RESEARCH INVENTION JOURNAL OF RESEARCH IN EDUCATION 3(3):20-29, 2024

©RIJRE Publications ISSN: 1597-8656

The Impact of Virtual Reality on Science Education in East Africa

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ABSTRACT

This paper examines the transformative effects of Virtual Reality (VR) on science education in East Africa. Despite the region's educational challenges, VR technology presents significant opportunities to enhance learning experiences, increase student engagement, and improve understanding of complex scientific concepts. Through a review of current literature, analysis of case studies, and evaluation of successful implementations, this study provides a comprehensive overview of VR's potential and its limitations in East African science education. The paper also offers recommendations for integrating VR into curricula and strategies for overcoming barriers to adoption.

Keywords: Virtual Reality, Science Education, East Africa, Student Engagement, Educational Technology, Immersive Learning, Curriculum Integration, Teacher Training, Educational Challenges

INTRODUCTION

The academic sector heavily supported the birth of virtual reality (VR). Then, virtual reality appeared to be just another gadget that would boost many sectors like health, entertainment, gaming, engineering, and architectural presentations on the capture of large crowds [1-6]. But it is in the scientific advancements where VR is having a major impact now. Based on effectiveness and timeliness, and feedback, newly emerged definitions of virtual reality are making more and more sense [7]. It is by far more valuable to understand that virtual reality is a complete post-immersion action instead of the characterization of a presentable virtual environment for computing a feelable human visual interaction. The importance of virtual reality (VR) on East African students cannot be overstated. This is strongly upheld because of the overengagement of other digital ways of learning, development, and recreation that is shown by the same students [8]. It is instructive that a huge section of digital development is guided by VR. Similarly, usage. On an equal scale, the tutoring that meets the needs of the users is equivalently pressing. Even though East African students are left behind, this Vanguard research topic paper seeks to guide readers into the importance of VR in East Africa by giving an in-depth revelation of the impacts that VR is having on science educational development [9-12]. This is to arm the reader with information so that they may know how and what to invest in to make a highly relevant but undervalued academic environment in East Africa work and thrive [6, 7].

Definition and Overview of Virtual Reality

Virtual reality (VR) is a computer-generated simulation of a real-life environment. The environment is presented in such a way that the user suspends belief and accepts it as a real environment. In a VR environment, the user feels present in a virtual world rather than the real world [13-18]. This is made possible by a head-mounted display (HMD). The HMD is worn in front of the eyes and presents the simulation of the virtual world. Through the HMD, the VR environment is experienced through two of the human senses: sight and hearing [19]. The ability to interact with the VR environment is determined by the software used and the controls of the HMD or data gloves [20]. Data gloves allow the user to grasp or touch virtual objects and receive direct feedback while interacting with them. The aim of VR is to allow users to experience a virtual world for at least some part of the time in the way they would experience a real world during everyday living [17]. With the VR technology, learners become active participants, setting the environment for problem-solving and enabling a holistic approach to learning. The use of VR in education is relatively new in East Africa. It holds a number of challenges and opportunities from teaching and learning perspectives, considering that there is little research in the field [21-23].

Historical Development and Evolution

In conclusion, the use of Virtual Reality applications can at times call for specialized or general software/hardware. Virtual Reality has been used to present architectural objects, VR healing preparations and therapy, entertainment and finance, and others [24]. These fields are easy to market and thereby make a lot of money, but in this situation, these innovations are generally for entertainment and then the process of learning a complicated concept may take a shorter period of time and be interesting [25]. It has been demonstrated that the use of specially designed tools for presenting difficult scenarios aids not only in reducing space time but also offers access which does not require strong prerequisites [26-30]. With applications developed to teach physical science, we have therefore developed a Virtual Reality toolkit that could be used to teach students in the field of physics. The term "Virtual Reality" was coined by Jaron Lanier in 1987. The Lawson Vision Corporation, founded in 1966, is one of the pioneers in Virtual Reality as it started the first corporate use of the term Virtual Reality [31-35]. From then on, Virtual Reality research was advanced through the development of technologies and applications like: The Data-Glove, The Virtual Environment Workstation Project, the VPL's IPO, Power Glove as HMD and so on. Over the period of its development, the operations of Virtual Reality were designed to have objects which are graphically and conceptually close to day to day objects but not to act being manipulated or altered by movement that represents the physical world [32, 33]. Systems designed to be used as educational tools were recently developed compared to those used for training and presentation [28]. Within these educational systems applicants are geared towards helping students perceive and understand concepts beyond what basic mental education setup can provide, by giving his on the spot emotions and reactions, therefore making the learning of concepts appear realistic [36] .

