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Science learning in 3D virtual environment multi-users online in basic education stage

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Abstract

Technological development is ever-evolving in all areas of life, its impact on the education field has emerged, and science is part of learning that teachers struggle with in their teaching methods. This study aimed to explore the effects of using a 3D virtual environment in learning science at the basic education stage and students' attitudes towards their use. A quasi-experimental design was used in this study. A total of 99 students participated in the study, divided into two groups: an experimental group (n=50) and a control group (n=49). In this study, an achievement test and questionnaire were used as study tools after validating their validity and reliability. The data were analyzed using SPSS. Results showed that in the experimental groups that were taught science topics in 3D virtual environments, there were statistically significant differences compared to the control groups. In addition, students in the experimental group who were learning the topics in science textbooks in a 3D virtual environment showed positive attitudes toward it. The study recommends the use of 3D virtual environments in science education.

Keywords: educational virtual environments, virtual learning, virtual world, avatar, 3D, science learning, attitudes, basic education stage

INTRODUCTION

Educational virtual environments are a form of e-learning that relies on student to learn using electronic devices such as computers, tablets, and others (Pai et al., 2022). The great shift in computer systems and the Internet technology has changed the way students learn (Sadeghi, 2019). Thus, as a result, a new education model called "virtual education" has emerged, which has ability to improve student achievement and access to schools at the lowest costs (Taylor et al., 2022). According to Franklin and Harrington (2019), virtual learning specifically uses computer software, the Internet, or both to provide instruction to students (Wei & Chou, 2020). This reduces or eliminates students' and teachers' need for classroom sharing (Franklin & Harrington, 2019). In virtual teaching, it is undertaken remotely via the Internet (Kumar et al., 2018). Teacher provides instructions, but he is not physically present with student. Teacher and student interact online instead (Cardullo et al., 2021), through means of communication such as online video, online forums, e-mail, and instant messaging (Symonenko et al., 2020). Here are essential components required for the best virtual learning environment (VLE) or online educational curriculum. According to Schott and Marshall (2018), the most important components of educational virtual environment (**Figure 1**) are, as follows:

1. Content management: creating, storing, and accessing information sources for scientific material (Benachio et al., 2020).
2. Communication and collaboration: emails, notifications, chats, and wikis (Guan, 2021).
3. Real-time communication: video or audio conferencing (Nayyef et al., 2018).
4. Administrative information about lesson: student record, attendance, registration, payments, and teacher contact information (Munthe et al., 2021).

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Contribution to the literature

- Using a 3D virtual environment in the learning of science is an important research point that is examined in this study.
- Science teachers may improve student achievement by using 3D virtual environments.
- Practice Science can be taught in a more meaningful way by utilizing a virtual environment strategy.

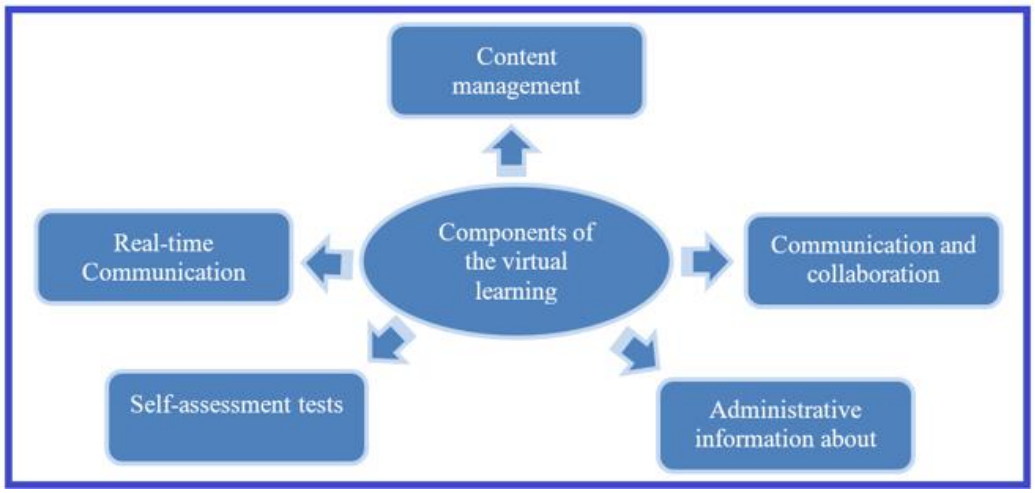

Figure 1. Components of educational virtual environment (Source: Author's own elaboration)

5. Self-assessment tests are usually scored automatically (Sera & McPherson, 2019).

The Importance of the Study

A VLE is becoming increasingly popular as a way for students to learn complex subjects. This acceleration, particularly in teaching chemistry and biology in a virtual environment, has resulted in an increase in interest from the scientific and educational communities. The study's significance implies the importance of incorporating virtual reality into the educational process through learning biology textbooks in classrooms.

Research Objectives

Learning science in the basic stage of education faces many challenges, and one of these challenges that teachers face in the classroom is the student's ability to understand scientific concepts. Traditional education lasted for a very long time. It showed a deficiency in correctly communicating knowledge, as it depends on dictation and memorization, not on linking knowledge and solving problems (Mokhtar, 2016). Following technological advancement, there is now a need for the development of learning methods suitable for the new generation. As teachers, we find that many of the concepts in science and the relationships between them are highly complex and difficult; we need to interact with them to understand them. This requires being a positive and active learner to build knowledge for your students (Mapolelo & Akinsola, 2015). Many studies emphasize modern learning skills through modelling or simulation in virtual educational environments (deNoyelles & Seo, 2012). This simulation is either textual or graphic in a 3D graphics environment, which attracts today's school students, who grow up and coexist with 3D video games (Bote-Lorenzo et al., 2008). The objective of this study was to examine the effectiveness of using a 3D virtual environment in ninth grade science textbooks to improve students' academic performance in biology topics and their attitudes toward using the 3D virtual environment.

Study Questions

The following research questions are addressed in this study:

1. **RQ1.** What is the effect of using a 3D virtual environment on improving students' achievement in biology topics in science textbook of ninth grade in the middle stage?
2. **RQ2.** What are the students' attitudes in the experimental group towards using a 3D virtual environment in learning biology topics in the science textbook of grade ninth?

LITERATURE AND PREVIOUS STUDIES

Virtual Learning Environments: Virtual World

VLEs described by Laurillard (1993) are viewed as alternative environments for traditional methods of instruction. Furthermore, Bruce and Curson (2001) defined it as computer-based applications aimed at facilitating the distance education process and making it easier and more flexible. This environment provides

many tools and functions to facilitate the process of giving and presenting lessons and lectures. VLE is accessed through Web browsers. In e-learning, modern technological features are used to enhance the learning process through the use of VLEs. Typically, a VLE operates through the Internet, and provides students with a range of tools to assess their learning, communicate, upload content, give their work to peers, manage student groups, collect student grades, conduct surveys, track, and monitor their progress, among other things. Wikis, blogs, RSS readers, and virtual learning spaces in 3D are among the new features of these systems. This type of environment was originally intended for distance education; however, it is now widely used to support traditional classroom activities, which is sometimes known as blended learning. It is usually delivered to students via a web page that runs on a server. According to Hamed (2012), the Internet offers users three-dimensional virtual environments through the concept of the virtual world, where a virtual agent known as (Avatar) roams them through the three-dimensional environment and interacts with other people. Users interact with this avatar by using it as their virtual agent. VLEs, according to Guomin and Jianxin (2010), enable learners to interact with them through the simulation of a realistic or imaginary learning environment. Through the use of material and technological capabilities, life situations can be created that attract those who interact with them and enter into their world, resulting in life situations that draw people in. As identified by Agudo-Peregrina et al. (2014), interaction is a fundamental component of VLEs, but the exact interactions relevant to effective learning are still being debated. VLEs are online sites where students can interact and interact with each other for the purpose of learning (Al-Obaydi, 2020). Ashrafi et al. (2020) and Flavin (2020) refereed that VLEs or learning management systems were originally designed as interconnected, communicative, and interactive learning environments to promote online and hybrid learning, but the educational innovations enabled by VLEs. Even so, COVID-19 has contributed to the development of online education and provided opportunities for critical reflection (Green et al., 2020).

