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EFFICACY OF VIRTUAL REALITY AND AUGMENTED REALITY FOR EDUCATION: A REVIEW

Chibuike E. **UZOECHINA**[1], Elizabeth T. **BABARINDE**[2], & Victoria Y. **FAGBEMI**
Library and Information Science, University of Nigeria Nsukka[1,2,3]
chibuike.uzoechina@unn.edu.ng[1],elizabeth.babarinde@unn.edu.ng[2],
victoria.fagbemi@unn.edu.ng[3]

Abstract

Purpose: *In this paper, we reviewed the state-of-the-art scholarly studies on the application of Virtual Reality (VR) and Augmented Reality (AR) in education. We focused on studies that investigated the use of these technologies for teaching and learning in higher institutions.*

Design/Methodology/Approach: *Were viewed studies published on the effectiveness of VR/AR for education over the past five years. Four databases - Educational Full Text, Taylor & Frances, IEEE Xplore, and Scopus were used for the literature search. A combination of keywords, such as virtual reality, augmented reality, education, teaching, and learning, were used as search terms. From the search results, we read the abstracts to select the first (and most recent) nineteen relevant publications that adopted empirical methodologies, such as surveys or experiments, for our review.*

Findings: *The literature revealed that the efficacy of VR and AR in education is dependent on the teaching context. In a teaching context where either of these technologies is suitable, it enhanced collaboration, attention, communication, engagement, understanding, motivation, performance, achievement, and positive attitude towards VR and AR technologies in teaching and learning. Also, there are challenges and difficulties that stifle the use of these technologies in higher education.*

Originality/Value: *This review is important as it highlights the need for more research related to the efficacy of VR/AR in higher education, and offers suggestions on how VR and AR can be leveraged to enhance teaching and learning in the Information Science and Technology subject area.*

Paper type: *Review*

Keywords: *Virtual reality, Augmented reality, Education, Information Science and Technology, VR and AR in education.*

Introduction

Education is the process of imparting knowledge, skills, and values to learners. The study of how to better facilitate this impartation using technology has been a subject of interest for centuries, as educationists, researchers, and industries seek to improve the means of knowledge transfer to both make the learning process fun and improve learning outcomes using various technologies. In this paper, we reviewed the current research in Virtual Reality (VR) and Augmented Reality (AR) for education. We focused on the concepts of VR and AR as well as their features that enhance learning outcomes. We also examine past studies on the efficacy of VR/AR in their application to various educational domains in higher institutions. We further provide research trends, suggestions, and future research directions in this area, as well as suggestions on how VR/AR can be leveraged to enhance teaching and learning in the Information Science & Technology (1ST) subject area.

Concepts of VR and AR

According to the Oxford English dictionary, VR refers to the "computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors." VR allows a user to interact with a computer generated three-dimensional model or virtual environment. A VR system comprises five key features (Wickens, 1992): (1) 3D

(perspective and/or stereoscopic) viewing; (2) Dynamic (vs. static) display; (3) Closed-loop (interactive or learner-centered) interaction; (4) Inside-out or viewer's (ego-referenced vs. world-referenced) frame-of-reference; (5) Enhanced sensory experience.

On the other hand, AR is an immersive environment through which digital content is displayed over the real-world, using a technological medium such as a smartphone (Allison et al., 2016). It involves extending the real world environment with a digital overlay, in which the real world is enhanced by computer-generated images and sound (Siegle, 2019). AR also allows users certain affordances, such as the capability of allowing users to see, communicate, exchange data, and interact with digital elements superimposed in their physical environment (Giasiranis & Sofos, 2017).

AR is distinct from VR in that AR projects or superimposes a digital representation over the real world. VR portrays a complete virtual world or reality where all you can see is programmed, whereas AR allows the real world to be the basis of the visual image (Lovsletten & Kionig, 2019). In other words, the users of VR are immersed completely in a virtual environment (i.e., that does not include or involve the real world) while AR systems combine the real and virtual worlds, and hence, are more close to reality and provides more visual fidelity than VR systems (Si & Wang, 2018). In this review, we argue that each of them has specific technological requirements and that VR or AR should be chosen with the learning objectives of a course in mind.

