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VR/AR Environment for Training Students on Engineering Applications and Concepts

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Abstract

Modern technologies in virtual reality (VR) and augmented reality (AR) provide unique features that can be used to facilitate tasks in everyday life. Several courses can be built using augmented reality, such as engine maintenance, computer maintenance, chemistry lab, etc. Augmented reality technologies provide dynamic and interactive instructions to resolve problems or present required concepts. Building an educational system based on augmented reality is not simple due to some difficulties and challenges, such as the cost of augmented reality tools and other hardware and software required. Also, training students with engineering concepts and precise parts involves a lot of analysis and practice to know problems and then design solutions. The paper aims to develop a virtual educational environment for training students in engineering sectors in practical laboratory sessions based on AR/VR techniques. The questionnaire results show that the participants agreed that the proposed system provides a safe and low-cost environment to train the student in the engineering sector, such as basic electrical, mechanical, and renewable energy engineering concepts.

***Keywords**:* virtual reality; augmented reality; training student; educational system; engineering applications

1. Introduction

Augmented reality (AR) and virtual reality (VR) are widely used in training, production, maintenance, and manufacturing (Solmaz & Van, 2022). In addition to making systems accessible and minimizing manufacturing costs by building scalable and scalable models easily and quickly (Hatta et al., 2022). Computer vision advances have enabled the blending of physical and digital worlds and 3D human, computer, and environment interactions (Hui et al, 2022) as shown in Figure1.

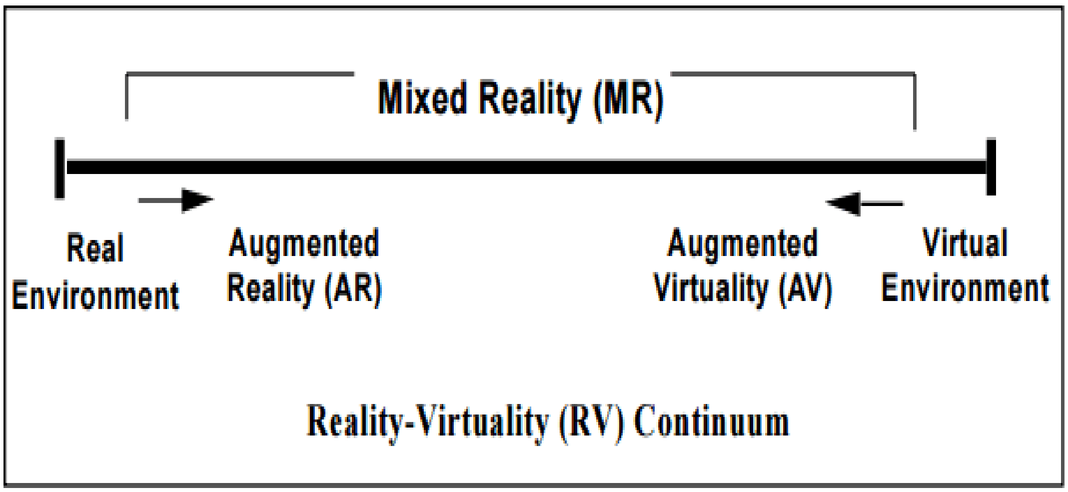


Figure 1: Mixed reality (MR) environment

It also uses augmented reality and virtual reality techniques to train students by building an interactive virtual reality for training that is safe without risk and at a lower cost, where the same experience can be repeated many times without the need to pay additional amounts (Kanade & Duffy, 2022). At the same time, practical experiments in engineering laboratories permeate the danger of injury with sensitive materials and cutting machines, the high costs of materials used, and the danger of some chemical (Alvarez-Marin & Velazquez-Iturbide, 2022). Therefore, augmented reality provides a learning environment for training with larger spaces for learning through illustrations and video instructions, which helps to explain complex concepts quickly.

This project aims to develop and design a virtual reality framework for training students in engineering sectors, including assembly and maintenance of machine parts in a safe and interactive environment. The report will include a critical analysis of some of the previous studies conducted regarding AR & VR systems in the education and training sector, which will help identify the gaps and problems in implementing fundamental training courses in the engineering field (Hasan et al., 2022). The virtual reality market is growing very fast (Statista, 2019). In 2014, the market value reached 90 million dollars, and it will grow to a staggering 5.2 billion dollars in four years.