Current State of Science Education in East Africa

Science is seen as too difficult for the supposed "less bright" student, as constituting "many unknown and undefined terms," and "requiring specialized or pre-instructed students." Teacher professional development programs in science focus on the delivery of pre-packaged, static, and sanitized information which are pre-packed to be given in the examination room [37]. We consider it essential to address the nature and quality of teacher preparation, support, and learning experiences as well as produce genuine learners of science in a region where there is an increased awareness of the importance of new technologies in transforming the social fabric [38]. Coordinated and informed by existing theory and evidence, cross-sectional discussions also need to focus specifically on fostering and sustaining belief in the health informatics of science education teacher training, preparing teachers who will have the knowledge, disposition, and skills to educate their students soundly [39-41]. From their experiences, they should be willing and able to utilize this infusion technology to bridge the gap between their classroom lectures and their students' absorptive capabilities [42]. They are really influential in shaping powerful arguments for schools to utilize VR as a catalyst for change. Currently, East Africa faces many challenges in science education [36, 37]. The major operational education issue in many East African schools is a shortage of science teachers. Conditions for teaching and learning are often inadequate [39]. As a result, science curricula, teaching, and learning strategies in East African secondary schools perpetuate a concept of science as a passive body of knowledge to be transmitted from youth to students, one that is largely divorced from the communities in which students live [43]. The encouragement of students to be critical and creative thinkers and decision makers deters both students and teachers. This has been the state of science education in this region for some time now with no hope for change [44].

Challenges and Limitations

Having made several looks at primary research in 2002, Kearsley and Shneiderman reported that a good proportion of other research on VR education has engaged in how VR can complement its applications in education, such as in educational administration and educational management, rather than in addressing how VR can be effectively used for the purposes of teaching and learning [45]. As we have moved into the later part of 2003, the promise of VR tools, which help facilitate learning in different disciplines, especially those in the science discipline, has arrived [46]. A more recent review done by Huang et al. produced a much more detailed look at potential virtual reality and its related 3D user interface and related innovative technologies in science education as they analyzed a number of different scientific disciplines with the majority concentration being on chemistry [41, 43]. The new area of interest has created a huge interest in science education on a global scale, especially with the advent of many research tools under the guidance of the technology-based science discipline known as Virtual Reality, usually referred to as VR [47]. Despite the various policies, strategies, and actions taken to improve science education in many developing African countries, students still perform poorly in the majority of subjects. This study seeks to answer the research question: to what extent are virtual reality tools being used in science education? It also seeks to know the challenges and limitations that hinder the use of VR tools in science education in East Africa. The IR and reticle approach have been employed based on the scope of the study's findings regarding the current VR research discipline in science education. Management collaboration techniques and educational approaches for addressing challenges and limitations in education will also be addressed [48-54].

