRE, there is a wide range of options available. Some of the software that can be used for environment design is described in this section.

Online Platforms

There are online platforms that researchers can use over the internet to design their own environments and support VR, such as Second Life, InstaVR, Steam, Wild, Hub and PartySpace. Second Life platform provides VR support through an online platform that allows researchers to design their own environments (Uribe & Dillon, 2022). InstaVR platforms can create a 360-degree VR-supported image of a city, region or place with Google Tour, While Steam platform with ready-made VR applications held around 75% of the market share for PC gaming digital distribution platforms in 2013. It is a digital distribution platform that provides video games to PCs and consoles. Wild is a virtual augmented reality platform that uses virtual and augmented reality to help architecture, engineering and construction (AEC), design, and enterprise teams come together to make better decisions by experiencing their work together in a shared virtual collaborative environment. With Hubs, you can create web-based rooms to meet and interact with others in Mixed Reality. Party space is an interactive 3D virtual event platform. Our clients compare events on PartySpace to their favourite online games but from a single browser tab.

You may design the greatest virtual area for drawing in your audience with the aid of a wide range of user-friendly 3D virtual spaces and robust customisation features. In order to create the greatest VR presentation software, Yulio wants to make VR a portable and cost-effective tool for enterprises. You may make spectacular immersive presentations and elaborate on your visual storytelling with robust customisation capabilities. Facebook Spaces is a virtual reality (VR) application that allows users to communicate with one another as if they were in the same room. The app encourages social interaction amongst friends by utilising 3D avatars. Breakroom, a fully customised 3D environment created for all your virtual needs, is the next step in the evolution of digital collaboration and interaction. The designer may design the virtual area to draw in the audience with the aid of a wide range of user-friendly 3D virtual spaces and robust customisation features. In order to create the greatest VR presentation software, Yulio wants to make VR a portable and cost-effective tool for enterprises. You may make spectacular immersive presentations and elaborate on your visual storytelling with robust customisation capabilities. Facebook Spaces is a virtual reality (VR) application that allows users to communicate with one another as if they were in the same room. The app encourages social interaction amongst friends by utilising 3D avatars. Breakroom, a fully customised 3D environment created for all your virtual needs, is the next step in the evolution of digital collaboration and interaction. The new world of work is not the 2D video conferencing hell you've been trapped in. It is an immersive digital experience that empowers connection, collaboration, and communication. Arthur currently enables your organisation to meet and collaborate in VR. It helps organisations improve remote productivity using a diverse set of productivity tools.

The infinite office space can be accessed flexibly from anywhere, leading to possibilities beyond the capabilities of even physical offices. The Unity software could well be considered an industry-standard in VR production (A. J. A. Alnagrat et al., 2022a). With the widespread use of VR tools and the relative decrease in costs compared to previous years, the number of studies in this field has also increased (Brown & Green, 2016). It is becoming increasingly common to find low-cost VR hardware. Currently, Virtual reality hardware and software options are available right now that are inexpensive and easy to use for educators. Students can gain experience and develop expertise in designing and creating VR presentations in the classroom using these low-cost or no-cost VR options. VR presentation and production software are available for free to educators and students. The technology for immersive VR is easy to use and durable enough to endure the rigours of a classroom because it provides you with a low-cost, easy-to-use way to get started. Google Cardboard is one of the most inexpensive VR viewers, allowing pretty much any smartphone or phablet to be turned into a VR viewer at a very low cost. For example, Google offers 3D cardboard for less than $10. You can even experience VR through YouTube with your phone and cardboard, as shown in Figure 2.

Today, VR is easily accessible and affordable through a cardboard head-mounted display (HMD) called Google Cardboard, which is sold by Google and can be constructed by anyone. Basically, (Nurbekova et al., 2022) claim that these commercialised high-end VR systems are always tethered to a high-end PC, which is what makes them capable of delivering high frame rates, providing attractive environments, and supporting different options for user interaction. The issue is that they are restricted to the vicinity of the PC and need a lot of processing power, which makes them rather expensive to run because of how much electricity they consume. In addition to VR headgear, there are VR-ready mobile devices (smartphones) that, because of their reduced processing power, provide a lower VR experience for a far lower price (Jamah et al., 2014; Knapova et al., 2021). The user can also take advantage of a significantly larger degree of movement throughout the VR experience thanks to the wireless (no cable) connection. In general, high-end VR HMDs operate at a higher level of immersion than their low-cost competitors, which is reflected in their capacity to deliver a more immersive experience.