The worldwide augmented reality (AR) and virtual reality (VR) market size is expected to grow exponentially from 2016 to 2022, as shown in Figure 1.

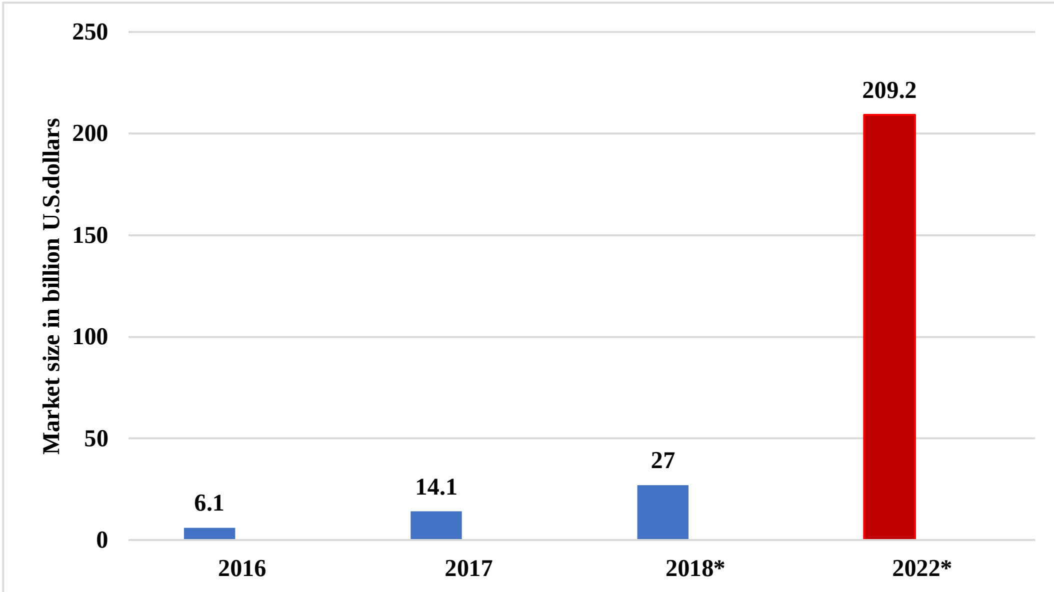


Figure 1: Market size of (AR)/(VR) forecast worldwide from 2016 to 2022 (in billion US dollars)

2. Literature Survey

Many studies were published on implementing VR/AR in different applications, such as education (Sanfilippo et al., 2022; Yang & Goh, 2022), Training (Chiang et al., 2022; Chan et al. 2022), Manufacturing (Laviola et al. 2022; Xie et al, 2022). Figure 3 shows the analysis of published papers on google scholar, which shows that a total of 733000 research was published related to using VR elements technologies in 2020. Also, a total of 16800 research was published related to using VR devices in 2019. Besides, a total of 16200 research was published on using VR devices in 2018.

Various teaching tools and environments were proposed and deployed, including robot-integrated VR, to improve student training and learning skills (Yousif J., 2021; Yousif J., 2020; C. & Rus, 2020; Yousif et al., 2019; Yousif et al., 2018; Matsas et al., 2017;). In addition, many studies used the Humanoid Robot to enhance the social and communication Skills of Autistic Children in teaching environments (Yousif M., 2021 a; Yousif M., 2021 b; Yousif M., 2021 c; Schweinberger et al., 2020).