The term virtual world refers to an environment simulated by a computer, typically in the form of a 2D or 3D environment in which many users may create avatars and explore the virtual world independently and simultaneously and communicate with others. The avatar can be a textual representation, a graphical representation, or even a video avatar with auditory and tactile feedback (Aichner & Jacob, 2015; Chen, 2022). Furthermore, the concept of a virtual world is defined by Koster (2004) as a spatially based representation of a persistent virtual environment that can accommodate multiple users simultaneously.

Benefits of Using Virtual Learning Environments in Education

There are many benefits of using VLEs in the education system through learning and teaching processes, where (Alharbi et al., 2013; Alves et al., 2017; Britain & Liber, 1999; Hearrington, 2010; Pem et al., 2021) points out of these benefits, which can be summarized, as in the following points:

1. Learning becomes student-centered.
2. Encourage dialogue and critical discussion about the educational content provided to the student.
3. Create a collaborative learning environment.
4. Learning different contents can help students master competences.
5. Provide educational opportunities for students without being restricted to time and place.
6. Students' reality and knowledge are inextricably linked.
7. It is an active and collaborative process.
8. Ensures constant feedback and continuous evaluation.
9. Equality among students.
10. Improve students' understanding of topics content.

Furthermore, Atkinson (2005) found that teachers' use of electronic and VLEs in the educational process is statistically positively related to the use of feedback and peer review, so these environments are likely to increase interaction between student and teacher peer groups. In contrast, Khafaji (2022) and Maggie (2004) state that the interactivity, modularity, collaboration, and learning styles of distance teaching methods in virtual environments are four pivotal factors for evaluating their quality. As Bell (2008) makes clear, in virtual worlds, avatars refer to digital representations of users (graphical) within the digital environment. Hence, the avatar goes beyond mere labeling or identification. The system is controlled solely in real-time by a human agent with an agency (capacity to perform actions). Thus, avatars are more than simple labels or names. In real-time, a human agent controls it solely because it has agency (the ability to act). Unlike social network sites like Facebook and Myspace, virtual worlds do not provide avatars for users, despite their persistent environment. Thus, to give this definition a more complete definition, a virtual world can also be defined as an ongoing computer-simulated environment where avatars represent users that interact with each other in real-time (Sivan, 2008).

Idea of Virtual Environment

In the virtual world, the mind is free from the limits of space, and human consciousness is transferred to a virtual world and environment that has been

electronically prepared and planned by the programmer on this environment from all tangible and imaginary aspects (Keller & Keller, 2005). The virtual environment is equipped with three-dimensional components in which there are people in the form of avatars or different models, even the series of events we may control if we want in our virtual environment. Thus, we reach to control the mental awareness of the user, and this is the most that a person seeks as a teacher or coach. The user, if he is a student or player, interacts in the virtual environment within a series of interactive events by simulating with virtual people and three-dimensional models, in environments that are difficult to reach realistically, oriented to the imagination, yet achieving a goal greater than real life and a greater impact on the interacting with it. In our virtual world, you can roam in the circulatory system, starting from head to foot; you can fly in blood, muscle, or even nerve cells discovering its components in an easy and fun way without forgetting from your memory, but it prompts you to think and search more for the smaller parts (Shudayfat et al., 2014a). As a result, and after we realized the importance of changing the methods of teaching science, we set out to make virtual lessons more interesting for today's generation in which the element of active interaction is between the student and the lesson, in addition to the element of suspense accompanying enjoyment of learning. So, the idea of our project was launched, the virtual science lesson.

Previous Study

Previous works on virtual education in journals and conferences were numerous, but now it has become necessary that virtual environments exist within the teaching plans of every teacher. It is because trends of today's youth are more technical and technological progress that require us to keep pace with these developments. Several studies referred that virtual simulation plays a big role in encouraging students to learn and even compete among themselves through interaction and raising their experiences level, and even access to explore new means (Alsalhi et al., 2022; Alves et al., 2017; Boulton et al., 2018; Cramer et al., 2007; Dede et al., 2006; Khaled, 2008; Stewart et al., 2006).

The results of these studies confirmed and concluded that 3D virtual environments aid in increasing students' academic achievement. Moreover, a 3D virtual environment offers students a more interactive, engaging, and participatory learning experience. Moreover, the Norwegian Refugee Council (NRC, 2012) stated that e-learning experiences provide opportunities for students to develop and use scientific and engineering practices for developing their ideas to explain phenomena and even solve problems. Likewise, the study conducted by Al-Shehri (2002) aimed to determine the impact of virtual laboratories on scientific experiments in biology in Saudi Arabia for learners, and the results revealed that academic achievement was better after using virtual laboratories. Also, another study conducted by Kopec (2002) aimed at whether it is possible to replace virtual anatomy with traditional anatomy. He made two groups, one of them anatomized a frog in the laboratory and put the results and observations, while the experimental group tended to enjoy the virtual anatomy of the frog and observe and interact with the anatomy. The teachers were present with the students of the virtual anatomy group, and they monitored the performance and made notes. The study concluded that there is no objection to using virtual anatomy if the student so desires to do so. Furthermore, Shudayfat et al. (2014b) in her study found in her comparison of the virtual laboratory the students dealt with as an alternative to the traditional laboratory the effectiveness of using virtual labs because it has a major role in solving many of the obstacles that we face in the event of using the traditional laboratory, such as the availability of materials and public safety. Also, several studies pointed out the positive attitudes of students toward the 3D virtual environment (Alrayes & Sutcliffe, 2011; Emam et al., 2019; Mikropoulos et al., 1998; Olatunji, 2022).

Table 1. Demographic information for participants

Group	n	Level	Learning method
Experimental	50	Intermediate	3D virtual environment
Control	49	Intermediate	Conventional learning
Total	**99**		

METHODOLOGY

Study Approach

As a result of its suitability to the nature of the study, this study used the quasi-experimental approach to explore the impact of a three-dimensional virtual environment on students' science achievement in ninth grade basic education stage. See **Figure 2** for a description of the study design. Moreover, a quantitative approach was used through a questionnaire distributed to students.

Study Participants

The participants in the study consisted of 99 male students in the ninth grade. They were divided into two groups, an experimental group consisting of 50 students and a control group consisting of 49 students in the basic education stage in the Ibn Al-Bitar for boys in the Marka Education Directorate/Capital Governorate Amman in Jordan, through the first semester of the academic year 2020/2021 schedule. **Table 1** shows demographic information for participants.

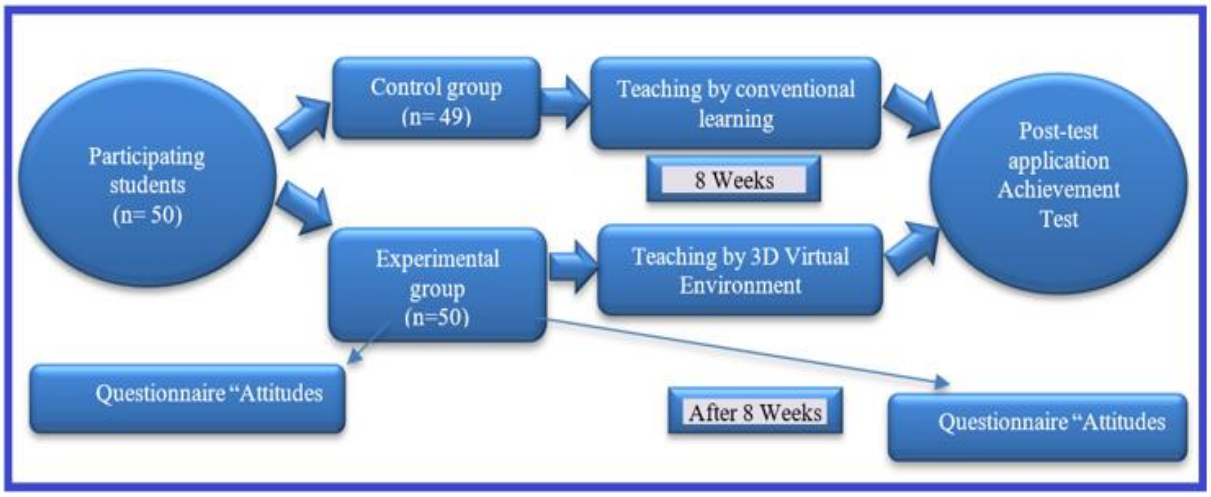

Figure 2. Design of the study (Alsalhi, 2020s)

Study Instruments

Achievement test

An achievement test was prepared for unit four of the ninth-grade science textbook (Human body systems) consisting of 20 multiple-choice questions, each with four options, one of which represents the correct answer, and the total score is 20. In this test, cognitive domains were assessed according to Bloom's taxonomy (Adams, 2015), 60 minutes were allotted for the test.