Figure 2. Using Cardboard to Experience VR

Modelling

Virtual reality environment developers need to be aware of a number of factors. The construction of the environment programming infrastructure, the development of the infrastructure necessary for the environment to function, and the modelling of three-dimensional objects to be used in the environment all come first. The products that will be used in the virtual reality environment must be chosen when the researchers or designers have created their scenarios for it. The ability to programme the intended usage of the objects has a significant impact on the development process. How effectively things are portrayed in three dimensions significantly affects how realistic and authentic a virtual reality environment seems.

At this point in the project, it is important to decide in advance how the object will respond to events in the real environment, as well as how the thing will seem from all sides. Through the use of effectively modelled and transferred to the VRE objects, the environment's efficiency can be raised. The significance of the software to be utilised in the modelling phase must now be mentioned. Currently available software for creating three-dimensional models includes Autodesk Maya, Autodesk 3DS MAX, Zbrush, Blender, Houdini, etc. (Hendriyani & Amrizal, 2019). Designers can utilise the aforementioned programme or a comparable one to accomplish their goals.

The development platform is now another critical concern. Both three-dimensional design and virtual reality (VR) should be supported by the development platform that will be used to model a VRE. Though this capability can be added via plug-ins, and some platforms do directly support VR devices, not all of them have a three-dimensional layout that supports VR settings. When choosing the development platform, researchers need to consider VR support and three-dimensional design (Oh & Nussli, 2014). Unreal Engine is one of the platforms that allows researchers to create three-dimensional models and employ the VR feature. Real-time rendering, a multiprocessing interface, and customised menu options are all provided by Unreal Engine for designers (Bock & Schreiber, 2018). Apart from the interface options, Unreal Engine allows source coding in C++ and Python languages, and it is possible to find ready-made elements such as animation, sound, simulation, and effects in Unreal Engine, which also supports three-dimensional design elements. In addition to these features, the platform supports the use of VR equipment developed by Oculus, Sony, Samsung, HP Reverb G2, Oculus Rift S, and HTC Vive Pro (TIAN, 2019).

Another of the most preferred platforms by designers and researchers that support three-dimensional modelling is the Unity platform. With its advanced editor structure and interface, Unity is a platform suitable for use by users of all levels (Foxman, 2019). Unlike other platforms, it has a very wide add-on structure and educational content. The platform, which enables source coding in C#, also allows multiple designers to work together online on the same project. The platform, which presents the virtual reality infrastructure to the users without the need for any add-ons, also supports multiple three-dimensional file types.

Peripherals

Peripherals, namely VR equipment, have a very important place for the person to fully enter the environment, explore the environment effectively, to interact with objects and characters in VREs. The most basic part of the developed peripherals is the VR glasses. The only way to be included in the developed environment is to use these glasses. In addition, other peripherals used are defined as control devices, stations, and wearable technologies (gloves, sensors, etc.). There are many VR glasses and other peripherals developed in different types but using the same system as the working logic, such as Oculus Rift, Oculus Quest, HTC Vive, Playstation VR, Samsung Gear VR, Nintendo Labo VR, Lenovo Mirage Solo, Valve VR, HP Reverb, and Google Daydream View.

When we examine the technologies more closely, we can observe that there are many platforms and development tools for VR. As a result, numerous applications have been developed. There are apps that can be used with Cardboards or that can only be viewed through VR goggles, as well as apps that can be used with controllers and wearable technology. When VR applications are seen from this angle, it becomes evident that there are numerous educational applications for teachers and students available on many platforms. Several applications, for instance, are made for modelling the human body and teaching science and medicine. Similar to this, there are programmes that provide students with a virtual laboratory experience and VR programmes that enhance their creativity and engineering abilities. Through applications created to be utilised in history and literary classes, social science applications also give users access to various historical eras and geographic locations.

In addition, to use many VR applications with in-depth content, VR head-mounted glasses are required. It is believed that every student and educator may have access issues, given the price of relevant technologies. At this point, it will be feasible to enhance the predominance of applications that are designed in line with both low-cost VR technologies and head-mounted VR glasses.

Hardware

In the field of entertainment and computing, researchers and innovators have worked long-term to create devices that enable XR-experiences (Stanney et al., 2021).In order for an immersive experience to be achieved, there must be a minimum field of view (FOV), refresh rate, and resolution. In order to provide an immersive virtual experience, optics advances have made it possible to provide a FOV that is wide enough to cover the entire area the user can see. The sense of immersion is immediately distorted if the user can see the VR headset frame instead of the virtual scene. A sense of immersion is also created by tracking the user's head movement and adapting the perspective accordingly.