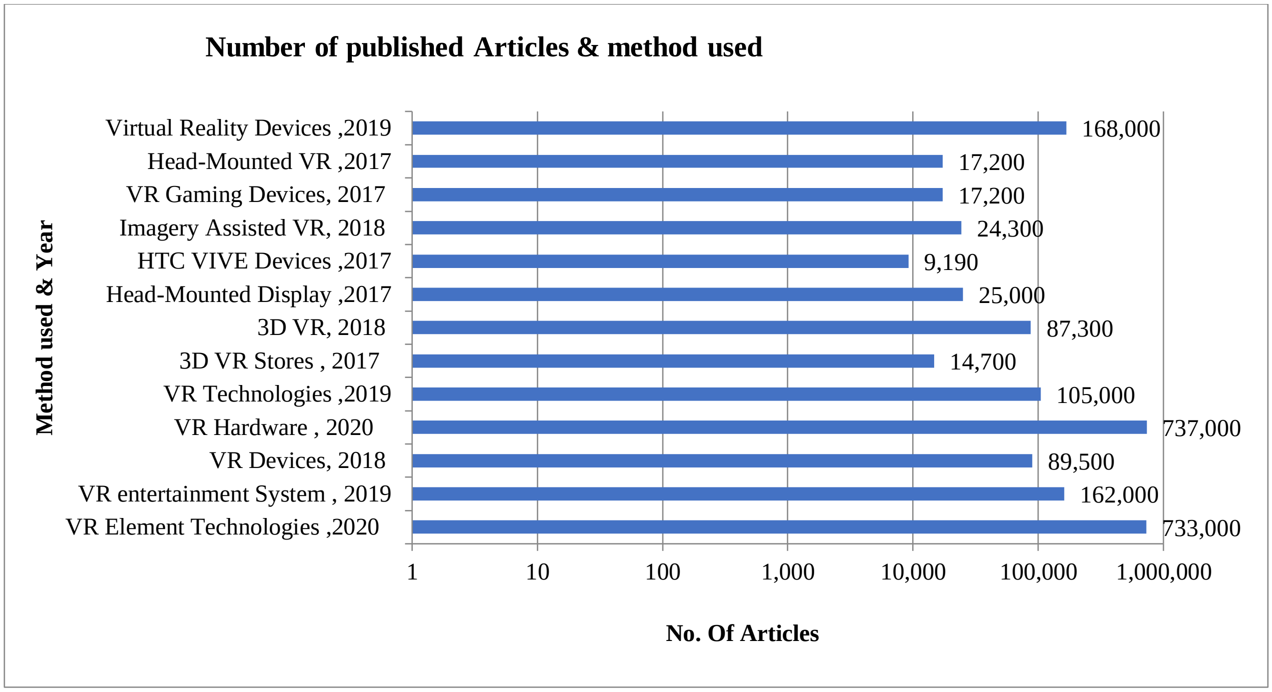


Figure 3: Number of published Articles & method used in 2017 to 2020

A critical analysis of previous studies of current AR and VR systems in training and education. In addition, we are summarizing the most critical current gaps in the application and implementation of systems with augmented reality, knowing the most effective tools for system design, and examining the difficulties and solutions (Vuta, D., 2020). Also, identify the advantages and disadvantages of each previous system and benefit from applying the best effective solutions. In this stage, we explored and reviewed the used method and then identified the research gaps (Sala, N., 2021). The authors' contributions and the methods used are shown in Figure 4, which includes the use of VR in different fields, such as teaching, training, gaming, marketing, aviation, etc.

The focus of this review is on immersive virtual reality in systematic reviews examining a variety of different application areas besides education, such as healthcare (Mao et al, 2021) and marketing (De Regt et al, 2021). In contrast, the application of immersive VR in education is not discussed in much detail but rather the tools (Hamilton et al, 2021).

The following gaps need to be filled related using VR in education.

- To date, virtual reality design elements used in teaching have not been assigned to learning content.
- The researchers studied only the characteristics of virtual reality in general and did not examine its characteristics in specialized fields.

- There is no specific information about the types of learning content that can be taught using VR applications (e.g., declarative knowledge or procedural and practical knowledge) in the broad application areas of VR in education (e.g., medicine or psychology).
- The learning theories used as a theoretical basis for VR-based learning is still missing.
- The evaluation of learning outcomes when using virtual reality in teaching activities are still few and need further investigation.