VR and AR technologies are becoming more versatile over the past few years, and are beginning to filter into everyday usage. Primarily for advertising purposes, their applications have now hit the education domain, with a canyon of recorded significant benefits. Pantelidis (2010) posits that at every level of education, these technologies have the potential to make a difference in learning outcomes, and the use of VR in education cannot only enable learners to make new discoveries, but can also motivate, encourage, and excite the learners. According to Pantelidis (2010), a learner using VR can participate in the learning environment with a sense of presence - of being present in (or perceived to be in) that environment. Similar postulation, however, may be made of AR in education because AR can also generate a sense of having virtual objects in the real world (Smink et al., 2020) AR can motivate and engage users (Nanthanasit & Wongta, 2018) and generate a sense of mixed reality of having virtual objects superimposed on the user's view of the real world. AR can bring a digital object to a learner's environment for interaction and close examination (Lovsletten & Kionig, 2019). In the following section, we examine the benefits of VR/AR in education.

Benefits of using VR/AR in Education

To acknowledge the benefits of using VR/AR technologies in education, we refer to the Chinese Proverb: "Tell me, I'll forget; show me, I'll remember; and, involve me, I'll understand." While the traditional education method does not favor constructivism (i.e., the psychological belief that humans generate knowledge or learn from their experiences) because it "tells" learners rather than "involves" learners, educational VR/AR applications are advantageous in providing learners with the opportunity to visualize and interact with an object, and thus become involved in the learning process. Siegle (2019) observed that VR and AR afford students the opportunity to interact and learn in environments beyond their physical reach. These technologies enable students to explore the great museums of the world, bring dangerous or extinct animals virtually into students' environments where they can walk around and examine them, and enables students to conduct hazardous science experiments without fear of being harmed (Siegle, 2019).

Pantelidis (2010) listed the following advantages of using VR (and, by our extension, AR) in education: it is not only highly motivating, but it also helps to arrest and retain students' attention, allows extreme close-up examination of a digital object, and encourages active participation rather than passivity. Overall, VR and AR provide a constructivist approach to learning such that a learner using these technologies can learn by doing. There are however, a number of issues that stifles

exploitation of these technologies in teaching and learning.

Barriers in using AR/VR in Educational Settings

Elmqaddem (2019) reminded us that VR and AR are not actually new technologies, but several constraints have prevented their actual adoption. According to Boyles (2017), high cost of these technologies proved to be one of the main barriers to its adoption in education, outside of experimental studies. Pantelidis (2010), for instance, pointed out that the disadvantages/challenges of using virtual reality are primarily related to cost, time necessary for learning how to use hardware and software, possible health and safety effects, and dealing with possible reluctance to use and integrate new technology into a course or curriculum. Pantelidis, however, furthered that (as with all new technology) each of the above challenges may fade with time paving the way for the technology to become commonplace. It is now a decade since Pantelidis made this interesting remark, and it would be interesting to have a closer look into what researchers have published on the effectiveness of VR/AR for education over the past five years to identify trends, noting the challenges that have persisted or fizzled out.

Review Methodology

This review focuses on the effectiveness of VR/AR in teaching and learning in higher institutions, and explores the most recent studies done within and beyond the laboratory settings. Four databases - Educational Full Text, Taylor & Frances, IEEE Xplore, and Scopus - were used for the literature search. A combination of keywords, such as virtual reality, augmented reality, education, teaching, and learning, were used as search terms. However, we adopted three search strings that we used across the databases: "Augmented and virtual reality in university education", '"augmented reality" AND education', and "'virtual reality" AND education'.

Based on our search on these databases on 16th and 17th November, 2020 Taylor & Frances yielded the highest number of publications when the above strings were used (2,365). It is followed by Educational Full Text (1,028 search results) and IEEE Xplore (297 search results). Scopus (3 search results) showed the least number of publications. From the search results, we read the abstracts to select the first (and most recent) nineteen relevant publications that adopted empirical methodologies, such as surveys or experiments, for our review to explain the effectiveness of VR and/or AR technologies in the instruction of students in higher institutions (universities and colleges). We will extend the literature review in our future research.