Benefits of Virtual Reality in Science Education

The CSCL literature suggests that another important premise includes opportunities for the teacher to model aspects of learning and specific problem-solving strategies as well as opportunities for employers to model cross-disciplinary integrations [36]. We are only starting to understand the broader implications of immersive collaboration and learning in complex and distributed learning environments [55]. Maintaining presence means not just providing a continual sense of virtual world about the virtual world. Guidelines for those developing collaborative environments as well as best practices for integrating such environments into curricula and professional development training for faculty are in order [56]. Indeed, the challenges transcend initial implementation; how to sustain a network of faculty interested in extending and improving virtual world collaboratory experiences will become more apparent. Studies on prolonged use by the same set of students suggest that a positive experience in such a space attracts and sustains students' interest [57-59]. The virtual environment provides new ways of thinking about learning. We emphasize the type of collaboration and interaction emphasized in real-world science training, a supportive learning environment and motivation that leads to deeper understanding of concepts, and the ability to investigate how the concept is being constructed [60]. The ideas for using virtual reality as a medium for education of science education can be traced to previous work on multimodal experience for language learning and tutorials as an entry point into learning how to use computer visualizations effectively for introductory chemistry students. All of these projects emphasize immersion in the learning environment: specialized tools and interaction methods, collaborative work, and the use of multiple views for learning [59]. These features also characterize an environment for scientific exploration [39].

Enhanced Learning Experiences

The use of VR in education is steadily becoming popular, especially in geosciences. Its use in combining real and virtual worlds provides this technology the opportunity to bring about an almost hands-on sensation to the teaching of traditionally difficult scientific concepts. Peter Luff attests to the effectiveness of VR in teaching geoscience in his paper [60-63]. He insists that aspects of studying some of the complex scientific phenomena can never be fully carried out in the real world. VR provides the ideal platform to create fully featured virtual worlds to model the behavior of these phenomena and allow students to interact with them [64-67]. The traditionally taught science content in today's classrooms is abstract and distant from the real-life experiences of the learner. As a result, students often fail to find it relevant to their everyday lives [68]. The use of VR in education is steadily becoming popular, especially in geosciences. It has the potential to improve understanding of abstract and complex phenomena like infinitesimal calculus, quantum physics, and relativity, among others. Furthermore, hands-on practical experiences could go a long way in enhancing students' understanding of scientific principles [69]. We conclude that experiences provided by virtual reality provide the ideal platform for such practical experiences. Science classrooms need to move from the teacher-centered transmission of information to a learner-centered, hands-on approach to learning science concepts [48].

Increased Student Engagement

When the virtual reality information is immersive, as is the case when body movements have a one-to-one mapping to the movements (or virtual movements) of the viewer, the observer experiences a strong sense of being present in the environment [70]. It is found that using immersive receptor technology increases the perception of being present within the virtual environments, and as the user's level of technological literacy increases, their perceptions of presence within the informative environment also increase. It is found that virtual reality users have the intention to play, learn, and interact more with the informative content, suggesting possible educational consequences [32,33]. Because knowledge can be constructed and manipulated in an environment where action occurs, it is now easier for experts to draw on their existing representations. When students experience 3D models in virtual reality, their level of immersion increases, resulting in more memorable experiences. This is different from 3D models displayed on 2D screens, where learners do not have a sense of presence and find it hard to recognize the different components of the models [71]. This presence is partly why currently, an increasingly high number of students can apply gaming technology very quickly and more effectively compared to generating, manipulating, and visualizing scientific data. This direction would be very helpful for use in the field of scientific dissemination and certainly in the educational field. For this reason, virtual reality should not be only seen as a technology for entertainment and/or leisure, but also a technology for educational and scientific purposes, with learning occurring in a more creative and enjoyable way [72-74].

Case Studies and Successful Implementations in East Africa

EAC has developed several science, mathematics, and technology (SMT) learning resources using VR technology [75]. The resources allow the use of virtual artifacts as visual aids, field trips as virtual environments, and simulations as animated analysis. Case studies on successful and ongoing implementations of these tools in 6 EAC countries are outlined. Hundreds of teachers have successfully been trained on how to customize these apps to suit the content and pedagogy taught in their local schools [76-80]. The first two apps under EAC Virtual School have been used in four arithmetic series and gaseous diffusion lessons. Follow-up default observations have so far produced recommendations for improvements on various aspects of VR technology in order to make them more useful to teachers and their students [81]. Key recommendations are also made on similar implementations in Africa for the Rising Africa Program. The reports demonstrate in detail how various historical, cultural, and local scientific information have been added to make the resources relevant to the students in these six EAC countries [82].