Validity and reliability of achievement test

In order to verify its virtual validity, the achievement test was submitted in its initial form to the jury members of the universities whose doctorate and master's degree holders are in curricula and methods of teaching science. Based on their suggestions and recommendations, some questions were deleted, and others were added, and even the test became valid. In order to verify the reliability of the achievement test, the researchers used the test-retest method. the Pearson correlation coefficient was counted between the two applications, a sample reconnaissance of 18 students was conducted from another school in the same area, and two weeks after the test was administered to the same sample of students, the total reliability coefficient (0.802) was determined for the purposes of this study based on the Pearson correlation coefficient between the two applications.

Questionnaire

The purpose of this questionnaire was to collect data about 50 students of the experimental group's attitudes toward learning science topics using the 3D virtual environment. 22 items were included in the questionnaire as part of the study's purpose. The validity method confirmed the validity of the questionnaire. The validity method confirmed the validity of the questionnaire. They also conducted a pilot study with 20 students from another school in the same area to verify the questionnaire's reliability using SPSS, which gave a Cronbach's alpha coefficient of 0.794.

Pre-Test

Table 2 shows how the researchers used a t-test to compare the students' achievement in science before applying the 3D virtual environment, to examine the equivalence of the two groups in the study. **Table 2** illustrates that since the obtained p-value=0.590 is greater than 0.05, the test is not significant at the 0.05 level, indicating that the experimental and control groups are not significantly different. Therefore, it was determined that the experimental and control groups were equivalent before the study could be carried out.

Virtual Environment Implementation Procedures

This project will be a three-dimensional VLE in which users will be in contact first through direct communication styles. The project includes the creation of a science lesson, a biology class as part of their general education requirement so that the components of the lesson are three-dimensional components as moving images, not as parts of the human body. We have found that when the student deals with the pictures of biology in the traditional science book, he finds it difficult to understand them. We have studied virtual environments, and we are trying to help teachers solve these problems through three-dimensional presentations that allow users (students) to study the

Table 2. t-test results of pretest between the experimental and the control groups

Group	n	Mean	Standard deviation	t-value	Significance (tailed)	Significance level
Pre-control	49	10.23	2.35	0.542	0.590	Not significant
Pre-experimental	50	9.83	2.87			

Note. *The significance level is p<0.05

shape with all its components and parts from all sides, especially with regard to organism cells of different dimensions. For many students, our virtual lesson was distinguished by how they look at the organs and thus may provide a greater opportunity to learn and understand. Virtual reality allows learners to interact with 3D models, through a set of elements of multimedia (Shudayfat et al., 2014a):

1. The VR (virtual reality) is one of the components of multimedia. It includes:
   a. **Text:** They render their worlds via text description.
   b. **Acoustics:** It is of the influences that exist to achieve lesson goals, and it is either a voice heard, or a voice issued by the user (the student) or the teacher.
   c. **Digital pictures:** They are taken through pictures available in the virtual environment, or from a digital camera, or scanners.
   d. **Animation:** They are those images that create a fluent illusion of motion in all directions while you are in your place.
2. Video clips accompanied by sound effects and 3D animations.

This is what the specialists in creating the virtual environment, especially the educational ones, gather upon. The design of the virtual environment goes through four successive stages including, planning the virtual idea, programming it in three dimensions, building the basic components of the educational environment like the educational material, scientific questions, and tests, and finally experimenting with the virtual lesson and applying it to the students.

Components of Virtual Environment Lesson

At first, we are preparing for our virtual biology lesson. The preparation phase begins with the use of suitable software to present a three-dimensional lesson in 3D-VLEs. Through the researcher's previous experiences in creating virtual environments, she uses the eon creator software, which is free software available for programmers to use within a certain period of use and within a limited range of 3D shapes ready to be presented in our virtual environments. Our lesson is a virtual lab. **Figure 3** indicates many virtual three-dimensional images of human organs that are studied through the science book for the seventh and eighth grades in the Jordanian Ministry curriculum.

A number of shapes were created for the virtual science lesson and then are collected in our virtual laboratory of biology, the most important parts of the human body in our virtual lesson.

Figure 4 extends throughout the entire length of the body. In the virtual model, we will walk, rotate, or even fly within the path of blood flow in the cardiovascular

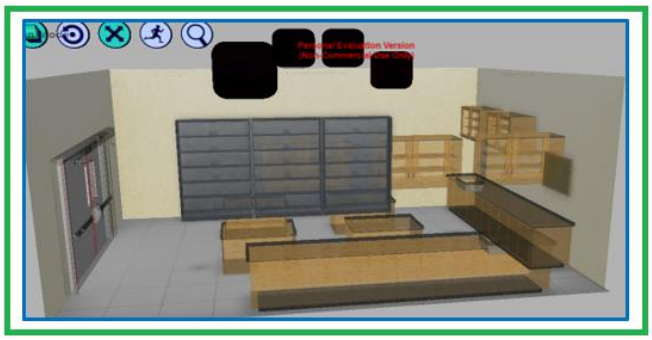

Figure 3. Our virtual laboratory (Platform - EON Reality, 2022)

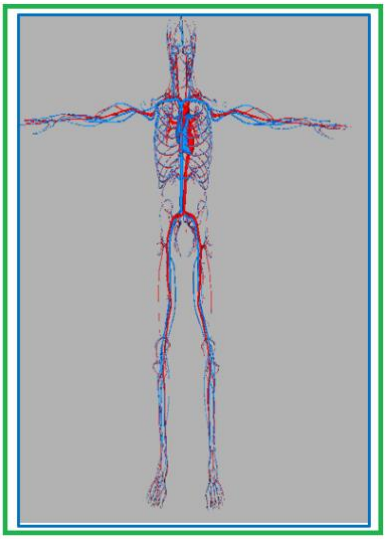

Figure 4. The embodied virtual circulatory system in our laboratory (Platform - EON Reality, 2022)

system. Through an interesting virtual journey, we stand at stations that are part of the body that the blood reaches. The embodied virtual circulatory system will also be displayed in a transparent environment that shows the parts of the blood flow in its path. The teacher has the option to record a video that he transmits to the student in any virtual simulated movement with our virtual embodied to be a tracker of the blood path with different parts of the body.

Heart

The heart is one of the parts that are difficult for students to understand in the usual way because of the complexity of its components, so we will follow ways in which we display its parts in a three-dimensional way, thus making it easier for the student to study and understand the parts of the heart. Our virtual heart is very wonderful and attractive, as it attracts the learner in a way enjoy rotating in three dimensions in the heart model, and even flying in the heart, let us take time to learn without getting bored, and get the best results in understanding. A three-dimensional embodied heart (**Figure 5**) shows the main components of the heart: the right atrium, right ventricle, left atrium, left ventricle,

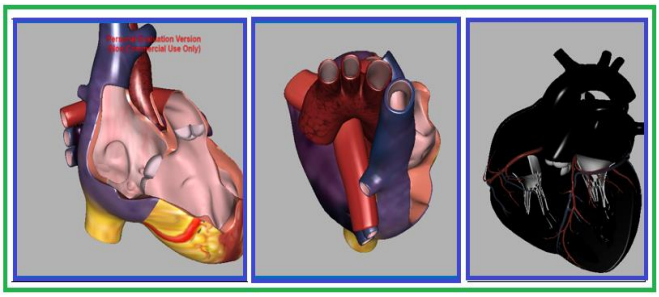

Figure 5. The embodied pictures of the heart (Platform - EON Reality, 2022)

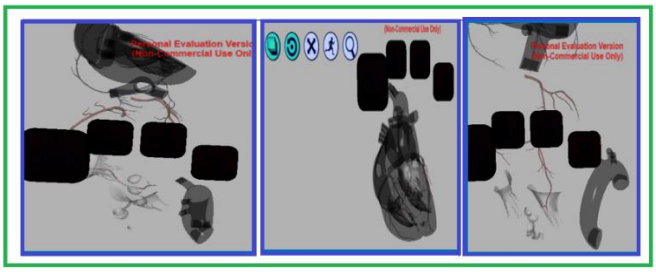

Figure 6. Parts of the simulation images in our laboratory (Platform - EON Reality, 2022)

permeated by arteries and veins. All of them are minute parts that need contemplation and focus in understanding how they are structured to know how they perform their basic functions in the body. All these requirements are fulfilled through the virtual heart. The student now enters the virtual lesson in the form of an avatar and is present with the triangular shapes.