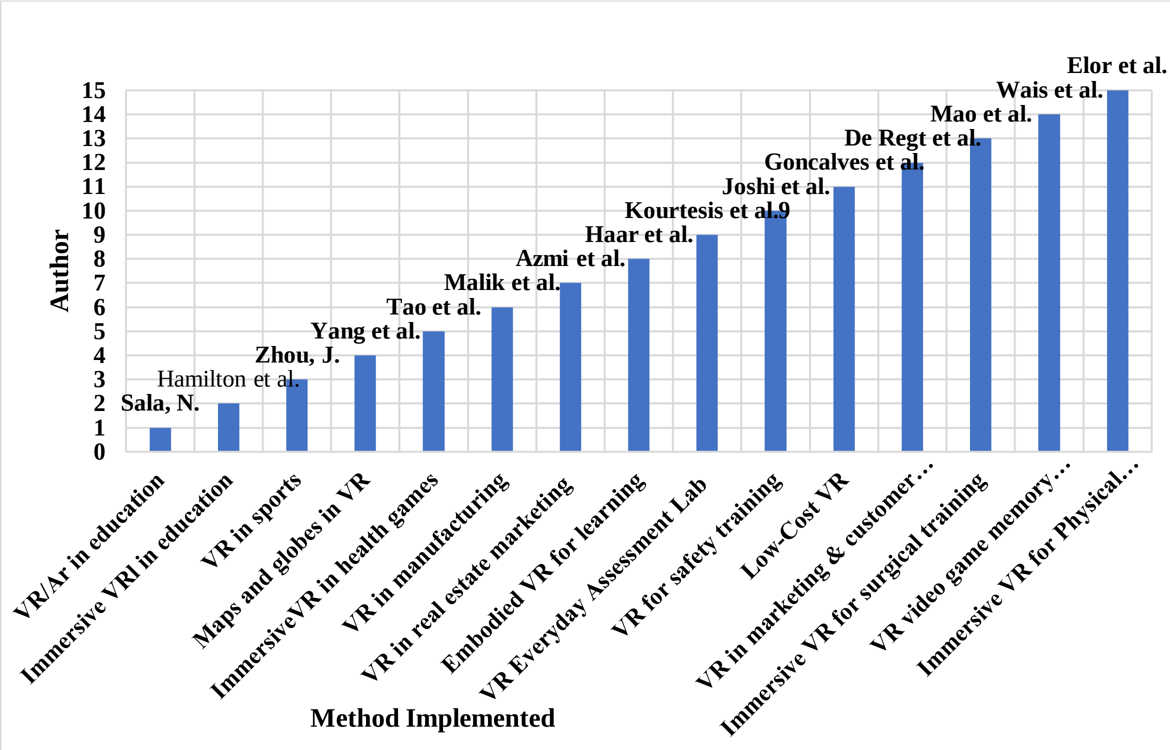


Figure 4. Author Contribution & Method used

According to the literature survey analysis, using virtual reality for training and education has the following advantages and disadvantages. Table 1 summarizes the advantages and disadvantages of using virtual reality in teaching.

Table 1: Advantages and disadvantages of using virtual reality in the teaching

Advantages of Using VR	Disadvantages of Using VR
Provides Outstanding Visualizations	Deteriorates Human Connections.
Creates more interest in the classroom.	Lack of Flexibility
Increases the Students' Engagement.	Functionality or tools damage Issues
Eliminates the Language Barrier	Expensive tools and software
Improves the Quality of Education	Need special training and guides

The following are some future directions for VR-related education.

- Integration of emerging educational paradigms,
- development of VR-related educational kits,
- development of VR-enhanced online education,
- implementation of hybrid visualization for ubiquitous learning, and
- development of rapid as-built virtual training scenes.

3. Research Methodology

The research methodology relied on two parts, practical and theoretical, that depended on the qualitative research method (Yousif et al., 2021 a) to build a complete training environment for students based on virtual reality technology. Implementing the project requires multiple experiences in the theoretical and practical fields, including computing (Yousif et al., 2011), information technology (Yousif J., 2011), systems analysis (Yousif & Saini, 2020), and building systems with augmented reality, as shown in Figure 5. The project started with an in-depth analysis of the system and its requirements, evaluating previous studies of current training systems based on virtual reality systems, and using the results to design this project. Then, designing and developing interactive study materials to train students during seminars and training. In addition, building and implementing a virtual environment based on augmented reality technologies provides the user with an interactive and guiding environment to learn challenging concepts quickly and accurately.

