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Virtual reality systems enhance students' achievements in engineering education

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ABSTRACT

Virtual reality (VR) is being used for many applications, ranging from medicine to space and from entertainment to training. In this research paper, VR is applied in engineering education, the scope being to compare three major VR systems with the traditional education approach when we do not use any VR system (No-VR). The Corner Cave System (CCS) is compared with the Head Mounted Display (HMD) system. Both of these systems are using a tracking system to reflect the user movements in the virtual environment. The CCS uses only three coordinates: *x*-, *y*- and *z*-axis. The HMD system has six degrees of freedom, the *x*-, *y*- and *z*-axis, as well as the roll, pitch and yaw. Those two systems are also compared with HMD, as a standalone device (HMD-SA) without the tracking system where it has only roll, pitch and yaw. The objective of the study was to evaluate the impact of VR systems on the students' achievements in engineering colleges. The research examined the effect of the four different methods and compared the scores of the students after each test. The experiments were ran over 48 students. Those systems show incredible results.

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KEYWORDS
Virtual reality; head mounted display; corner cave; engineering education and tracking system

1. Introduction

Virtual reality (VR) is one of the most modern, prominent and fastest technologies because it is considered a distinct and efficient technique to explore the virtual world details. It is responsible for building virtual environments, having a very precise representation of reality. The technology mainly depends on systems that use graphics to represent and co-ordinate the information. It also represents the ability to interact with the virtual environment, using aiding tools such as Head Mounted Display (HMD), special glasses, gloves, joysticks, a mouse and other devices. This technique has offered quite a lot of privileges to many fields, such as medicine, treatment, tourism and education, as well as all other aspects of life.

Many different environments of the virtual world can help in the education process. For example, the virtual university offers educational services to its students as if they were actually enrolled in a real university. In addition, the educational virtual environment is considered an excellent alternative to the real requirements needed for education and training, thus eliminating dangers from the actual practice. These environments have the ability to frame scientific concepts and indulge the students in situations that cannot be entirely and perfectly recreated in reality. Thanks to such a technique, medical students can now preview the human body and explore it (see Figures 1–3). The technology is an effective way to transfer technical information using graphics and illustrative pictures that offer better accuracy. It also allows the students to practise in step-by-step experiments and provides the opportunity to go on with the tests for an unlimited period of time. Using VR in education can improve students' performance and achievements, leading to the support and development of the educational process, along with clarifying abstract symbols.

2. Background and previous studies

The term VR first appeared in 1960 in many research papers that were discussing the utilisation of the HMD and glasses. First, Hall and Miller (1963) described the HMD and how they can be used for VR purposes. Next, Sutherland (1968) added the use of the HMD as a three-dimensional display tool. Vickcrs (1970) added stereo to the 3-D HMD, this being considered an integrated system that can be used as a 3-D VR system. Another study, performed by Chung et al. (1990), showed that using the 3-D VR and its sound effects causes individuals' immersion in a virtual environment that imitates the natural one. In addition, it confirmed that the virtual environments totally mimic the reality. All these studies placed the VR at the top of all the

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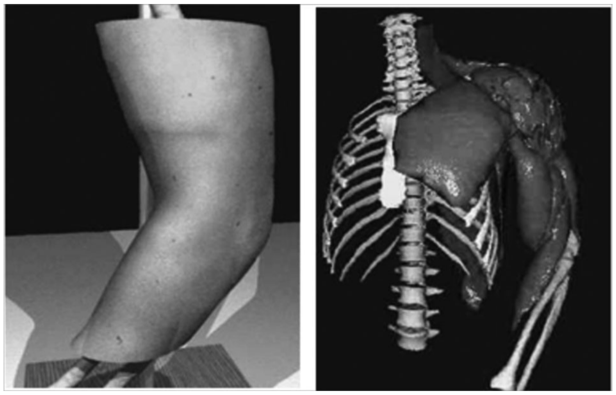

Figure 1. Exploring human's body using VR systems (http://www.polhemus.com/page=Motion_Applications_VR_Edu).

techniques that can be used in all possible fields, such as education, medicine, training, engineering and others.