Figure 5 shows the embodied pictures of the heart taken while the student was simulating with the heart model. In the image of the heart, the student interacts with it in several ways, the first of which is to fly or rotate in the heart by controlling the keyboard or mouse (**Figure 6**). The student has options that control how to view the hologram and options that allow him to watch the small parts of the hologram as it flies and separates from the heart, some are in an attractive manner, allowing him to distinguish the different parts and understand their structure.

Muscular system

One of the systems that the student studies in our laboratory, consisting of several different organs. **Figure 6** helps in studying more to study the structures and functions of these organs. **Figure 7** shows the human muscular system in three dimensions

Urinary system

One of the organs in human body. **Figure 8** explains in detail its components, and so the student interacts with the model to learn by himself and answers the questions that are directed to him in virtual laboratory.

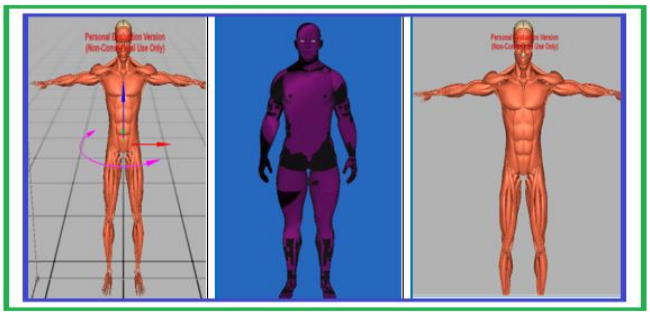

Figure 7. Pictures of models of the human musculoskeletal system (Platform - EON Reality, 2022)

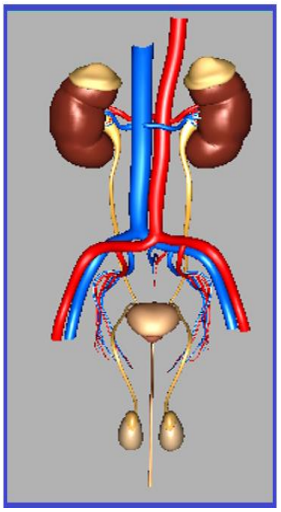

Figure 8. The urinary system with all its parts (Platform - EON Reality, 2022)

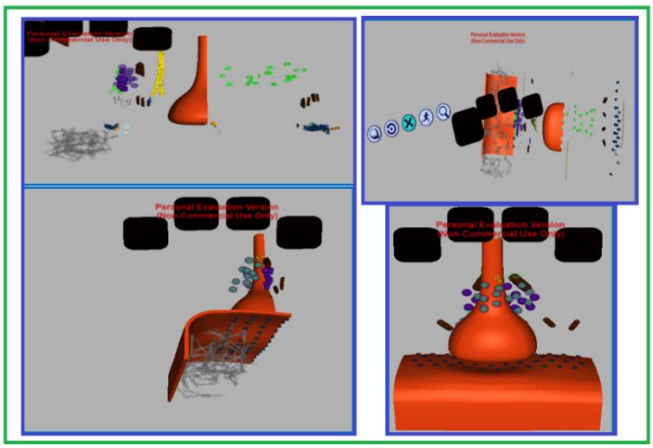

Figure 9. Bone: Ways & shapes of muscle models in front of the AVATAR (Platform - EON Reality, 2022)

Muscle

One of the components of the muscular system is the bones. **Figure 9** shows the anatomy of the basic components of the muscle, with images of hologram views in our laboratory.

The skeleton

The skeleton gives the body and the support that distinguishes it from all other types of organisms, which

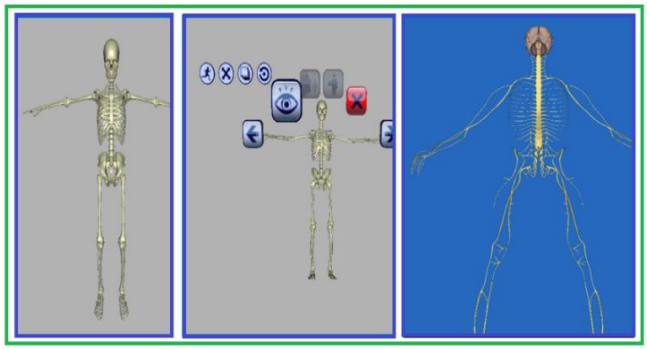

Figure 10. Different pictures of a human skeleton (Platform - EON Reality, 2022)

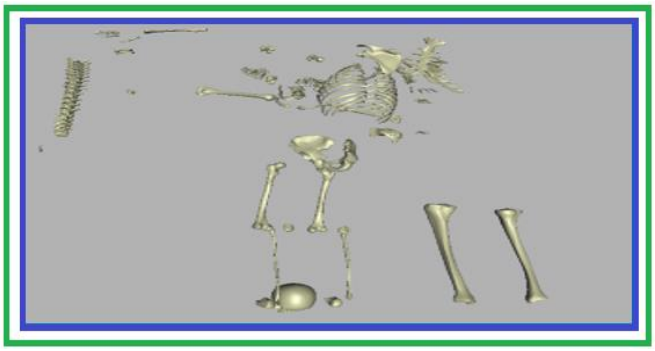

Figure 11. How components of skeletal system are volatilized (Platform - EON Reality, 2022)

distinguishes the forms of living organisms from each other in even more precise forms. Our student will follow a skeleton and can compare the shapes of the bones and determine their location, in the model with which **Figure 10** interacts.

Figure 11 shows a picture taken while the skeletal system was scattered into its parts in front of the student, who was interacting with the model. The parts would fly in front of him and rotate as he wanted. He scrutinizes them and records his observations, learning with enjoyment and playing.

Nerve cell

What is a nerve cell made of? What is the shape of a nerve cell? What is the function of a nerve cell? Our students access all this information through the model of the neuron. All information is available in different presentation methods as shown in **Figure 12**.

Figure 13 shows the neural tangle in a neural tree, explaining its basic components. Through the components, the study of how the synapse allows nerve messages to be transmitted between parts of the body.

In the neural tangle, we move between the parts of the neuron and go to choose the cell segmentation, so the student's interaction with it will be according to the apparent form **Figure 14**.

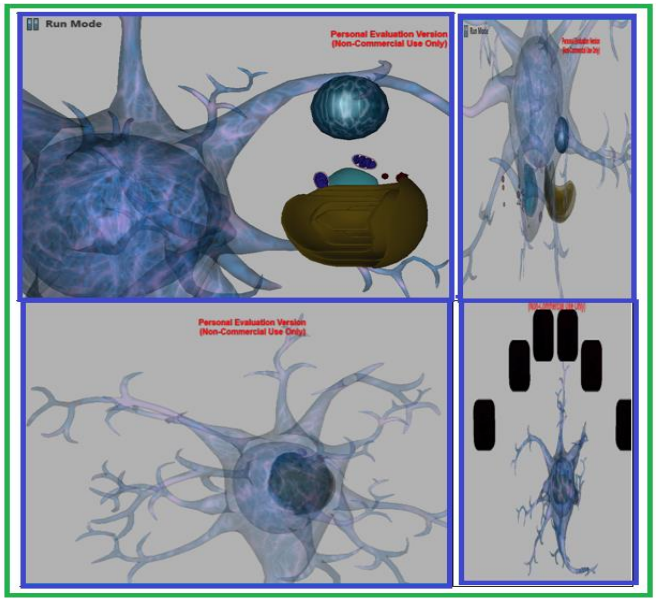

Figure 12. A group of images of a neuron (Platform - EON Reality, 2022)