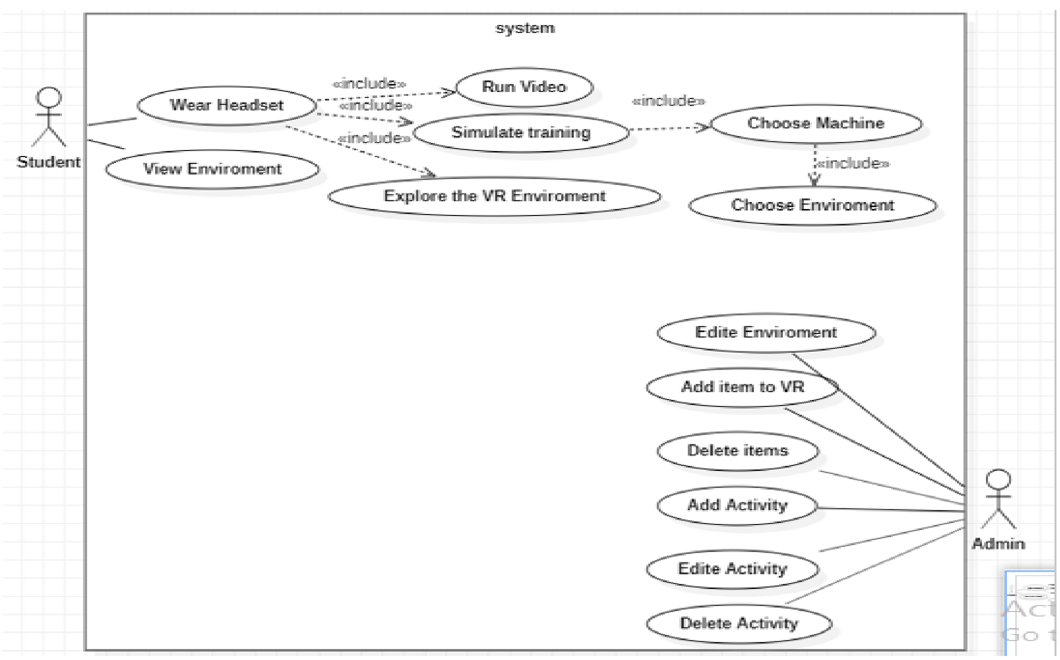


Figure 5. Use Case Diagram of the proposed VR/AR system

4. Results

4.1. Questionnaire Results

Designing and implementing a questionnaire to collect the necessary data for the project and knowing the proposed system's users' opinions (Yousif et al., 2021 b). The questionnaire results showed that a total of 180 participants were 54% male and 46% female. Table 2 shows the Descriptive Statistics details the demographic details of the respondents.

Table 2: Descriptive Statistics details of demographic details of the respondents

	N	Min.	Max.	Mean	Std. Deviation	Variance
1. Gender	180	1	2	1.54	.500	.250
3. Marital Status	180	1	2	1.27	.443	.197
4. Working status	180	1	2	1.32	.469	.220
5. Major/ Specialization	180	1	7	1.69	1.196	1.431
6. Level	180	1	4	3.07	.919	.845
8. Residence	180	1	24	9.08	5.593	31.284
9. Do you know virtual reality?	180	1	2	1.29	.457	.209
10. Have you ever used Virtual reality before.	180	1	2	1.99	.075	.006

Furthermore, 71% of the participants were familiar with virtual reality technologies. The results also show that 64% agreed that virtual reality training sessions could reduce the mechanical risks expected during hands-on learning, and only 16% opposed it. In addition, most of the questionnaire respondents indicated that virtual reality enhanced the understanding of complex materials quickly and easily and enhanced the feature of remembering things and concepts quickly.

Figure 6 shows that 62% of the participants strongly agreed and agreed that virtual reality techniques enhance the understanding of subjects. However, 21% were uncertain whether virtual reality techniques made it easy to understand subjects or not. In comparison, 17 % of the participants indicated that they either disagreed or strongly disagreed that virtual reality enhanced the understanding of subjects.

Figure 7 indicates that 67% of the participants strongly agreed and agreed that virtual reality promotes the ease of remembering lessons. However, 17% were uncertain whether virtual reality techniques promote the ease of remembering lessons. In comparison, 17 % of the participants indicated that they either disagreed or strongly disagreed.