There are two types of user movement tracking systems: internal and external. Users can play twice as much with external tracking systems as they can with integrated tracking systems. A recent development in display technology has led to lightweight, high-resolution units capable of displaying realistic graphics(Morimoto et al., 2022). The HMD is now referred to as a VR headset since it combines optics, displays, tracking devices, and speakers to provide an immersive VR experience. VR headsets can operate without a PC or as an accessory connected to one. A headset connected to a PC can use high-end graphics processors as well as wired or wireless connections. The user can move freely within the limits of the play area with wireless VR headsets without having to worry about hanging cables. Varjo XR-3, which was released in 2021, enables a high-resolution wide field of view augmented, virtual, and mixed-reality experiences(Goedicke et al., 2021). Experiencing extended reality is most affordable with mobile phones and tablets. A mobile device's built-in camera and position sensors make it possible to support augmented reality (Zulkifli et al., 2016). In order to experience immersive VR, a Google Cardboard or similar VR headset casing is required, as well as the mobile device itself. With a combination of mobile devices and Google Cardboard, extended reality can be experienced more inexpensively with lower FOV and resolution specifications than with purpose-built devices.

Programming Platforms

Computer scientists and game developers with solid technical backgrounds might be interested in using VR with their own applications. Those who have access to technical development resources onsite can benefit from the same. The game development engines Unity and Unreal are most likely to be used in either case. The above approach might be time-consuming, but it provides a greater level of control and flexibility over the system, and it would most likely be more cost-effective than other approaches compared to a conventional approach. According to some reports, the learning curve for developing XR applications from scratch is steep, just like the learning curve for developing games in general or making 3D models, as summed up by (Comber et al., 2019): "The cost of Unity is its complexity". The following is a list of the most popular tools for software developers who are interested in pursuing VR development as a career path.

The Unity engine is a cross-platform game engine that includes an integrated development environment (IDE). Digital games have traditionally been developed for web plug-ins, desktop platforms, and mobile devices. Additionally, it can be used to develop VR, AR, and MR applications. An example is Unity's interactive physics laboratory and experiment environment, which is designed to engage and immerse students in physics. There is no doubt that Unreal Engine is one of the most powerful game engines on the market. It is capable of creating immersive environments that will cater to VR experiences, such as making games which are interactive. There is a report that presents a research project on educational research using UE (A. J. A. Alnagrat et al., 2022b).

Conclusion and Future Work

Virtual reality entered our lives in the early 1960s. In the last ten years, VR devices have become suitable for individual use, and reduced costs have allowed VR to be recognised by a lot of users. VR equipment used today has technical features that are easy to use, comfortable and provide a more realistic experience compared to their ancestors used in the past. In addition, users can access many VREs and online applications. Users can also develop their own VR applications using various platforms. As a result, VR is now being used in a wide range of fields. As one of these fields, the education sector has begun to use VR as a solution to the problem of increasing learning outcomes in education that has been ongoing for years. Using VR for educational purposes is seen as one of the most important advantages due to its ability to create virtual worlds experience. VR learners can practice and authenticate learning opportunities because of this advantage. VR technology is effectively used to present events to learners that cannot be observed in the classroom environment for a variety of reasons, as well as to facilitate authentic learning without leaving the classroom environment as examples of the possibilities VR provides educators. On the other hand, as with any technology, VR must be used correctly and in accordance with its purpose to be effective and create positive outcomes in education. In this context, it is important to be aware of current VREs and equipment, as well as benefitting from instructional design models as a subject of the design process of VREs.

The majority of the studies in this article focused on the student's interest, motivation, and engagement in the learning process. However, there are still problems associated with the use of this technology, as well as factors that play a role in its adaptation that is not explored in a detailed manner. There is no doubt that the use of VR in education is still in its infancy in some countries and that there is still room for improvement in the methods of adopting this technology in the field of education. Despite the fact that all of the studies were conducted over a certain period of time, no specific methodology for integrating VR into regular teaching and learning practices has been developed. There is a lack of mapping between the learning theories and the VR content in the majority of studies that have been conducted.

The field of virtual reality is vast and advanced, and numerous researchers are exploring it around the world. It is evident from the results of the studies that if educational institutions' stakeholders carefully choose the VR content they require for their courses, they can see good results. In addition, it makes more sense to start with low-cost VR devices rather than invest a huge amount in infrastructure until teachers and students get comfortable using them.