VR is an alternative world, created by technology, in order to ensure a state of integrated presence and to

Figure 3. The HMD (http://s.hswstatic.com/gif/vr-gear-8.jpg).

give a new prospect to the evolution of humanity. VR enables the user to dive into a three-dimensional world, very similar to the reality. This virtual world is

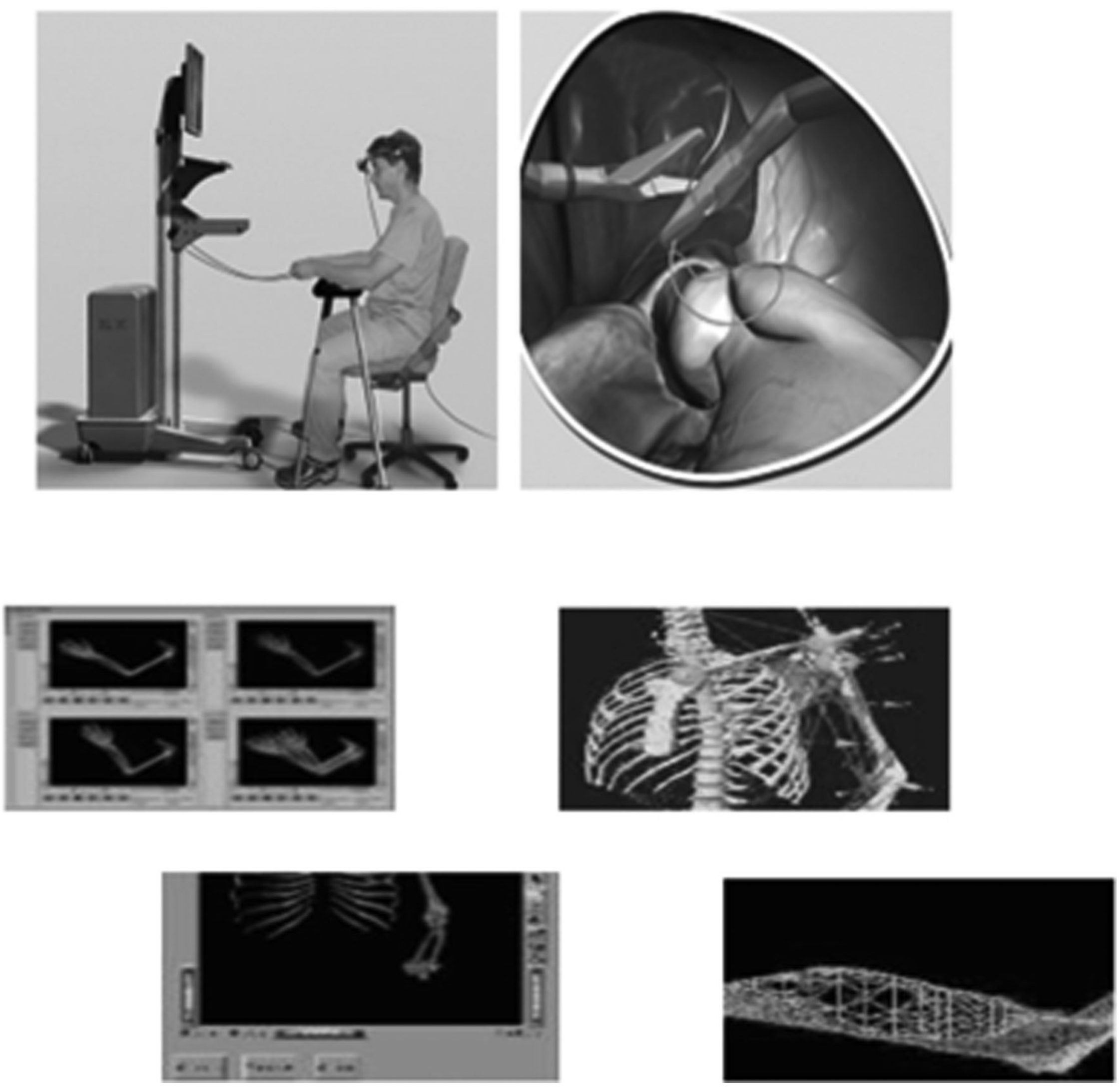

Figure 2. Practising surgery using VR (http://www.polhemus.com/page=Motion_Applications_VR_Edu).

made of graphics that are displayed using an advanced computer and that enable the user to interact with these graphical scenes. All the user needs are special tools to put on his or her head. In addition to gloves, these tools contain a visual display. A VR system can detect the user movements through attached sensors. When the user moves, the computer detects the movements using sensors, the computer then reacts by altering the scenes. These scenes could be a winding street that the user walks on in the same way that he walks on a real street, where he can turn right and left and look around in all directions.