The rest of this paper is organized as follows: a synthesis of the results of previous studies (e.g., themes and major findings) is presented in section 3; section 4 discusses the findings and presents future research directions on VR/AR for education. It also provides suggestions for appropriating VR/AR to enhance teaching and learning in the 1ST subject area. Section 5 concludes the paper.

Results

Issues addressed in previous studies

Our review indicates that previous empirical studies on the efficacy of VR/AR for education have done one or more of the following: examined the effectiveness of VR and/or AR in teaching and learning; compared the effects of different types of VR (in terms of type, for instance, immersive vs desktop based VR (Makransky & Lilleholt, 2018) or by other characteristics such as cost of the technology (for example, see Diaz, Zarraonandia, Sanchez-Francisco, Aedo, & Onorati, 2019 in the **Appendix).** A majority of the studies compared the outcome of VR/AR based teaching or learning approach to the traditional approach in order to demonstrate the effectiveness of VR/AR in an educational domain of interest (Hurrell & Baker, 2020; Kelly et al., 2018; Kim et al., 2017; Si & Wang, 2018); a few others investigate the effects of VR/AR based teaching and learning on students' performance (Alhalabi, 2016). Some designed and evaluated the efficacy of a VR/AR technology in a teaching and learning context (Si & Wang, 2018) and examined perceptions of students and teachers on the use of VR/AR in teaching (Erolin et al., 2019). Please refer to the **Appendix** for a comprehensive list of the studies.

Where VR/AR has been used the most

We identified the disparate educational domains where VR/AR technology has been used to augment teaching and learning in higher institutions. They include: medical education (including surgery, anatomy, nursing, and dentistry), engineering, biological sciences, education (including: arts education, and teacher education), real estate education, business classes, fashion design, and physiotherapy. However, it is evident that VR/AR has been used the most in the field of medicine, where the two technologies appear to have most prospects. In anatomy education, for instance, both VR and AR have been tested, and while both have positive effects on learning outcomes, AR simulators were found to be effective in providing more accurate and precise augmented visualization and affords deeper immersion for novice surgeons than VR simulators (Si & Wang, 2018). Our review further reveals that although VR/AR technologies have been designed to support teaching and learning in other fields, their real world applications and usage in those fields is not common. Please refer to the column "Context" in the Appendix for a complete list of all the fields represented in the works reviewed.

Popularly used method

There seems to be a general trend on the methodology used for the studies. The prevailing methods of enquiry adopted by the researchers are experiments and surveys; and the common methods for data collection were questionnaire, interview, and observation. Moreover, the experimental studies were mostly laboratory experiments. There was only one field experiment which was by Kelly et al. (2018); however, their findings were in consonant with the other studies.

Summary of Findings

Generally, all the studies reported positive effects of VR/AR in teaching and learning. Where the purpose was to compare VR or AR based teaching and learning approach, the studies reported that both VR and AR technologies lead to positive learning outcomes, enhanced engagement, increased interests in learning, greater enjoyment and fun, and higher students' attention (see the Appendix for more details on the specific study's findings). However, where the goal was to demonstrate the suitability of either technology to a teaching context, studies reported varying results. For example, in a study that examined the roles that VR and AR play in teaching structural biology, it was found that no difference exist between VR and AR in terms of experience and relevance in teaching and learning structural biology (Jensen & Katona, ad.). However, in another study, Si and Wang (2018) compared AR interactive environment for neurosurgical training with traditional virtual reality based neurosurgical simulator. They found that the AR simulator provided higher accuracy in augmented visualization effects and deeper immersion for novice surgeons than the VR counterpart.