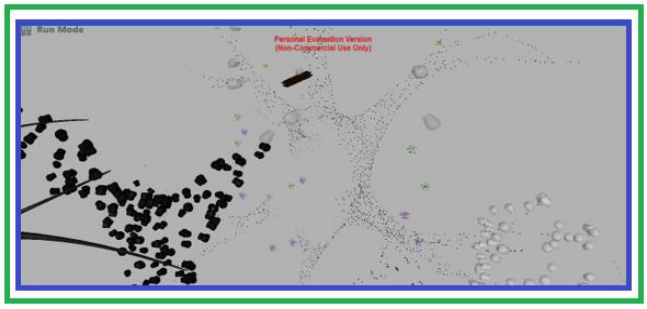

Figure 13. Flight and rotation of synaptic components (Platform - EON Reality, 2022)

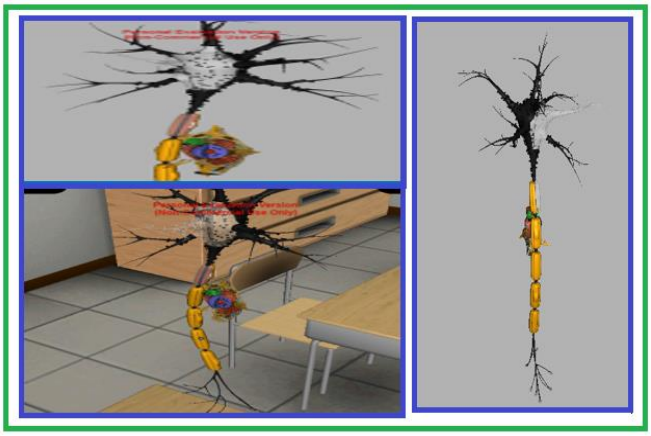

Figure 14. Parts of a synapse (Platform - EON Reality, 2022)

Digestive system

How is digestive system arranged between the ribs? How student passes between arteries and veins. Where it begins and ends? Our models respond and give accompanying information as shown in **Figure 15**.

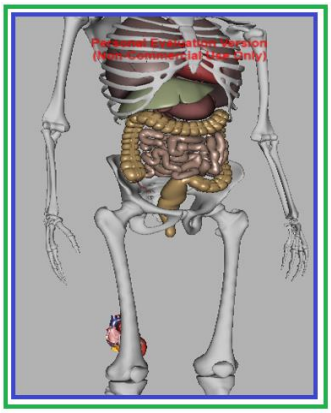

Figure 15. Digestive system (Platform - EON Reality, 2022)

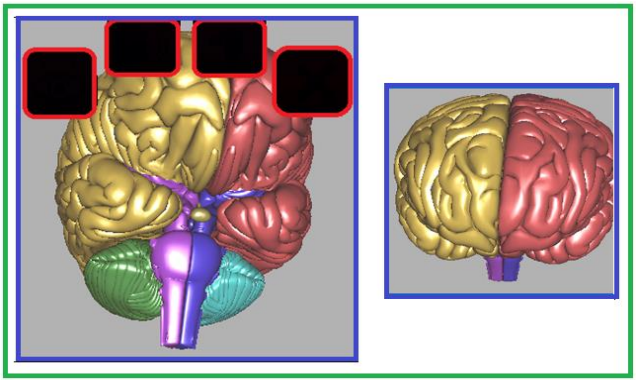

Figure 16. A virtual brain (Platform - EON Reality, 2022)

Brain

Figure 16 is an illustrative model of brain images that our student interacts with. Colors in the model play a big role in helping the student to anatomy the brain.

The most important features of our lesson in our virtual laboratory:

1. Easy to use, any student can easily register and enter our virtual environment and interact with it.
2. An interactive environment is full of 3D visual effects and supportive audio.
3. Virtual presentation supported by three-dimensional holograms.
4. Virtual media systems provide us with possibilities to create educational environments in imaginary virtual worlds, which are not available in the real physical world that is traditional. These virtual worlds help students to enhance their scientific mental imaginations. This is what requires learning science.

Using Our Virtual Lesson

We created our virtual learning lesson in the biology lab. In the process of creation, we used a free-to-use application that has three-dimensional models available, which help us create our educational environment, then prepare the environment with simulation effects and three-dimensional interaction in a creative way.

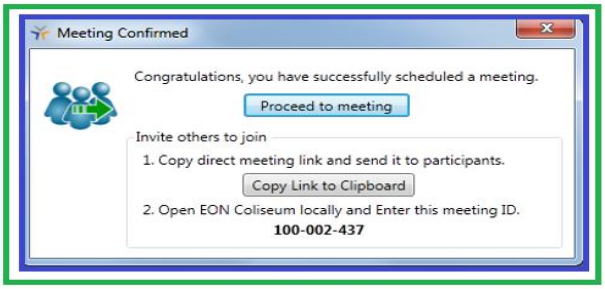

Figure 17. A message sent to the user (Platform - EON Reality, 2022)

After completing the software preparation equipment, we will move to the process of publishing our virtual lesson to be available to any interactive user on the world wide web. Then enter the interactive lesson, and a stage of educational play begins by simulating our lesson in our environment with other players (students) who are present at the same time in the class.

For the process of simultaneous communication and communication between users and even the teacher, we use the EON coliseum application, so certain numbers from the teacher are distributed to students to register and be allowed to enter the lesson.

The teacher communicates these special numbers in the way he prefers between him and his students. He may send it via e-mail, or a short message by mobile (**Figure 17**).

Figure 17 shows a message sent to the user to find himself here, "meeting ID".

After sending and receiving a "meeting ID" to all students, the user downloads the free EON coliseum program from the Internet. Now you enter and specify a name that you use in the virtual environment, which will interact with our virtual environment.

The most important stage in the registration process is the student's freedom to choose the avatar that he represents in the virtual lesson, so the student's presence will be through the avatar. The most important stage in the registration process is the student's freedom to choose the avatar that he represents in the virtual lesson, so the student's presence will be through the avatar. The student can choose what he wants from it according to his personality and desire. This matter is chosen for our students. **Figure 16** explains options from the avatar. Let's highlight play and enjoy learning.

The second point in the registration is to choose a code name "nickname" that represents the student in the lesson and leave him the freedom to choose the code name. Now a special side record must be available with the teacher only with the names of the real students against the symbolic name he chose in the virtual environment so that the teacher monitors the student's performance in the lesson and record notes and give

Figure 18. User meeting (Platform - EON Reality, 2022)

marks, especially as it is one way to interact with our lesson with short exams.

In the same way, other students can access the lesson through "join multi-user attendee" and choose a code name "nickname" see **Figure 18** so that all students are present at the same time and in the same virtual environment.

The most important problems faced by the teacher in the traditional lesson are the presence of students who are ashamed of their answers, so they do not interact in the classroom. This problem was solved by using an avatar- the graphical representation of the user's own character or persona, so we encouraged our students to answer without shame.

Now our students are present in our virtual laboratory of biology, physically within different geographic locations but virtually in the same location, with the presence of the teacher, they exist in a virtual world in which they interact through virtual 3D simulation. The virtual environment is designed for a number of users interacting with each other in a fun world with attractive pictures of biology lessons that show cooperation between students.

In our virtual lab, the choice is left to the student to choose the way to move in the lab. It turns more to be fun and because it is fun, young people often become very absorbed in what they are doing. It is going to fly or have fun by walking among the three-dimensional models that abound in our virtual lab or circling the models, and the student moves by using the keyboard and even the mouse for the computer.

Figure 19 shows three ways to interact with the virtual environment: walking, flying, and spinning to discover our models.

Cooperation between students is simultaneous at the same time, which is one of the most important features of our virtual educational environment, which differs from that of e-learning method. Cooperation between users and communication among them in our virtual lab is followed by methods that have been prepared in advance for this goal. Communication is in writing by

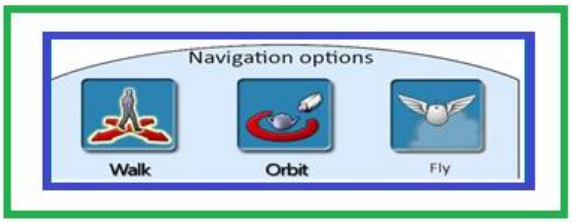

Figure 19. Interaction methods in the virtual environment (Platform - EON Reality, 2022)

Figure 20. A display screen in front of the users (Platform - EON Reality, 2022)

text messages that are displayed on the side screen of the virtual lab as shown in **Figure 20**, which is between text messages, a student and the professor, and thus the messages are the script recorded and visible to all players in our virtual lab.