This technique allows users to live through experiences that they could not have gained through the real world for multiple reasons such as risk, high cost, lack of time and others. VR technique is based on combining both fantasy and reality through the formation of virtual environments that are able to represent reality, adapt and interact with the user.

Warren, Welch, and McCarthy (1981) proved that VR systems have an enormous impact on the human sensory system. The study of Zimmerman and other scientists in 1987 is also considered crucial because they added a device that transforms hand movements into electrical signals (Zimmerman et al. 1987). These valuable additions came hand-in-hand with the addition that Minsky et al. introduced in 1990 (Minsky et al. 1990; Fatimah and Alhalabi 2008). These additions develop the concepts of interacting with the virtual world.

The 3-D VR, with sound and interactive effects, has been used in fields such as data representation (Brooks 1988), astronomy (McCreevy 1991), engineering (Orr 1989), architecture and environmental design (Brooks 1987). All this research demonstrates the effectiveness of VR of emulating different environments and applications, including education and training. In the late 1980s and early 1990s, many universities and research centres proposed various studies related to the use of the VR in education and training, and numerous scientific papers were published, including those by Merickel (1990), McCormic (1992), Byme (1992) and McCluskey (1992).

The medical field has a severe need for finding an alternative for conducting experiments, especially in surgeries where a single mistake can be fatal. VR techniques contribute to ensuring a substitute for the human body. Computers started to be used for teaching anatomy about 20 years ago, but the practical successes did not take place until recently. The reason for this is that finding a device to simulate surgical operations, and make it as close as possible to reality, required a significant amount of information, which is difficult to gather and manipulate. Hardware and software surgical simulators have been developed to simulate different organs and tissue anatomy, thus allowing the exploration process. These devices lead to reducing mistakes in real surgical operations and increasing the surgeon's skill, which means saving lots of lives and improving the quality of service. The Japanese created a virtual environment that was used in the 'Kansy' project designed at the National Centre of Oncology Hospital in Japan. It was observed that the patients who watched movies on different display devices (two- and three-dimensional) felt completely relieved from stress and it helped them forget the fact that they were in hospital. It also assisted in reducing the symptoms associated with chemical therapy, such as nausea, weak heartbeat and high levels of pain. Through this experience, it was observed that the patients' stress was reduced (http://www.polhemus.com/page=Motion_Applications_VR_Edu; http://imej.wfu.edu/articles/2001/2/02/index.asp; http://coe.sdsu.edu/eet/articles/VRAppa/start.html). The Japanese used VR to simulate battles, infiltration tactics, hostage rescue tactics and warfare manoeuvring. This helped in many ways, such as reducing costs, as manoeuvres are considered very expensive, and eliminates the potential for injury and loss.

The VR system has hardware and software requirements. Regarding the hardware requirements, the visitor can follow VR shows using special screens, but these screens do not live up to the quality provided by tools such as: (i) The Head Mount Display (Figure 4) and (ii) The Cave (Virtual Environment-CAVE).

Depending on the required complexity and quality, the following equipment can be used:

(i) Image generators
(ii) Manipulation and control devices
(iii) Mouse
(iv) Joystick
(v) Instrumented glove
(vi) Position tracking
(vii) Ultrasonic sensors
(viii) Magnetic trackers and
(ix) Optical position tracking systems

The programs responsible for displaying VR scenes could be extensions included in the Internet browser, or could be independent display programs (Cortona VRLM Client). Some researchers carried out studies about the programs that can be used in specialised VR applications, such as special presentation tools specified with robot control and their usage in the educational process, as was provided by Manseur (Robinette and Manseur 2001). The author explained that