With the rapid advancement of technology, resources are also becoming more readily available. The free resources related to their subjects can be used by teachers with low-cost mobile VR devices like Google cardboard before investing in more expensive devices. There has been a growth in virtual reality. It is now an important topic for the engineers of tomorrow. The cost of purchasing equipment, and software, maintaining the system, training the teachers, and requiring physical lab spaces is identified as a major barrier to implementing VR technologies. The cost issue can be overcome by setting up mobile labs, which do not require a large investment for the construction of labs, the purchase of software and hardware, training teachers, or maintenance upgrades.

Conducting experiments in the laboratory helps students to understand engineering concepts as part of the teaching and learning process. It has been proven that the introduction of virtual laboratories in engineering education has a profound effect on the learning process of students. It should be noted that during the COVID-19 pandemic, colleges were closed due to lockdown and classes were conducted online for the completion of the courses. The students had difficulty completing the laboratory experiments, however, because they encountered a variety of problems.

Learning with VL helps in the learning process, and they feel it has enhanced their teaching abilities. It was evident from the feedback collected from the students that the virtual learning environment had helped them students understand the concepts in the engineering curriculum better.

Since COVID-19 infections are increasing worldwide, online classes will be preferred in the academic year 2020–2021. As a result of the VLs, students will be able to fulfil their laboratory classes on time without compromising the quality of their learning. There are many VR development platforms, including Unity, Unreal Engine, OpenVR, Amazon Sumerian, and Google VR, for everyone. All of them serve different purposes in VR application development and can either be used individually or in combination with one another. Various software is used to create 3D objects, animations, and motion graphics, depending on the type of object. Software such as Blender, 3DS Max, SketchUp Studio, Unity 3d, Unreal EU5, Maya, etc., are the most common. An engineering education VR application requires a robust workflow to utilise these tools. Regardless of the workflow, developing a VR app for engineering education entails a great deal of effort and expertise in the above software as well as coding since it is essential that the design is correct to eliminate the dysfunctions and distracts the students.

References

Achuthan, K., Kolil, V. K., & Diwakar, S. (2018). Using virtual laboratories in chemistry classrooms as interactive tools towards modifying alternate conceptions in molecular symmetry. *Education and Information Technologies*, *23*(6), 2499–2515.

Akçayır, M., Akçayır, G., Pektaş, H. M., & Ocak, M. A. (2016). Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. *Computers in Human Behavior*, *57*, 334–342.

Al-Amri, A. Y., Osman, M. E., & Al Musawi, A. S. (2021). The Design Principles of 3D-Virtual Reality Learning Environment (3D-VRLE) in Science Education. *Interdisciplinary Journal of Virtual Learning in Medical Sciences*, *12*(4), 238–249.

AlAwadhi, S., AlHabib, N., Murad, D., AlDeei, F., AlHouti, M., Beyrouthy, T., & Al-Kork, S. (2017). Virtual reality application for interactive and informative learning. *2017 2nd International Conference on Bio-Engineering for Smart Technologies (BioSMART)*, 1–4.

Albus, P., Vogt, A., & Seufert, T. (2021). Signalling in virtual reality influences learning outcome and cognitive load. *Computers & Education*, *166*, 104154. https://doi.org/10.1016/j.compedu.2021.104154

Alnagrat, A. J. A., Ismail, R. C., & Idrus, S. Z. S. (2021). Extended Reality (XR) in Virtual Laboratories : A Review of Challenges and Future Training Directions. *Journal of Physics: Conference Series*, *1874*(1), 12031. https://doi.org/10.1088/1742-6596/1874/1/012031

Alnagrat, A., Ismail, R. C., Idrus, S. Z. S., & Alfaqi, R. M. A. (2022). A Review of Extended Reality (XR) Technologies in the Future of Human Education: Current Trends and Future Opportunity. *Journal of Human Centered Technology*, *1*(2), 81–96.

Alnagrat, A. J. A. (2022). Virtual Transformations in Human Learning Environment: An Extended Reality Approach. *Journal of Human Centered Technology*, *1*(2), 116–124.

Alnagrat, A. J. A., Ismail, R. C., & Idrus, S. Z. S. (2021). Extended Reality (XR) in Virtual Laboratories: A Review of Challenges and Future Training Directions. *Journal of Physics: Conference Series*, *1874*(1), 012031. https://doi.org/10.1088/1742-6596/1874/1/012031

Alnagrat, A. J. A., Ismail, R. C., & Idrus, S. Z. S. (2022a). *Design Safety Training Using Extended Reality Tracking Tools in Semiconductor Fabrication Laboratory Furnace* (pp. 1041–1046). Springer Singapore. https://doi.org/10.1007/978-981-16-8129-5_159

Alnagrat, A. J. A., Ismail, R. C., & Idrus, S. Z. S. (2022b). THE EFFECTIVENESS OF VIRTUAL REALITY TECHNOLOGIES TO ENHANCE LEARNING AND TRAINING EXPERIENCE: DURING THE COVID-19 PANDEMIC AND BEYOND. *Journal of Creative Industry and Sustainable Culture*, *1*, 18–34.