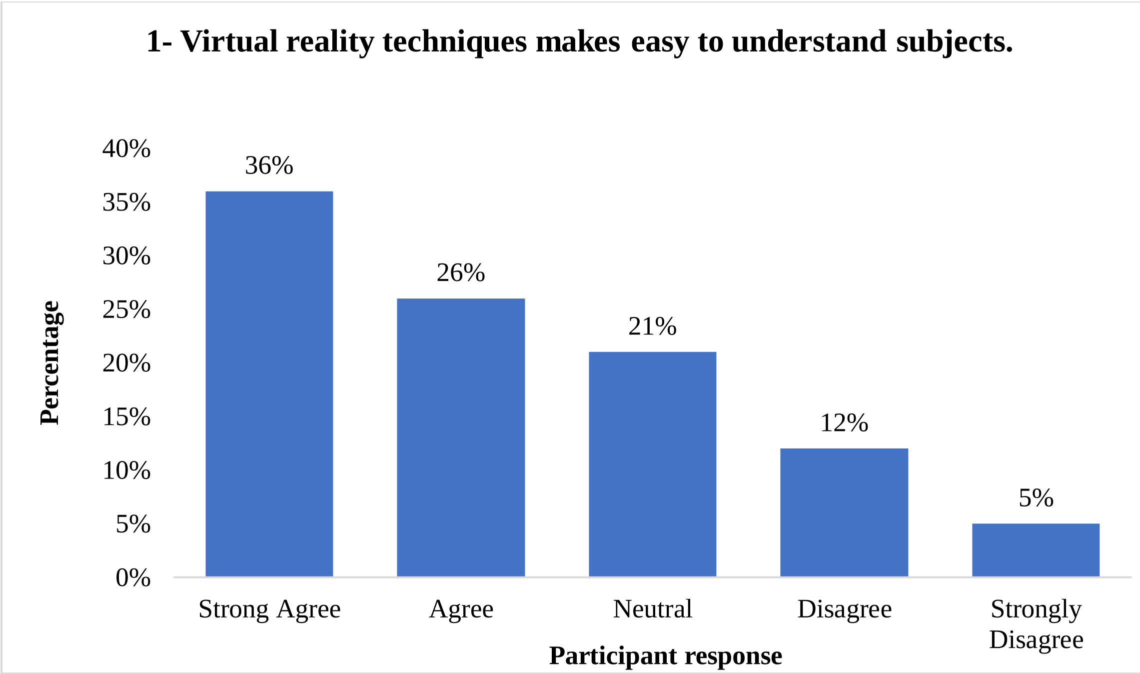


Figure 6: Participant response to question "Virtual reality techniques makes easy to understand subjects"

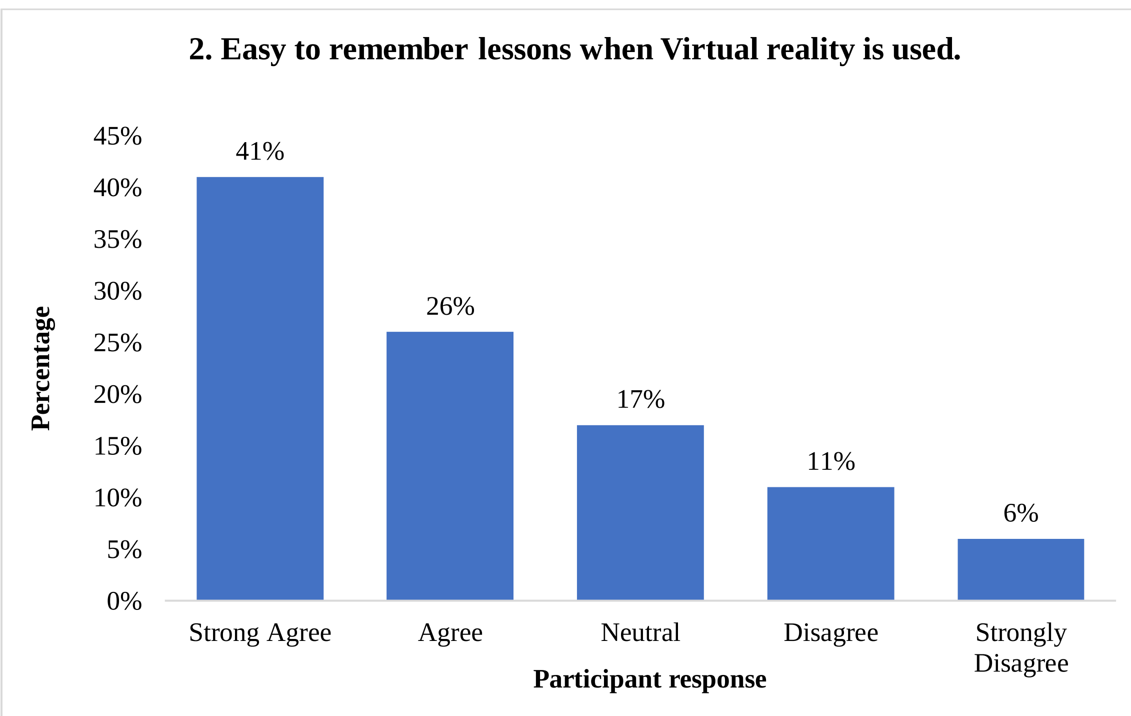


Figure 7: Participant response to question "Easy to remember lessons when Virtual reality is used"