The second means of communicating with voice messages is through the voice. Each user has a microphone connected to his device through which he interacts with our lab. The teacher can now control the voice messages through the option of controlling the student speakers' showcase.

The student operates virtual lab and interacts with its components. There are different resources for learning in our virtual models where the teacher's interaction with the student synchronizes online at the same time. These resources are YouTube, Wikipedia, presentation, video, a link to a website, in addition to options for the rotational movement of the model, or the transparency of each part. Each model shown in the components of our lesson contains all these resources for learning.

All of these methods provide the information the student needs about the model. **Figure 21** shows the screen that appears in front of the student in the virtual lab when he clicks on a particular model.

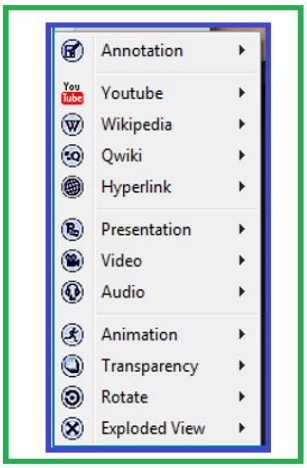

Figure 21. Learning resources accompanying each model in our laboratory (Platform - EON Reality, 2022)

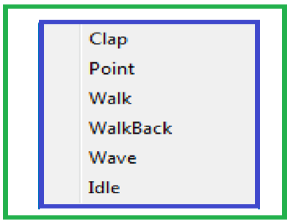

Figure 22. Options in front of Avatar (Platform - EON Reality, 2022)

All information resources are available online for each student to interact with the models displayed in our virtual lesson. This is how the student gets all the information he needs in the fastest way and shortest time, and even has a role in interacting with these resources in our virtual laboratory with our models.

Several options are available in front of the avatar to move while running the virtual environment. He can clap, walk, walk backward, wave his hands, or spin as in **Figure 22**. All of these options attract students and let them enjoy learning.

While the students are in the virtual laboratory, many of our virtual models of biology are available and a short test appears in front of them to answer to get a mark recorded by the teacher in his record of marks. **Figure 23** shows the appearance of a quiz in front of the avatar

Our Virtual Experiment Application

After completing the preparation of our virtual laboratory for biology for the primary classes, we began to implement our work. The beginning was with choosing a group of 10 students in the seventh grade from King Abdullah School for Excellence.

Figure 23. A short exam in front of the student (Platform - EON Reality, 2022)

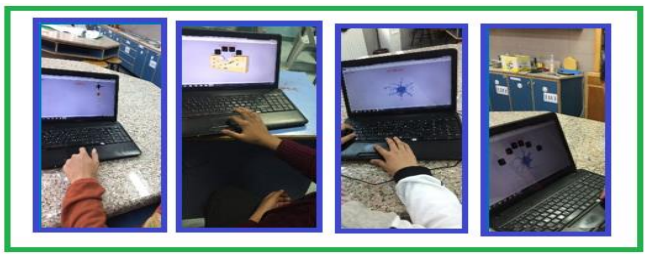

Figure 24. Virtual lab application (Platform - EON Reality, 2022)

The students were unanimously agreed in the school laboratory (**Figure 24**), and an idea of the virtual experiment was clarified, and students were prepared with computers to accomplish the task. The most important tasks were presented.

RESULTS

Study Findings Related to RQ1

The question was what is the effect of using a 3D virtual environment on improving students' achievement in biology topics in science textbook of ninth grade in the middle stage?

A t-test was used to calculate the difference between the mean scores of students in the experimental group and the control group in the science achievement post-test. **Table 3** shows the results.

The results in **Table 3** indicate that the t computed value was 9.661. This is larger than in the t table, and p-value (0.000) is smaller than 0.05, which means there are significant differences at the significance at 0.05 level, which indicates that there is a significant difference between the mean scores of the control group and the experimental group in the science textbook post-test, in favor of the experimental group.

Table 3. Differences between experimental and control groups in the post-test as measured by the t-test

Group	n	Mean	Standard deviation	t-value	Significance (tailed)	Significance level
Post-control	49	15.66	1.619	9.661	0.000	Significant
Post-experimental	50	18.51	1.214			

Note. *The significance level is p<0.05

Table 4. Means and standard deviations of pre- and post-application for experimental group on attitudes scale towards using 3D virtual environment

Experimental group	n	Mean	Standard deviation
Post-application	50	3.62	0.616
Pre-application	50	2.42	0.857

The mean score of the experimental group was 18.51 in the post-achievement test, while the mean score of the students in the control group was 15.66 in the post-achievement test. This result referred that students who learned using the virtual environment scored higher on the post-test, indicating that the experimental group was taught using the virtual environment during the 6-week period, whereas the control group was taught also during the six-week period using conventional methods. Based on the findings of the study, it can be concluded that the virtual environment has a positive effect on improving the students' science achievement.

Study Findings Related to RQ2

The question was what are the students' attitudes in the experimental group towards using a 3D virtual environment in learning biology topics in the science textbook of grade ninth?

To determine whether there is a difference between the results of the experimental group's students regarding their attitudes towards the use of 3D virtual environment in their teaching the topics of science content before and after application, paired samples t-test was applied to the pre-application and post-application scores of the 3D virtual environment attitude scale. As the results obtained are shown in **Table 4**.

According to result in **Table 5**, it is seen that there was a significant difference ($t[49]=3.968$, $p<0.05$) between the experimental group students' post-application mean (3.62) and their pre-application mean (2.42). It can be concluded from the findings of the study that experimental group students learn science content in a virtual environment with a positive attitude.

DISCUSSION

The results regarding the first study question, t the effect of using a 3D virtual environment on improving students' achievement in biology topics in the science textbook of ninth grade in the middle stage, the experimental group was significantly outperforming the control group in terms of achievement in biology topics. **Table 3** shows that for students in the experimental group, the average post-test score of students is 18.51, while for those in the control group it is 15.66. As a result, students in the experimental group achieved a higher score on biology topics than students in the control group thanks to the application of a 3D virtual environment while they were learning biology topics when compared to the learning of students of the control group via conventional learning. Furthermore, as indicated in **Table 3**, the results showed that significance was significantly at the 0.05 level where the p-value was equal 0.000 and was less than 0.05. As a result, there is a significant difference between the two groups of learners when it comes to understanding the human body systems unit topics. This finding confirms several earlier studies, which also found that 3D virtual environments have a positive impact on students' achievement (Alsalhi et al., 2022; Alves et al., 2017; Boulton et al., 2018; Cramer et al., 2007; Dede et al., 2006).

In conclusion, both the current study and the studies reviewed show that 3D virtual environments aid in increasing students' academic achievement.

Moreover, a 3D virtual environment offers students a more interactive, engaging, and participatory learning experience. The second study question related to the students' attitudes in the experimental group towards using a 3D virtual environment in learning biology topics in the science book for the ninth grade. Before the experimental students used the 3D virtual environment for the first time, a questionnaire was introduced to them. Eight weeks later, the questionnaire was reapplied to the same students (post-application). 3D virtual environment attitude questionnaire pre- and post-application scores were compared using a paired samples t-test. The results shown in **Table 3** and **Table 4** show that the average for pre- and post-application was 3.62 for the post-application, compared to the pre-application questionnaire (where the average was 2.42). Additionally, there was a significant difference ($t[49]=3.968$, $p<.05$) at the 0.05 level where the p-value was equal 0.000 and was less than 0.05. Additionally, there was a significant difference ($t[49]=3.968$, $p<.05$) at the 0.05 level where the p-value was equal 0.000 and was less than 0.05. this result confirmed that the experimental group held positive attitudes toward the application of a 3D virtual environment. This finding is consistent with prior studies (Alrayes & Sutcliffe, 2011; Emam et al., 2019; Mikropoulos et al., 1998; Olatunji, 2022). On the contrary, the results of study do not agree with some previous studies whose results did not find significant differences in students' attitudes towards using the 3D

Table 5. Comparison of the experimental group students pre- and post-application scores mean of the 3D virtual environment attitude scale via the paired samples t-test

Experimental group	n	Mean	Mean differences	Standard deviation	t	df	Significance (2-tailed)	Significance level
Post-application	50	3.62	1.20	0.616	3.968	49	0.000	Significant
Pre-application	50	2.42		0.857				

Note. *The significance level is $p<0.05$

virtual environment (Okeke, 2021) as results showed that there is no significant difference between students' attitudes towards 3D virtual environment.