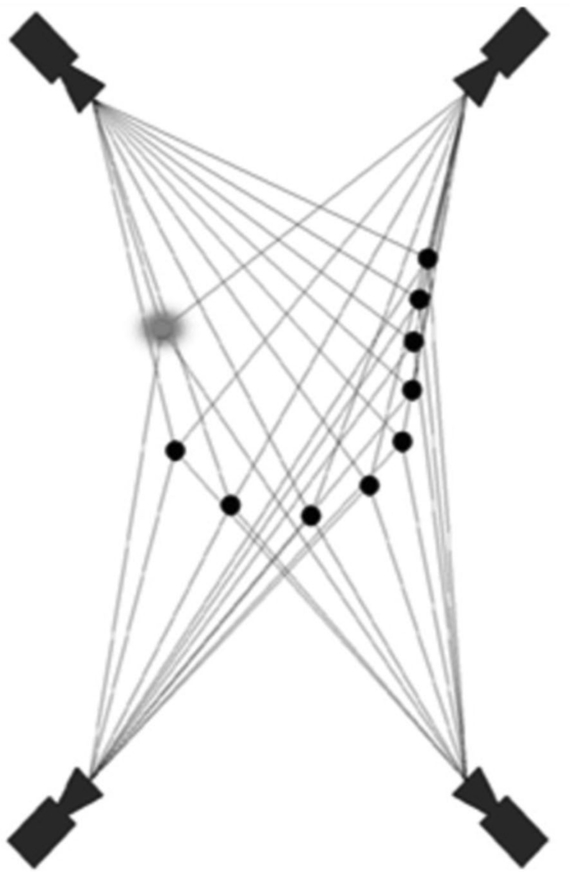

Figure 4. Optical tracking system (Worldviz Company).

such applications have more than one influential factor, as it is in need for continuous interaction with the user.

3. Methodology

The objective of the research is to evaluate the impact of VR systems on students' performance. The experiment was set as follows:

We set up four different systems: CCS, HMD, HMD-SA and No-VR regular test, or the controlled group.

The student used the system. While they were using the system, they were learning new concepts and materials.

The experiment set up was as follows:

In the VR systems, we could have three degrees of freedom such as (x-axis, y-axis and z-axis). In order to be able to use these movements as inputs to the virtual environments, we have to use a tracking system. The tracking system in our experiment consists of eight cameras. Figure 5 shows the optical tracking system. Figure 6 shows the software that controls the eight-camera tracking system.

Another three degrees of freedom could be achieved by detecting the rotation about X (pitch), rotation about Y (Yaw) and rotation about Z (Roll). In order to detect these movements, an inertial measurement unit (IMU) must be used. This device is installed inside the HMD. Figure 7 shows these actions.

In this experiment, we divide the data collection into four different parts as follows:

- With VR (Corner Cave System with the tracking system) and it is called CCS.
- With VR (Head Mounted Display with a tracking system) and it is called HMD.
- With VR (Head Mounted Display without tracking system (Standalone system) and it is called HMD-SA