4.2. Design of Virtual Environment

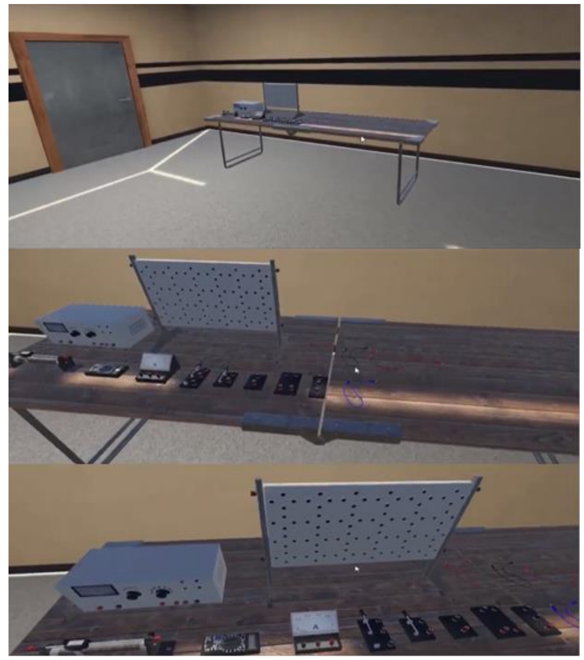
Design and implement interactive materials to train students in engineering sectors and build assembly systems (car engines, engines, chemistry lab). The materials were characterized by ease of presentation and application, for example, the trainee can apply the law of similar magnetic poles repel, and different magnetic poles attract. Moreover, applying a cutting machine for materials in different shapes and sizes and opening the car engine to small parts with the definition of each part by adding a picture, text explanations, and videos according to the required study material.

Design and implement an interactive virtual environment supported by augmented reality to train students in the engineering sectors. Moreover, controls to navigate the virtual reality and control the tools and the number inside it. The system is designed with several training rooms, providing numerous training and education options as shown in Figure 8.