CONCLUSIONS

The study reached the following results, including virtual ones, as synchronous learning environments directly with users, for programmers and teachers in technical learning. We found that virtual learning has many advantages to be a basis for learning complex science subjects, often for students. Students are present in interactive virtual environments that are attractive and entertaining for them, and at the same time play a role in their education. Today's youth are turning a lot to virtual electronic games with sound, audio, and even visual effects (Stiles, 2000). Skills help to direct to virtual environments and exploit them in education, and at the same time benefit from the skills of today's generation. Virtual communication techniques such as text messaging, voice and chat are all ways that not only increase social communication among students that today we miss a lot in our classes, but also strengthen the exchange of opinions and ideas between them. They invite them to respect the other opinion through virtual discussions, their presence under Avatar characters removes social and class differences between them.

Limitations of the Study

Like any other analysis, this study has had some limitations that should be acknowledged. First, the study was limited to a sample size of 99 students participated in this study, which may be affected the generalizability of the result of this study. Second, the study faced a problem in the application of educational virtual environments the need to have two-way technical expertise in the field of programming and scientific expertise in the scientific subject with the availability of educational expertise to achieve educational and educational goals. Unfortunately, it is difficult to find such competencies in a particular person; solution is to gather groups that work within an integrated work team that complements each other for a distinct goal, scientific virtual lessons. Third, preparing for virtual lesson requires a long period of preparation and a great and intense effort to spread the application of virtual lessons.

Recommendations

Based on the results, the study recommends:

1. 3D virtual environments are useful for developing the knowledge and skills of students, so teachers should consider using them in their teaching.
2. Holding training courses for the use of a 3D virtual environment to improve teachers' ability to teach science.
3. The necessity of providing the necessary tools and devices for a three-dimensional virtual environment in middle schools.

Delimitations of the Study

1. **Subject limitations:** The study was limited to unit four (human body systems) of the science textbook, which had been taught during the academic year 2020/2021.
2. **Human limitations:** The study was limited to ninth-grade students in the basic education stage in the Ibn Al-Bitar for boys in the Marka Education Directorate/Capital Governorate Amman in Jordan.
3. **Spatial limitations**: Ibn Al-Bitar for boys in the Marka Education Directorate/Capital Governorate Amman in Jordan.
4. **Time limitations**: Academic year 2020/2021 first semester.

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REFERENCES

Adams, N. E. (2015). Bloom's taxonomy of cognitive learning objectives. *Journal of the Medical Library Association, 103*(3), 152-153. http://doi.org/10.3163/1536-5050.103.3.010

Agudo-Peregrina, A., Iglesias-Pradas, S., Conde-González, M., & Hernández-García, A. (2014). Classification of interactions for learning analytics and their relation with performance in VLE-supported F2F and online learning. Can we predict success from log data in VLEs? *Computers in Human Behavior, 31*(1), 542-550. https://doi.org/10.1016/j.chb.2013.05.031

Aichner, T., & Jacob, F. (2015). Measuring the degree of corporate social media use. *International Journal of Market Research, 57*(2), 257-275. https://doi.org/10.2501/IJMR-2015-018

Alharbi, M. T., Platt, A., & Al-Bayatti, A. H. (2013). Personal learning environment. *International Journal for E-Learning Security, 3*(1), 280-288. https://doi.org/10.20533/ijels.2046.4568.2013.0036

Al-Obaydi, L. (2020). Using virtual learning environment as a medium of instruction in EFL context: College teachers' attitudes. *Intensive Journal, 3*(2), 18-30.

Alrayes, A., & Sutcliffe, A. (2011). Students attitudes in a virtual environment (second life). *Journal of Virtual Worlds Research, 4*(10), 1-17. https://doi.org/10.4101/jvwr.v4i1.2107

Alsalhi, N. (2020). The effects of the use of the Know-Want-Learn strategy (KWL) on fourth grade students' achievement in science at primary stage and their attitudes towards it. *EURASIA Journal of Mathematics, Science and Technology Education, 2020, 16*(4), em1833. https://doi.org/10.29333/ejmste/115165

Alsalhi, N, R., Omar, K., Shehieb, W., Eltahir, M., & Al-Qatawneh, S. (2022). Undergraduate students' perceptions of the use of simulation software through online learning in colleges of engineering during the COVID-19 pandemic: A case study at Al-Balqa Applied University, Jordan. *Periodicals of Engineering and Natural Sciences, 10*(1), 678-691. https://doi.org/10.21533/pen.v10i1.2753

Al-Shehri, A. H. (2002). *The effect of using virtual laboratories in imparting laboratory experiment skills in the biology course for third-year secondary students* [PhD thesis, Umm Al-Qura University].

Alves, P., Miranda, L., & Morais, C. (2017). The influence of virtual learning environments in students' performance. *Universal Journal of Educational Research, 5*(3), 517-527. https://doi.org/10.13189/ujer.2017.050325

Ashrafi, A., Zareravasan, A., Rabiee Savoji, S., & Amani, M. (2020). Exploring factors influencing students' continuance intention to use the learning management system (LMS): A multi-perspective framework. *Interactive Learning Environments, 30*(8), 1475-1497. https://doi.org/10.1080/10494820.2020.1734028

Atkinson، L. C. (2005). *Schools as learning organization: Relationships between professional learning communities and technology-enriched learning environments* [PhD thesis, The University of Oklahoma].

Bell, M. W. (2008). Toward a definition of virtual worlds. *Journal of Virtual Worlds Research, 1*(1), 1-5. https://doi.org/10.4101/jvwr.v1i1.283

Benachio, G. L. F., Freitas, M. D. C. D., & Tavares, S. F. (2020). Circular economy in the construction industry: A systematic literature review. *Journal of Cleaner Production, 260*, 121046. https://doi.org/10.1016/j.jclepro.2020.121046

Bote-Lorenzo, M. L., Gómez-Sánchez, E., Vega-Gorgojo, G., Dimitriadis, Y. A., Asensio-Perez, J. I., & Jorrin-Abellan, I. M. (2008). Gridcole: A tailorable grid service based system that supports scripted collaborative learning. *Computers & Education, 51*(1), 155-172. https://doi.org/10.1016/j.compedu.2007.05.004

Boulton, C. A., Kent, C., & Williams, H. T. P. (2018). Virtual learning environment engagement and learning outcomes at a 'bricks-and-mortar' university. *Computers and Education, 126*, 129-142. https://doi.org/10.1016/j.compedu.2018.06.031

Britain, S., & Liber, O. (1999). A framework for pedagogical evaluation of the virtual learning environments. https://hal.archives-ouvertes.fr/hal-00696234/document

Cardullo, V., Wang, C. H., Burton, M., & Dong, J. (2021). K-12 teachers' remote teaching self-efficacy during the pandemic. *Journal of Research in Innovative Teaching & Learning, 4*(1), 32-45. https://doi.org/10.1108/JRIT-10-2020-0055

Chen, B. X. (2022). What is all the hype about the metaverse? *The New York Times*. https://www.nytimes.com/2022/01/18/technology/personaltech/metaverse-gaming-definition.html

Cramer, K. M., Collins, K. R., Snider, D., & Fawcett, G. (2007). The virtual lecture hall: Utilization, effectiveness and student perceptions. *British Journal of Educational Technology, 38*(1), 106-115. https://doi.org/10.1111/j.1467-8535.2006.00598.x

Dede, C., Ketelhut, D., & Ruess, K. (2006). *Designing for motivation and usability in a museum-based multiuser virtual environment*. http://www.gse.harvard.edu/~dedech/muvees/documents/AELppr.pdf

deNoyelles, A., & Seo, K. K.-J. (2012). Inspiring equal contribution and opportunity in a 3d multiuser virtual environment: Bringing together men gamers and women non-gamers in second life. *Computers & Education, 58*(1), 21-29. https://doi.org/10.1016/j.compedu.2011.07.007

Emam, O., Abdelsalam, M., Khedr, A. E., & Helmy, Y. (2019). A general approach students' attitude towards virtual reality technology in distance education environment. *Future Computing and Informatics Journal, 4*(1), 1-15. https://doi.org/10.54623/fue.fcij.4.1.2

Flavin, M. (2020). *Re-imagining technology enhanced learning*. Springer. https://doi.org/10.1007/978-3-030-55785-0

Franklin, H., & Harrington, I. (2019). A review into effective classroom management and strategies for student engagement: Teacher and student roles in today's classrooms. *Journal of Education and Training Studies, 7*(12), 1. https://doi.org/10.11114/jets.v7i12.4491

Green, W., Anderson, V., Tait, K., & Tran, L. T. (2020). Precarity, fear, and hope: Reflecting and imagining in higher education during a global pandemic.