Alnagrat, A. J. A., Ismail, R. C., & Idrus, S. Z. S. (2022c). *Design Safety Training Using Extended Reality Tracking Tools in Semiconductor Fabrication Laboratory Furnace BT - Proceedings of the 11th International Conference on Robotics, Vision, Signal Processing and Power Applications* (N. M. Mahyuddin, N. R. Mat Noor, & H. A. Mat Sakim (eds.); pp. 1041–1046). Springer Singapore.

Alnagrat, A. J. A., Ismail, R., & Idrus, S. Z. S. (2022d). The Significant and Challenges of Extended Reality Technologies in Learning and Training during Covid-19 Pandemic. *Journal of Human Centered Technology*, *1*(2), 44–55.

Angulo, I., Rodrìguez-Gil, L., & Garcìa-Zubìa, J. (2018). Scaling up the lab: An adaptable and scalable architecture for embedded systems remote labs. *IEEE Access*, *6*, 16887–16900.

Artdej, R. (2012). Investigating undergraduate students' scientific understanding of laboratory safety. *Procedia-Social and Behavioral Sciences*, *46*, 5058–5062. https://doi.org/10.1016/j.sbspro.2012.06.385

Attanasi, G., Egidi, M., & Manzoni, E. (2022). Target-the-Two: a lab-in-the-field experiment on routinisation. *Journal of Evolutionary Economics*, 1–33.

Bailey, J. O., & Bailenson, J. N. (2017). Immersive Virtual Reality and the Developing Child. In *Cognitive Development in Digital Contexts* (pp. 181–200). Elsevier. https://doi.org/10.1016/B978-0-12-809481-5.00009-2

Balali, V., Zalavadia, A., & Heydarian, A. (2020). Real-time interaction and cost estimating within immersive virtual environments. *Journal of Construction Engineering and Management*, *146*(2), 4019098.

Balzerkiewitz, H.-P., & Stechert, C. (2020). THE EVOLUTION OF VIRTUAL REALITY TOWARDS THE USAGE IN EARLY DESIGN PHASES. *Proceedings of the Design Society: DESIGN Conference*, *1*, 91–100. https://doi.org/10.1017/dsd.2020.159

Bock, M., & Schreiber, A. (2018). Visualisation of neural networks in virtual reality using unreal engine. *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*, 1–2.

Bogusevschi, D., Muntean, C., & Muntean, G.-M. (2020). Teaching and Learning Physics using 3D Virtual Learning

Environment: A Case Study of Combined Virtual Reality and Virtual Laboratory in Secondary School. *Journal of Computers in Mathematics and Science Teaching*, *39*(1), 5–18.

Brown, A., & Green, T. (2016). Virtual Reality: Low-Cost Tools and Resources for the Classroom. *TechTrends*, *60*(5), 517–519. https://doi.org/10.1007/s11528-016-0102-z

Castronovo, F., Nikolic, D., Ventura, S. M., Shroff, V., Nguyen, A., Dinh, N. H. P., Yilmaz, S., Akhavian, R., & Gaedicke, C. (2019). Design and development of a virtual reality educational game for architectural and construction reviews. *2019 ASEE Annual Conference & Exposition*.

Chan, V. S., Haron, H. N. H., Isham, M. I. B. M., & Mohamed, F. Bin. (2022). VR and AR virtual welding for psychomotor skills: a systematic review. *Multimedia Tools and Applications*, *81*(9), 12459–12493. https://doi.org/10.1007/s11042-022-12293-5

Chen, C. J., & Teh, C. S. (2013). Enhancing an instructional design model for virtual reality-based learning. *Australasian Journal of Educational Technology*, *29*(5). https://doi.org/10.14742/ajet.247

Cho, J., Jung, T., Macleod, K., & Swenson, A. (2021). Using Virtual Reality as a Form of Simulation in the Context of Legal Education. *Augmented Reality and Virtual Reality: New Trends in Immersive Technology*, p. 141. https://doi.org/10.1007/978-3-030-68086-2_11

Comber, O., Motschnig, R., Mayer, H., & Haselberger, D. (2019). Engaging Students in Computer Science Education through Game Development with Unity. *2019 IEEE Global Engineering Education Conference (EDUCON)*, 199–205. https://doi.org/10.1109/EDUCON.2019.8725135

Council, N. R. (2011). *Learning science through computer games and simulations*. National Academies Press.