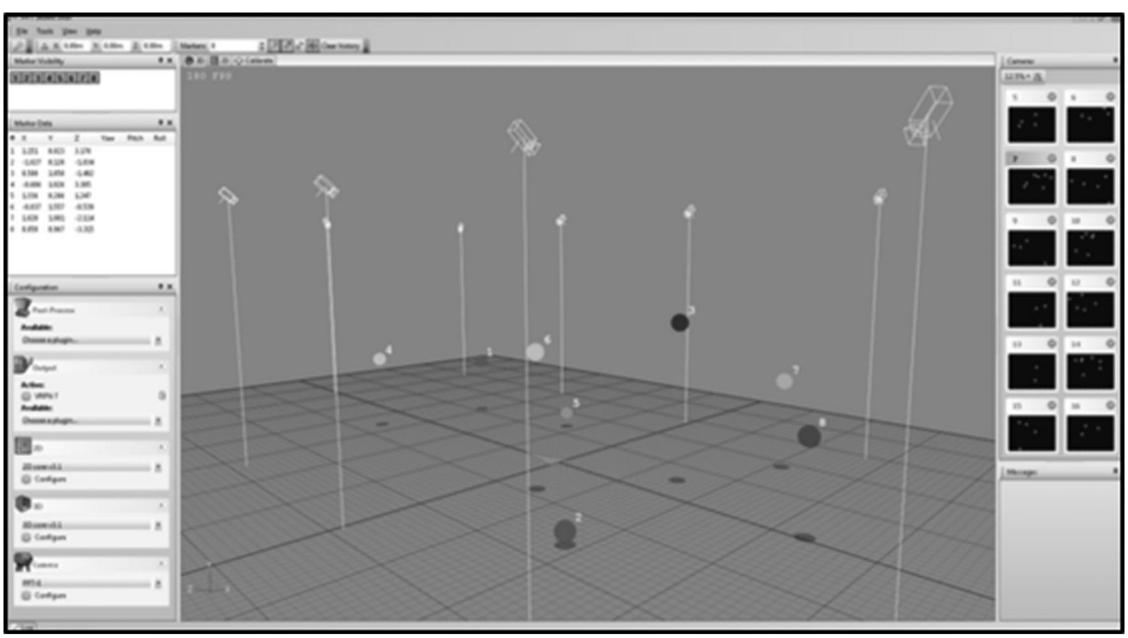

Figure 5. The eight-camera tracking system (Worldviz Company).

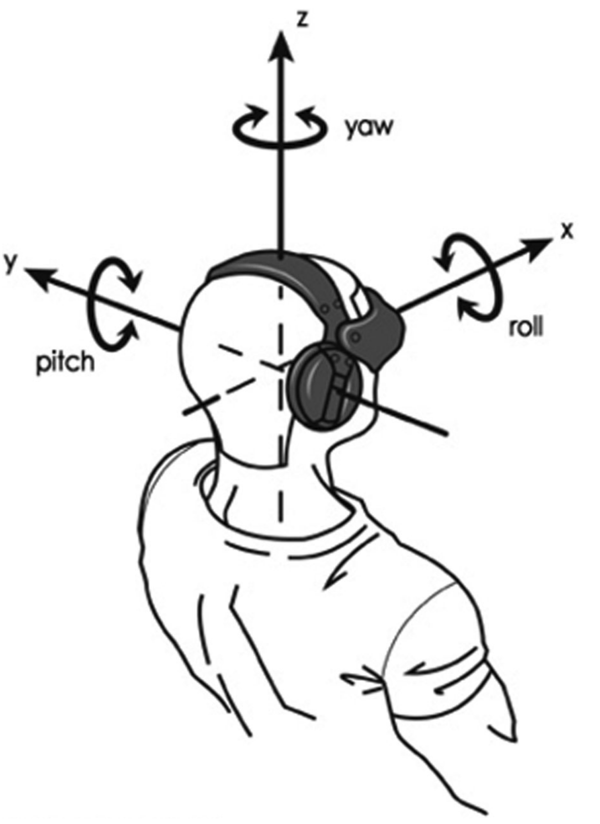

Figure 6. The device-oriented movements (http://s.hswstatic.com/gif/vr-gear-8.jpg).

- Control group, where no VR is used, and it is called No-VR.

System 1: *Corner Cave System* (CCS): CCS is shown in Figure 8. In this system, the user must wear the glasses shown in Figure 9. CCS is a large system and can accommodate up to 10 students. However, only one student can control or navigate in the environment. In our study, we asked only one student to use the CCS at a time.

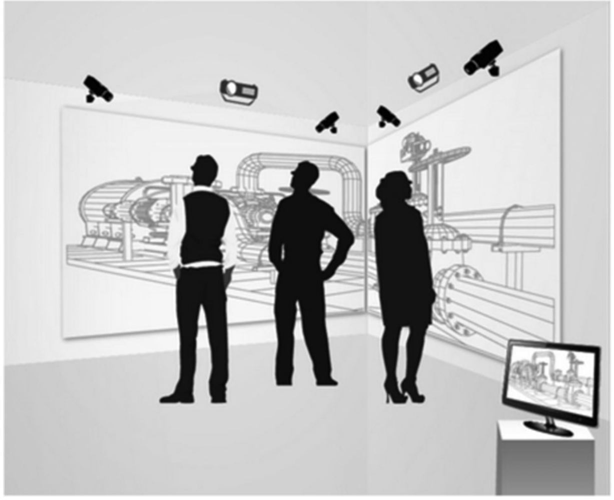

Figure 7. The Corner Cave VR system (Worldviz Company).