Higher Education Research & Development, 39(7), 1309-1312. https://doi.org/10.1080/07294360.2020.1826029

Guan, T. (2021). *Features of technologies that make remote work* [Doctoral dissertation, University of California, Irvine].

Guomin, Z., & Jianxin, Z. (2010). An educational value analysis of SLOODLE-based distributed virtual learning system. In *Proceedings of the 2nd International Workshop on Education Technology and Computer Science* (pp. 402-405). https://doi.org/10.1109/ETCS.2010.516

Hamed, M. H. (2012). *The effectiveness of a three-dimensional environment on increasing students' achievement motivation and their attitudes towards the virtual environment* [PhD thesis, Ain-Shams University].

Hearrington, D. (2010). Evaluation of learning efficiency and efficacy in a multi-user virtual environment . *Journal of Digital Learning in Teacher Education, 27*(2), 65-75. https://doi.org/10.1080/21532974.2010.10784659

Keller, H. E:, & Keller, E. E. (2005). Making real virtual lab. *Science Education Review, 4*(1), 2-11.

Khafaji, S. (2022). Designing a virtual environment to develop the female students' skills in draping on the mannequin. *Journal of Art, Literature, Humanities and Social Sciences, 83*(1), 300-327. https://doi.org/10.33193/JALHSS.83.2022.727

Khaled, J. S. (2008). *The effect of employing a virtual learning environment in teaching science on of the sixth-graders' achievement at UNRWA schools in Nablus District* [Master's thesis, An-Najah National University].

Kopec, R. H. (2002). *Virtual, on-line, frog dissection vs. conventional laboratory dissection: A comparison of student achievement and teacher perceptions among honors, general ability, and foundations level high school biology classes* [Master's thesis, Seton Hall University].

Koster, R. A. (2004). *Virtual world by any other name?* http://terranova.blogs.com/terra_nova/2004/06/a_virtual_world.html

Kumar, D., Radhamani, R., Nizar, N., Achuthan, K., Nair, B., & Diwakar, S. (2018). Virtual and remote laboratories augment self-learning and interactions: Development, deployment, and assessments with direct and online feedback. *PeerJ Preprints*. https://doi.org/10.7287/peerj.preprints.26715v1

Laurillard, D. (1993). *Rethinking university teaching: A conversational framework for the effective use of educational technologies*. Routledge.

Maggie, M. L. (2004). *Learning online*. Routledge.

Mapolelo, D. C., & Akinsola, M. K. (2015). Preparation of mathematics teachers: Lessons from review of literature on teachers' knowledge, beliefs, and teacher education. *American Journal of Educational Research, 3*(4), 505-513.

Mikropoulos, T. A., Chalkidis, A., Katsikis, A., & Emvalotis, A. (1998). Students attitudes towards educational virtual environments. *Education and Information Technologies 3*, 137-148. https://doi.org/10.1023/A:1009687025419

Mokhtar, F. A. (2016). Rethinking conventional teaching in language learning and proposing Edmodo as intervention: A qualitative analysis. *Malaysian Online Journal of Educational Technology, 4*(2), 22-37.

Munthe, B., Arifin, A., Nugroho, B. S., & Fitriani, E. (2021). Online student attendance system using Android. *Journal of Physics: Conference Series, 1933*(1), 012048. https://doi.org/10.1088/1742-6596/1933/1/012048

Nayyef, Z. T., Amer, S. F., & Hussain, Z. (2018). Peer to peer multimedia real-time communication system based on WebRTC technology. *International Journal of Engineering & Technology, 7*(2.9), 125-130.

NRC. (2012). *A framework for K-12 science education*. National Academies Press.

Okeke, G. (2021). *Students' perception of and attitude to online teaching during COVID-19 lockdown: Implications for students' achievement in English grammar* [Paper presentation]. The Conference of School of Education, Federal College of Education (Special), Oyo.

Olatunji, S. O. (2022). Students' attitude to virtual teaching of the English language in secondary schools in Oyo State: Implications for students achievement. *Educenter: Jurnal Ilmiah Pendidikan* [*Educenter: Educational Scientific Journal*], *1*(7), 1-7.

Pai, R. Y., Gopal, S., Padma, S., & Srivastava, S. (2022). Analyzing how e-learning and virtual reality could be integrated to enhance studies. *ECS Transactions, 107*(1), 13163. https://doi.org/10.1149/10701.13163ecst

Pem, U., Dorji, C., Tshering, S., & Dorji, R. (2021). Effectiveness of the virtual learning environment (VLE) for online teaching, learning, and assessment: Perspectives of academics and students of the Royal University of Bhutan. *International Journal of English Literature and Social Sciences, 6*(4), 183-197. https://doi.org/10.22161/ijels.64.30

Platform - EON Reality. (2022). *EON Coliseum*. https://eonreality.com/platform/

Sadeghi, M. (2019). A shift from classroom to distance learning: Advantages and limitations. *International Journal of Research in English Education, 4*(1), 80-88. https://doi.org/10.29252/ijree.4.1.80

Schott, C., & Marshall, S. (2018). Virtual reality and situated experiential education: A conceptualization and exploratory trial. *Journal of Computer-Assisted Learning, 34*(6), 843-852. https://doi.org/10.1111/jcal.12293

Sera, L., & McPherson, M. L. (2019). Effect of a study skills course on student self-assessment of learning skills and strategies. *Currents in Pharmacy Teaching and Learning, 11*(7), 664-668. https://doi.org/10.1016/j.cptl.2019.03.004

Shudayfat, E. A., Moldoveanu, A., & Gradinaru, A. (2014a). Learning the bases of chemistry in a content rich, game based 3D MMO virtual environment. In *Proceedings of the 10th International Scientific Conference eLearning and Software for Education* (pp. 50-59).

Shudayfat, E. A., Moldoveanu, F., Moldoveanu, A., Gradinaru, A., & Dascalu, M.-I. (2014b). 3D game-like virtual environment for chemistry learning. *Scientific Bulletin of UPB, Series C, 76*(3), 78-88.

Sivan, Y. (2008). 3D3C real virtual worlds defined: The immense potential of merging 3D, community, creation, and commerce. *Journal of Virtual Worlds Research, 1*(1), 1-32. https://doi.org/10.4101/jvwr.v1i1.278

Stewart, B. L., Ezell, S., DeMartino Darrell, R., Rana, & Patterson, B. (2006). Virtual technology and education a collaborative pilot case. *The Quarterly Review of Distance Education, 7*(4), 377-385.

Stiles, M. J. (2000). Effective learning and the virtual learning environment. In *Proceedings of the European University Information System 2000 Conference* (pp. 171-180).

Symonenko, S. V., Osadchyi, V. V., Sysoieva, S. O., Osadcha, K. P., & Azaryan, A. A. (2020). Cloud technologies for enhancing communication of IT professionals. *CTE Workshop Proceedings, 7*, 225-236. https://doi.org/10.55056/cte.355

Taylor, C., Dewsbury, B., & Brame, C. (2022). Technology, equity, and inclusion in the virtual education space. In H. J. Witchel, & M. W. Lee (Eds.), *Technologies in biomedical and life sciences education* (pp. 35-60). Springer. https://doi.org/10.1007/978-3-030-95633-2_2

Wei, H. C., & Chou, C. (2020). Online learning performance and satisfaction: do perceptions and readiness matter? *Distance Education, 41*(1), 48-69. https://doi.org/10.1080/01587919.2020.1724768