Dong, X. (2016). An overall solution of Virtual Reality classroom. *2016 IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI)*, pp. 119–123.

Elkoubaiti, H., & Mrabet, R. (2018). A Generic Architecture of Augmented and Virtual Reality in Classrooms. *2018 6th International Conference on Multimedia Computing and Systems (ICMCS)*, 1–4.

Elmqaddem, N. (2019). Augmented reality and virtual reality in education. Myth or reality? *International Journal of Emerging Technologies in Learning*, *14*(3).

Foxman, M. (2019). United We Stand: Platforms, Tools and Innovation With the Unity Game Engine. *Social Media + Society*, *5*(4), 205630511988017. https://doi.org/10.1177/2056305119880177

Fransson, G., Holmberg, J., & Westelius, C. (2020). The challenges of using head mounted virtual reality in K-12 schools from a teacher perspective. *Education and Information Technologies*, *25*(4), 3383–3404.

Georgiou, Y., & Kyza, E. A. (2018). Relations between student motivation, immersion and learning outcomes in location-based augmented reality settings. *Computers in Human Behavior*, pp. *89*, 173–181. https://doi.org/10.1016/j.chb.2018.08.011

Geris, A., & Özdener, N. (2020). Design Models for Developing Educational Virtual Reality Environments. In *Virtual and Augmented Reality in Education, Art, and Museums* (pp. 1–22). IGI Global. https://doi.org/10.4018/978-1-7998-1796-3.ch001

Goedicke, D., Bremers, A. W. D., Yasuda, H., & Ju, W. (2021). Xr-oom: Mixing virtual driving simulation with real cars and environments safely. *13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 67–70.

Goodwin, M. S., Wiltshire, T., & Fiore, S. M. (2015). Applying Research in the Cognitive Sciences to the Design and Delivery of Instruction in Virtual Reality Learning Environments. In *International Conference on Virtual, Augmented and Mixed reality* (pp. 280–291). Springer. https://doi.org/10.1007/978-3-319-21067-4_29

Grajewski, D., Górski, F., Hamrol, A., & Zawadzki, P. (2015). Immersive and Haptic Educational Simulations of Assembly Workplace Conditions. *Procedia Computer Science*, *75*, 359–368. https://doi.org/10.1016/j.procs.2015.12.258

Heilig, M L. (1962). *Father of Virtual Reality*. Morton L. Heilig (1926-1997): http://www. mortonheilig. com.

Heilig, Morton L. (1962). *Sensorama simulator*. Google Patents.

Hendriyani, Y., & Amrizal, V. A. (2019). The comparison Between 3D Studio Max and Blender Based on Software Qualities. *Journal of Physics: Conference Series*, *1387*(1), 012030. https://doi.org/10.1088/1742-6596/1387/1/012030

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, *88*(1), 28–54.

Howard, M. C., & Gutworth, M. B. (2020). A meta-analysis of virtual reality training programs for social skill development. *Computers & Education*, p. *144*, 103707. https://doi.org/10.1016/j.compedu.2019.103707

Innocenti, E. D., Geronazzo, M., Vescovi, D., Nordahl, R., Serafin, S., Ludovico, L. A., & Avanzini, F. (2019). Mobile virtual reality for musical genre learning in primary education. *Computers & Education*, *139*, 102–117. https://doi.org/10.1016/j.compedu.2019.04.010

Ip, H. H. S., & Li, C. (2015). Virtual Reality-Based Learning Environments: Recent Developments and Ongoing Challenges. In *International conference on hybrid learning and continuing education* (pp. 3–14). Springer. https://doi.org/10.1007/978-3-319-20621-9_1

Jamah, A., Alnagrat, A., Ismail, R. C., Zulkarnain, S., Idrus, S., & Ali, U. (2022). The Impact of Digitalisation Strategy in Higher Education : Technologies and New Opportunities. *International Journal of Business and Technopreneurship*, *12*(1), 79–94.

Jamah, A., Alnagrat, A., Zulkifli, A. N., & Yusoff, M. F. (2014). Evaluation of UUM Mobile Augmented Reality Based i-Brochure Application. *International Journal of Computing, Communication and Instrumentation Engineering*, *2*(2). https://doi.org/10.15242/IJCCIE.D0814014

Janin, A. L., Mizell, D. W., & Caudell, T. P. (1993). Calibration of head-mounted displays for augmented reality applications.