Figure 8. VR glasses and PPT Eye (Worldviz Company).

System 2: *Head Mounted Display* (HMD): The Oculus Rift Figure 10 was used as an HMD and we also used the eight-camera tracking system. Having the ability to interact with the environment using six degrees of freedom gives the user the feeling of immersion.

System 3: *Head Mounted Display, Standalone System* (HMD-SA): The Oculus Rift Figure 10 was used as an HMD. However, we did not use the eight-camera tracking system. This experiment uses only three degrees of freedom where the user has only three types of moves. The user can only use the pitch, yaw and roll. Any moves he takes in the *x*-axis, *y*-axis or *z*-axis cannot be reflected on the environment.

In this stage, four virtual environments were selected for four different topics in engineering. The students were divided into 4 groups (Group A, Group B, Group C and Group D) and 12 students participated in each group. We also selected four topics: Topic 1 (Astronomy), Topic 2 (Transportation), Topic 3 (Networking) and Topic 4 (Inventors).

We used each topic for the four environments, as presented in the follow models:

Model 1: Topic 1 for CCS (CCS1), Topic 2 for CCS (CCS2), Topic 3 for CCS (CCS3) and Topic 4 for CCS (CCS4).

Model 2: Topic 1 for HMD (HMD1), Topic 2 for HMD (HMD2), Topic 3 for HMD (HMD3) and Topic 4 for HMD (HMD4).

Figure 9. Oculus Rift (http://www.vrheadsets3d.com/wp-content/uploads/2014/10/Oculus-Rift-DK2.jpg).

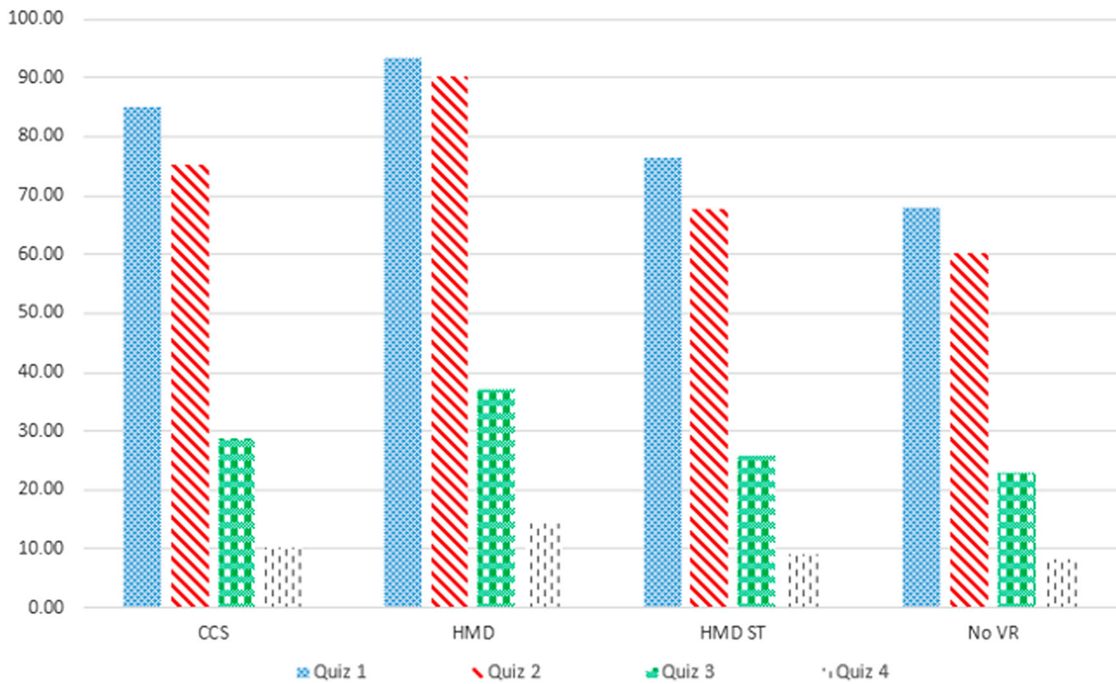

Figure 10. The result of four exams using the VR and No-VR.