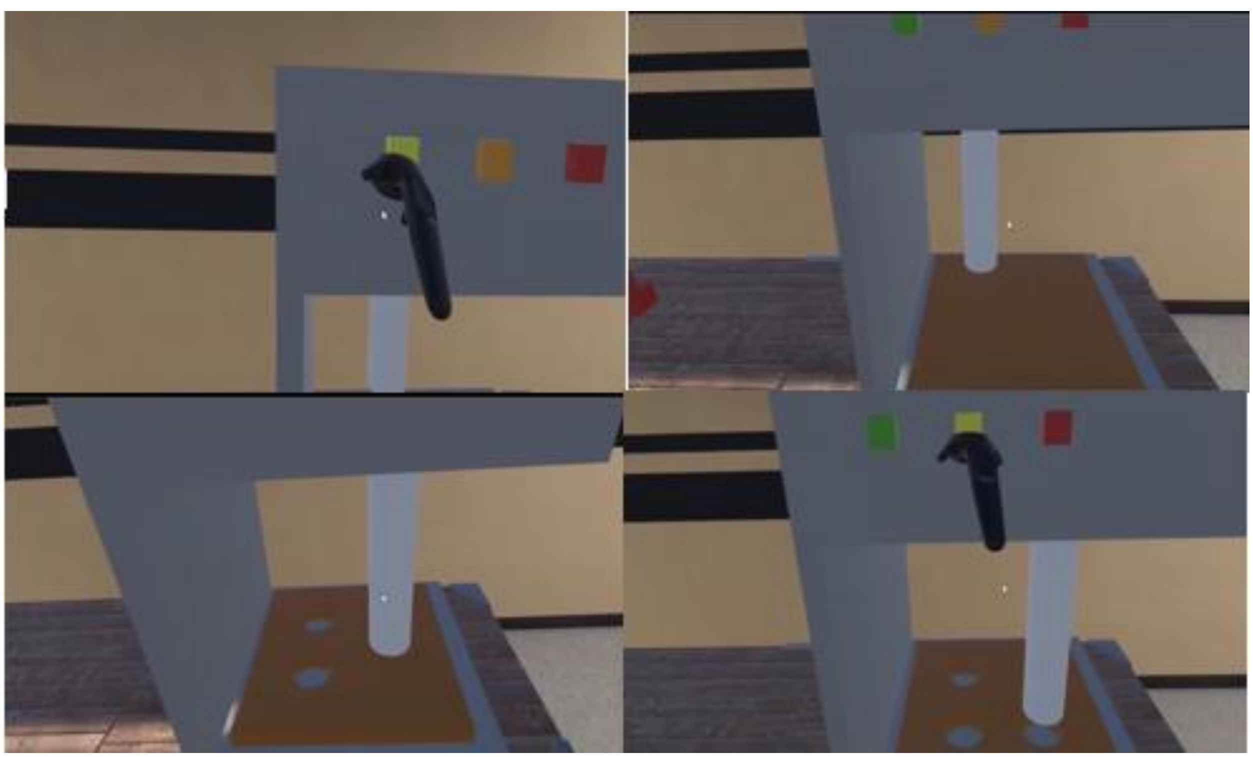
Figure 8: The proposed VR environment

The proposed VR environment provides the opportunity to teach Omani students to build systems with augmented reality and learn about the latest technologies and tools to build a virtual reality environment efficiently and quickly that is used for training and education purposes as shown in Figure 9.

(a)



(b)



(c)

Figure 9: Sample of training sessions (a) Solar Panel concepts; (b) electrical concepts; (c) Drilling machine

5. Discussion

In this study, VR/AR techniques were used to raise the understanding of the physical world by adding layers in an interactive environment of computer-generated information, for example, sounds, videos, and graphics. Also, providing a learning environment and training in larger spaces through illustrations, videos, and instructions helps explain complex concepts quickly. At the same time, the proposed virtual reality environment contributes to creating a complete simulated environment through computer graphics technology so that students can interact with three-dimensional objects, such as a binding solar panel. These features are widely used in training, production, maintenance, and manufacturing, as well as easy access to systems and minimal manufacturing costs by building scalable models and scaling easily and quickly, such as drilling machines. This machine is used to train students in a safe environment without risk and at a lower cost, where the same experience can be repeated many times without the need to pay additional amounts. In addition, this project is used to train students in the engineering sector to assemble parts of a specific machine, for example, the car engine assembly and maintenance, in a safe and interactive environment.

6. Conclusion

The study aims to develop a virtual educational environment for training students in engineering sectors in practical laboratory sessions based on AR/VR techniques. The system is designed with several training rooms, providing numerous training and education options. It helps provide the opportunity to teach Omani students about the augmented reality system and to identify the latest technologies and tools to build Virtual reality for training and education efficiently and quickly. The first step is critically analyzing previous studies on implementing augmented and virtual reality technologies in training and education. A summary of the most critical current gaps in the application and implementation of VR/AR systems were recorded. The questionnaire results show that the participants agreed that the proposed system provides a safe and low-cost environment to train students in the engineering sector, such as basic electrical, mechanical, and renewable energy engineering concepts. A total of 180 people participated in the questionnaire, 54% of males and 46% of females, and through Survey results, It was found that 71% of participants were familiar with VR technologies, 64% agreed that VR training sessions could reduce mechanical risks expected during hands-on learning, and only 16% were against it. In addition, most respondents indicated that virtual reality enhanced their understanding of complex materials with ease and enhanced the feature of remembering things and concepts quickly. Also, through this research, interactive materials were designed and implemented to train students in the engineering sectors and build assembly systems such as the car engine and the chemistry lab.

Recommendations and future work

The most important recommendations of the current project:

1. Increasing the chances of applying VR/AR in education and training because it provides a safe and risk-free environment that the trainee can try many times to obtain the most significant benefit.

2. Spreading the culture of using augmented reality among the training institutions because it allows explaining complex concepts quickly and efficiently, which helps to increase understanding and awareness.

3. The application of augmented reality in biological and chemical laboratories provides a safe environment enhanced with interactive materials to increase interaction and share opinions and experiences among the trainees.

4. Augmented reality can be applied at all primary, secondary, and university levels.

Directions for future work

1. The augmented reality application in chemistry laboratories for all school levels.

2. The application of augmented reality in production and manufacturing because it provides an interactive environment. It is possible to modify the model many times without incurring additional costs until the desired result is achieved.

3. Applying augmented reality to raise awareness of all emerging cases, including the current Corona pandemic, where a reinforced system can be built to increase awareness, alert, and guidance.

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