Proceedings of IEEE Virtual Reality Annual International Symposium, 246–255.
Kapici, H. O., Akcay, H., & de Jong, T. (2019). Using hands-on and virtual laboratories alone or together―which works better for acquiring knowledge and skills? *Journal of Science Education and Technology*, *28*(3), 231–250.
Knapova, L., Kruzikova, A., Dedkova, L., & Smahel, D. (2021). Who Is smart with their smartphones? Determinants of smartphone security behavior. *Cyberpsychology, Behavior, and Social Networking*, *24*(9), 584–592.
Kolb, A. Y., & Kolb, D. A. (2012). *Experiential learning theory In Steel RM (Ed,) Encyclopedia of the Sciences of Learning (pp. 1215–1219)*. New York, NY: Springer.[Google Scholar].
Krueger, M. W. (1977). Responsive environments. *Proceedings of the June 13-16, 1977, National Computer Conference*, 423–433.
Kugler, L. (2021). The state of virtual reality hardware. *Communications of the ACM*, *64*(2), 15–16. https://doi.org/10.1145/3441290
Leong, A., Herst, P., & Kane, P. (2018). VERT, a virtual clinical environment, enhances understanding of radiation therapy planning concepts. *Journal of Medical Radiation Sciences*, *65*(2), 97–105.
Makransky, G., Andreasen, N. K., Baceviciute, S., & Mayer, R. E. (2021). Immersive virtual reality increases liking but not learning with a science simulation and generative learning strategies promote learning in immersive virtual reality. *Journal of Educational Psychology*, *113*(4), 719.
Makransky, G., Lilleholt, L., & Aaby, A. (2017). Development and validation of the Multimodal Presence Scale for virtual reality environments: A confirmatory factor analysis and item response theory approach. *Computers in Human Behavior*, *72*, 276–285.
Makransky, G., & Petersen, G. B. (2021). The Cognitive Affective Model of Immersive Learning (CAMIL): a Theoretical Research-Based Model of Learning in Immersive Virtual Reality. *Educational Psychology Review*, *33*(3), 937–958. https://doi.org/10.1007/s10648-020-09586-2
Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*, *60*(May), 225–236. https://doi.org/10.1016/j.learninstruc.2017.12.007
Martín-Gutiérrez, J., Mora, C. E., Añorbe-Díaz, B., & González-Marrero, A. (2017). Virtual Technologies Trends in Education. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(2), 469–486. https://doi.org/10.12973/eurasia.2017.00626a
Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, *77*(12), 1321–1329.
Morimoto, T., Kobayashi, T., Hirata, H., Otani, K., Sugimoto, M., Tsukamoto, M., Yoshihara, T., Ueno, M., & Mawatari, M. (2022). XR (Extended Reality: Virtual Reality, Augmented Reality, Mixed Reality) Technology in Spine Medicine: Status Quo and Quo Vadis. *Journal of Clinical Medicine*, *11*(2), 470. https://doi.org/10.3390/jcm11020470
Mulders, M., Buchner, J., & Kerres, M. (2020). A Framework for the Use of Immersive Virtual Reality in Learning Environments. *International Journal of Emerging Technologies in Learning (IJET)*, *15*(24), 208. https://doi.org/10.3991/ijet.v15i24.16615
Murray, J. H. (2017). *Hamlet on the Holodeck, updated edition: The Future of Narrative in Cyberspace*. MIT press.
Narciso, D., Melo, M., Raposo, J. V., Cunha, J., & Bessa, M. (2020). Virtual reality in training: an experimental study with firefighters. *Multimedia Tools and Applications*, *79*(9), 6227–6245. https://doi.org/10.1007/s11042-019-08323-4
Nolin, P., Stipanicic, A., Henry, M., Lachapelle, Y., Lussier-Desrochers, D., & Allain, P. (2016). ClinicaVR: Classroom-CPT: A virtual reality tool for assessing attention and inhibition in children and adolescents. *Computers in Human Behavior*, *59*, 327–333.
Nop, K., Manissaward, J., & Oattarapon, T. (2019). Development of character design frameworks using game engine: unreal engine. *2019 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT-NCON)*, 54–59.
Nuguri, S. S., Calyam, P., Oruche, R., Gulhane, A., Valluripally, S., Stichter, J., & He, Z. (2021). vSocial: a cloud-based system for social virtual reality learning environment applications in special education. *Multimedia Tools and Applications*, *80*(11), 16827–16856. https://doi.org/10.1007/s11042-020-09051-w
Nurbekova, Z., Nurbekov, B., Maulsharif, M., Naimanova, D., & Baimendinova, A. (2022). Using Virtual Learning Objects in Educational Content. *Proceedings of the 23rd International Conference on Computer Systems and Technologies*, 174–178.
Oh, K., & Nussli, N. (2014). Teacher training in the use of a three-dimensional immersive virtual world: Building understanding through first-hand experiences. *Journal of Teaching and Learning with Technology*, 33–58. https://doi.org/10.14434/jotlt.v3n1.3956
Ou, C., Joyner, D. A., & Goel, A. K. (2019). Designing and Developing Videos for Online Learning: A Seven-Principle Model. *Online Learning*, *23*(2), 82–104. https://doi.org/10.24059/olj.v23i2.1449
Ouyang, S., Wang, G., Yao, J., Zhu, G., Liu, Z., & Feng, C. (2018). A Unity3D-based interactive three-dimensional virtual practice platform for chemical engineering. *Computer Applications in Engineering Education*, *26*(1), 91–100.
Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, *147*, 103778. https://doi.org/10.1016/j.compedu.2019.103778
Rehan, R., Ahmed, K., Khan, H., & Rehman, R. (2016). A way forward for teaching and learning of Physiology: Students' perception of the effectiveness of teaching methodologies. *Pakistan Journal of Medical Sciences*, *32*(6), 1468.