Model 3: Topic 1 for HMD-SA (HMD-SA1), Topic 2 for HMD-SA (HMD-SA2), Topic 3 for HMD-SA (HMD-SA3) and Topic 4 for HMD-SA (HMD-SA4).

Model 4: Topic 1 for NO-VR (NO-VR1), Topic 2 for NO-VR (NO-VR2), Topic 3 for NO-VR (NO-VR3) and Topic 4 for NO-VR (NO-VR4).

We prepared a unique test for every topic. The topic test was the same throughout the topic.

Quiz 1 is a quiz given for topic 1 (CCS1, HMD1, HMD-SA1 and No-VR1)

Quiz 2 is a quiz given for topic 2 (CCS2, HMD2, HMD-SA2 and No-VR2)

Quiz 3 is a quiz given for topic 3 (CCS3, HMD3, HMD-SA3 and No-VR3)

Quiz 4 is a quiz given for topic 4 (CCS4, HMD4, HMD-SA4 and No-VR4)

Then we exposed the students to the systems and gave them the tests as follow:

Group 1 = [CCS1, HMD2, HMD-SA3 and No-VR4]

Group 2 = [CCS2, HMD3, HMD-SA4 and No-VR1]

Group 3 = [CCS3, HMD4, HMD-SA1 and No-VR2]

Group 4 = [CCS4, HMD1, HMD-SA2 and No-VR3]

After the students were exposed to each system for five minutes, the students will take the test immediately.

4. Results

Forty-eight students participated in this study. The students were divided into 4 groups of 12 students in each group, as explained in the methodology section.

We measured the performance of the students according to their achievement in answering the quiz given after each session. Figure 11 shows the quizzes results for each topic. The quizzes are as follows:

Quiz 1 was MCQ questions, given to the students, and it was related to knowledge skills.

Quiz 2 was short answers, and was testing the cognitive skills.

Quiz 3 was all about mathematics skill.

Quiz 4 was testing the students related to some graphics and charts.

The result in Figure 11 shows that in quiz 1, the HMD system achieved an average score of 93.5% where CCS was 86%. The HMD-SA scores an average of 77% and the last one was No-VR with an average rating less than 70%. When we analysed the result of quiz 2, as

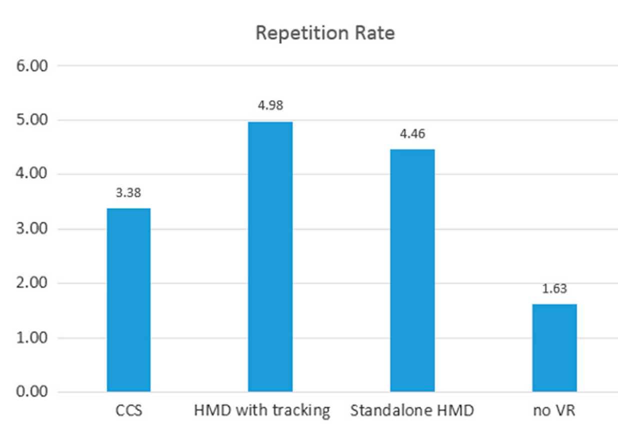

Figure 11. The repetition rate.

shown in Figure 11, we got the same order where HMD got an average score of 90%; CCS got an average of 75% then HMD-SA at 68% and No-VR at 60%. We got a similar result with quizzes 3 and 4. When we run the *t*-test on the data collected, we got the p value <.05, which is a highly significant difference between the VR groups and the control group.

Figure 12 shows the number of times a student may repeat the experiment voluntarily. The figure indicates that the HMD system is repeated 4.98 times, where the HMD-SA is repeated 4.46 times. This might reflect the amount of interest a student has when using the systems. The result in Figure 11 was based on a one-time use. Thus, Figure 11 does not have any influence on Figure 10. The second experiment (which is shown in Figure 11) shows that students are more interested in using the HMD than other systems.