In a yet related study, Huang et al. (2019) questioned the possible psychological and cognitive mechanisms that might explain any potential differences between VR and AR in an educational context, and whether VR or AR is a more effective tool/medium for educating students about science. They found that while participants in the AR condition retained less visual-related science information, they retained more auditory-related science information compared with those in the VR condition. In a similar vein, studies that examined the various types of VR (e.g., immersive vs desktop and high vs low cost VR) also have dissimilar findings. Immersive VR was found to be superior to desktop VR in arousing, engaging, and motivating students (Makransky & Lilleholt, 2018). However, low cost VR technologies, such as Google Cardboard, support learning in the same or similar way as high cost VR technologies such as the Oculus Rift VR headset (Diaz et al., 2019).

One other finding worthy of mention in our review is the populations of the studies. For almost all the studies, the samples were drawn from courses, teachers, undergrads (and in fewer cases, graduate) students in higher institutions domiciled in America, Asia, and in very few cases, Europe. We did not find studies on this subject conducted in African, Caribbean, and Australian higher institutions. Also, the studies we reviewed were admittedly limited by the small sample sizes, which impede the

generalizability of the findings. Moreover, no study in our review investigated effectiveness of VR/AR in teaching and learning subject areas such as 1ST, Geography, and Agriculture.

Finally, some studies reported similar challenges and difficulties associated with the use of VR/AR in teaching and learning. The most frequently mentioned include: technical difficulties in operating within the virtual space and cost of these technologies. These findings have many implications both for practice and for further studies.

Discussion

The use of VR and AR in education is slowly becoming more widespread and popular. Many disciplines have adopted and tested its effectiveness in teaching and learning. Chief among these disciplines is medicine (under which we subsumed anatomy, dentistry, neurosurgical studies, and nursing). However, we did not find any study in a number of disciplines where VR and AR could be applied to enhance teaching and learning, such as 1ST, Geography, and Agriculture as mentioned earlier. Those programs possess features (subject areas and learning objectives) that meet Pantelidis' (2010) criteria for deciding when and when not to use VR (and AR) in education. They are huge areas or potential that can be further investigated. We will be discussed later where we see VR/AR to be applicable for enhancing 1ST education.

All the selected studies conducted in separate educational arenas made analogous findings about the efficacy of VR/AR in education, and present important implications for educational institutions. These studies demonstrate that using VR/AR in education leads to positive learning outcomes and enhances students' engagement with the learning resources. It was also found that these technologies raise students' interests in learning, lead to enjoyment and fun, and can help to capture and retain students' attention. Our review corroborates the earliest findings of Siegle (2019) and the opinions of Pantelidis' (2010). We also recommend the use of VR/AR to facilitate teaching and learning in various disciplines that have not been covered.

Discrepancies in the research findings suggest suitability of these technologies is contextual and that teachers and tutors should bear in mind course objectives in both selecting appropriate VR or AR technology and in choosing and designing contents for purpose. In addition, the results further reveal that these studies were limited by their sample sizes. First, we found that only one subject area and a relatively small group of students were chosen for each of the studies, which limits the generalizability of the findings. To obtain more reliable and generalizable results, we recommend future research energies be directed towards studying other subject areas (other than the ones used in the articles we reviewed) and with larger sample sizes.

In sum, our review indicates a number of problems still impede the successful use of VR/AR in education. They include technical issues and the costs of the technologies, which might be the reason for the fewer to no research found in most fields of study and in various continents, like Africa, where education is poorly funded.

Suggestions for using VR/AR in the 1ST Subject Area

Pantelidis (1996) gave insightful admonitions on when to consider using VR in teaching and learning. Among others, he encourages stakeholders to consider using this technology: when a simulation could be used; when a model of an environment can help with teaching or training; when travel, cost, and/or logistics of gathering a class for training are high; when information visualization is needed for manipulating and rearranging information using graphic symbols, so it can be more easily understood; when a training situation needs to be made to perceive to be real; and when it is essential to make learning more interesting and fun (Pantelidis, 2010). Using these criteria, we examined the various subject areas in 1ST education that can be enhanced using VR or AR technology. Below are a few courses/program that have high potential.