Samadbeik, M., Yaaghobi, D., Bastani, P., Abhari, S., Rezaee, R., & Garavand, A. (2018). The applications of virtual reality technology in medical groups teaching. *Journal of Advances in Medical Education & Professionalism*, *6*(3), 123.

Sattar, M. U., Palaniappan, S., Lokman, A., Shah, N., Khalid, U., & Hasan, R. (2020). Motivating Medical Students Using Virtual Reality Based Education. *International Journal of Emerging Technologies in Learning (IJET)*, *15*(02), 160. https://doi.org/10.3991/ijet.v15i02.11394

Schunk, D. H. (2012). *Learning theories an educational perspective sixth edition*. Pearson.

Sherman, W. R., & Craig, A. B. (2019). *Chapter 1—introduction to virtual reality. understanding virtual reality, 2nd eds. Interface, application, and design*. The Morgan Kaufmann Series in Computer Graphics.

Siemens, G. (2014). Connectivism: a learning theory for the digital age. 2004. *Online: Http://Www. Elearnspace. Org/Articles/Connectivism. Htm (Accessed October 2012)*.

Slater, M. (2003). A note on presence terminology. *Presence Connect*, *3*(3), 1–5.

Soliman, M., Pesyridis, A., Dalaymani-Zad, D., Gronfula, M., & Kourmpetis, M. (2021). The Application of Virtual Reality in Engineering Education. *Applied Sciences*, *11*(6), 2879. https://doi.org/10.3390/app11062879

Stanney, K. M., Nye, H., Haddad, S., Hale, K. S., Padron, C. K., & Cohn, J. V. (2021). eXtended reality (XR) environments. *Handbook of Human Factors and Ergonomics*, 782–815.

Sutherland, I. E. (1968). A head-mounted three dimensional display. *Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I*, pp. 757–764.

TIAN, F. (2019). Human-computer interactions for virtual reality. *Virtual Reality & Intelligent Hardware*, *1*(3), I–II. https://doi.org/10.1016/S2096-5796(19)30028-2

Uribe, S., & Dillon, F. (2022). *Social and academic relations in Design students through the "Second Life" platform*.

Vergara, D., Rubio, M., & Lorenzo, M. (2017). On the Design of Virtual Reality Learning Environments in Engineering. *Multimodal Technologies and Interaction*, *1*(2), 11. https://doi.org/10.3390/mti1020011

Vergara, D., Rubio, M. P., & Lorenzo, M. (2018). A virtual resource for enhancing the spatial comprehension of crystal lattices. *Education Sciences*, *8*(4), 153.

Winkelmann, K., Keeney-Kennicutt, W., Fowler, D., Lazo Macik, M., Perez Guarda, P., & Joan Ahlborn, C. (2020). Learning gains and attitudes of students performing chemistry experiments in an immersive virtual world. *Interactive Learning Environments*, *28*(5), 620–634.

Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C., Schramm, H., Saari, T., Laarni, J., Ravaja, N., & Gouveia, F. R. (2007). A process model of the formation of spatial presence experiences. *Media Psychology*, *9*(3), 493–525.

Zulkifli, A. N., Ahmed Alnagrat, A. J., & Che Mat, R. (2016). Development and evaluation of i-Brochure: A mobile augmented reality application. *Journal of Telecommunication, Electronic and Computer Engineering*, *8*(10), 145–150.