5. Conclusion

Using any VR system dramatically improves the students' performance. There are different VR systems available, most of which can be used in education and engineering. In this study, we tested three major VR systems: the CCS, the HMD and the HMD-SA systems. We compared the result with the controlled group No-VR, and we found a significant advantage of using any VR system compared with no VR. However, the HMD was superior over the other two systems. This might be due to a higher level of immersion this system has over the others. Future experiments might investigate different topics in detail. We might compare the performance of science classes vs. art classes, or Mathematics vs. Physics or Chemistry. We expected a different response based on the topic itself. However, we are sure that this experiment provides a qualitative evidence of the impact of VR over no VR. It also shows that the more the students are involved in the environment, the more they achieve.

Disclosure statement

No potential conflict of interest was reported by the author.

References

Brooks, Jr. F. B. 1987. “Walk Through a Dynamic Graphics System for Simulating Virtual Building.” *Computer Graphics* 9–21 (1): 3.

Brooks, F. P. 1988. “Grasping Reality through Illusion-Interactive Graphics Serving Science.” In *Proceeding of ACM SIGCHI*, edited by J. J. O'Hare, 1–11. New York: ACM.

Byme, M. 1992. *Personal Communication – Human Interface Technology Laboratory*. Seattle, WA: University of Washington.

Chung, J. C., M. R. Harris, F. P. Brooks Jr., H. Puchs, M. T. Kelley, J. Hughes, M. Ouh-young, C. Cheung, R. L. Holloway, and M. Pique. 1990. “Exploring Virtual Worlds with Head-mounted Display.” In *Proceeding of the SPIE Conference on Three-Dimensional Visualization and Display Technologies*, 42–52, Los Angeles, January 18–20.

Cortona VRLM Client. “Parallel Graphics. Internet Document.” http://www.parallelgraphics.com/products/cortona.

Fatimah, Alzamzami, and Wadee Alhalabi. 2008. “Using Guided Imagery as a Distraction Method During Dental Procedures.” In *Proceedings of the 19th IASTED International Conference on Modelling and Simulation*, edited by R. Wamkeue, 107–109, August 21. Quebec: ACTA Press.

Hall, M. R., and J. W. Miller. 1963. “Head-mounted Electro-ocular Display: A New Display Concept for Specialized Environment.” *Aerospace Medicine* 34 (4): 316–318.

McCluskey, J. 1992. “A Primer on Virtual Reality.” *The Journal* 20 (5): 56–59.

McCormic, K. 1992. “Panel Presentation on Work at Nueva Media Lab.” In *SRI International Conference on Virtual Worlds: Real Challenges*, June 18.

McCreevy, M. W. 1991. “Virtual Reality and Planetary Exploration.” In *Proceeding of the 29th AAS Goddard Memorial Symposium*, Washington, DC, March.

Merickel, M. L. 1990. “The Creative Technologies Project: Will Training in 2D/3D Graphics Enhance Kids' Cognitive Skills?” *The Journal* 18 (5): 55–58.

Minsky, M., M. Ouh-Young, O. Steele, F. P. BrooksJr., and M. Behensky. 1990. “Feeling Seeing: Issue in Force Display.” In *Proceeding of Symposium of 3-D Interactive Graphics*, Snowbird, Utah, March.

Orr, J. N. 1989. “Exotic CAD.” *Computer Graphics World* 12 (7): 88–89.

Robinette, M., and R. Manseur. 2001. “Robot-Draw – Visualization Tool for Robotics Education.” *IEEE Transaction on Education* 44 (1): 29–34.

Sutherland, E. 1968. “Head-mounted Three-dimensional Display.” *Proceeding of the Fall Joint Computing Conference* 33: 757–764.

Vickcrs, D. 1970. “Head-mounted Display Terminal.” In *Proceeding of the IEEE Int. Computer Group Conference*, 102–109. New York: IEEE.

Warren, D. H., R. Welch, and T. J. McCarthy. 1981. “The Role of Visual-Auditory Compellingness in the Ventriloquism Effect: Implication for Transitivity among the Spatial Senses.” *Perception and Psychophysiology* 30: 557–564.

Worldviz Company. http://www.worldviz.com/products/ppt/ppt-e.

Zimmerman, T. G., J. Lanier, C. Blanched, S. Bryson, and Y. Harvill. 1987. “A Hand Centre Interface Device.” *Proceeding of the ACM SIGCHI* 18 (4): 189–192.