First, there is potential in applying VR/AR in online distance education programs and online classes. Distance students taking online class(s) could experience "transportation" into a

simulated classroom environment where they could be perceived to be in the same environment as the rest of the students (Chen et al., 2012). VR and AR can help capture and retain their attention and encourage participation, engagement and interest in the class. VR/AR technology can help induce a sense of presence - "a feeling of being there" in a simulated classroom, which can elicit positive learning outcomes. This finding has been demonstrated in a study that used a science class to investigate how the level of immersion in VR impacted perceived learning outcomes (Makransky & Lilleholt, 2018). They found that immersive VR has significant potential for use in simulations and other e-learning applications and can induce a sense of presence, can help arouse learners' interest, engagement, and motivation in learning, and, thus, achieve positive learning outcomes.

Second, VR/AR can be specifically used in courses that teach prototyping and visualizations. Such courses in 1ST include but are not limited to Prototyping in Human Computer Interaction, Information Visualization, and Performance Dashboard Design. In most of these courses, visualization is an important component and can be better taught using VR or AR, which can facilitate close examination of prototypes and better visualizations. Studies show that VR/AR offer students the opportunity to "see" and examine an object in a simulated environment (Lovsletten & Kionig, 2019; Halabi, 2020).

In addition, project based learning courses like "Enterprise Resource Planning Systems Design and Implementation", "Advanced Information Systems Project Management" and courses that need to demonstrate global elements like "Case Studies in Project Management" and "Global Project Management", where students are required to complete group technical projects, can also leverage these technologies for improved teaching and learning. Using VR/AR technology in these subject areas can enhance collaboration and communication, improve students' skills, and simulate a global environment that is not possible in a traditional classroom as have been shown in previous studies. One of the studies we reviewed, Hernandez-Pozas and Carreon-Flores (2019), investigated teaching international business students with VR and concluded that VR scenarios could simulate varied global environments and illustrate national and local features that international business students should be familiar with. Also, using an engineering project based learning course, Halabi (2020) demonstrated that VR and 3D prototyping in the context of project-based learning promotes effective communication, increase problem solving skills, and enhance learning outcomes. Based on these empirical findings and the knowledge that some of these disciplines share commonalities with 1ST, we recommend using VR/AR technologies for improved teaching and learning in the 1ST subject area and beyond.

Future research directions on AR/VR for education

Future research can explore the possibilities we highlighted above to determine and further assess the efficacy of VR/AR technologies in the 1ST subject area. Also, given the issue with sample sizes, future studies should test the efficacy of these technologies with a larger sample and with disparate subjects.

Another gap identified in the literature is the use of VR in online distance education in higher institutions. We could not find a study in this nascent aspect of modem education. As online classes are becoming banal, online learners need to experience presence in the learning environment. They need to "feel like they are there" in a simulated classroom. They need to feel transported into a virtual classroom setting when they join a class. Therefore, we suggest that future research should investigate the possibility of creating a sense and feelings of presence using VR.

Our review also found mixed and varied findings on the studies that examined VR vs AR (Alhalabi, 2016; Huang et al., 2019; Jensen & Katona, n.d.; Si & Wang, 2018), and suggested that each subject, each learning or course objective, and each course content might be better facilitated or enhanced using either VR or AR technology. Therefore, it is imperative to empirically determine when, and when not to use, VR or AR, and how to create educational contents for VR or AR, so as to achieve the best possible

outcomes. Such studies might be guided by Pantelidis' (2010) advice on "When to use and when not to use virtual reality" (pp.64 -67) while studies are needed to discover similar guidelines for AR.

Conclusion

This review explored state-of-the-art scholarly studies that involved the use of VR and AR technologies for teaching and learning in higher institutions. The literature reveals that the efficacy of VR and AR in education is dependent on the teaching context: in the teaching context where either VR and/or AR technology is suitable, it enhanced collaboration, attention, communication, engagement, understanding, motivation, performance, achievement, and positive attitude towards VR and AR technologies in teaching and learning. This review is important as it highlights the need for far more research related to efficacy of VR/AR in higher education.

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