Future Prospects and Recommendations

These findings have strong potential implications when developing science learning materials for virtual reality. Virtual reality should be implemented in such a way as to encourage activities of the higher levels of students' cognitive abilities, especially with a focus on learning. As much as possible, virtual reality courses that aim for users not to have the same cognitive overload are expected to lower anxiety to enable better learning. End-user feedback is essential when designing virtual reality applications, such as collaborative science learning materials. It is essential that designers listen to feedback that thrives on better technology. Participants may also be able to come up with more creative and innovative solutions when they work with technologists. In virtual reality experiences for education, future developments include allowing students to learn through stimulating the natural real-world experiences that surround them. When interacting with others and conducting experiments with the same hands-on participation advantages, virtual reality games for education could succeed. The intervention in and of itself is inclusive about gender and with regards to the findings. Participants in the intervention did not experience any occurrences of cybersickness. Future research could possibly explore variations in the composition of the students to assess whether incidents of cybersickness occur when conducting Virtual Reality activities designed for the classroom, and a more technical examination of the reasons behind such incidents will be made.

Recommendations

Virtual reality technologies are costly within many educational systems in East Africa, which leads to virtual reality technologies being unavailable in many schools and students not reaping the benefits of these innovative technologies. Mass distribution of the Oculus Rift and HTC Vive could possibly open the doors to virtual reality, where, of course, the hardware would be very much at the ownership circumstances a large proportion of the region might find itself. If there are no hardware benefits, Africa's virtual reality developers will stop developing virtual reality-based education tools for schools as there is no platform to display their products on. At that stage, it is important for governments, Ministries of Education, together with industry organizations, to develop strategies to further expand virtual reality presence in schools both within urban areas and express interest in virtual reality programs. Many NGOs or CBOs who may build partnerships with developers of virtual reality applications may be able to implement this approach in East Africa.

Integration into Curricula

Staff are employed to operate the onboard facilities while the classes are in session – at least one geographical element is "obviously essential," said the project director. There is a measurable change in the attitude and performance of the children, expressed immediately not only in their dialogue but also in the lively bubble of interest that emerges. A further study, involving 400 young adults, had similar findings. Some marine biologists in Australia also have deployed VR in their field work to generate creative interest in a television generation. In these separate studies – and the use of VR will give these endeavors a more widespread longevity – the findings suggest very striking input. While there are few other reports available on this ability to draw filing subjects and students to a particular field of science, all these programs permit an immediate measure of "buy-in" from the students – i.e., a considerable reaction and excitement. The system at New York Hall of Science has a broader but equally direct approach to taking the technology to schools. It begins with a summer training seminar for teachers at the museum, during which participants undergo an intensive, five-week course in VR operation and use. These teachers then return to the museum several times, with their students, throughout the upcoming school year. Included are follow-up sessions of what is learned and mixing with peers, while the shadowing of students with VR 'enforced learning' forms a significant part of the virtual 'outreach'. The goals of the program are to establish in the teachers the confidence to use the new technology and to generate enthusiasm in the students.

CONCLUSION

Virtual Reality (VR) holds immense potential to revolutionize science education in East Africa. By providing immersive and interactive learning environments, VR can make complex scientific concepts more accessible and engaging for students. The successful implementations in various East African countries demonstrate VR's ability to enhance educational outcomes. However, challenges such as the high cost of VR technology, limited access to necessary hardware, and the need for teacher training must be addressed to fully realize VR's benefits. Strategic investments, partnerships with developers, and support from governments and educational institutions are essential for integrating VR into science education. Future research should focus on optimizing VR applications for educational use, ensuring inclusivity, and exploring long-term impacts on student learning and engagement.

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CITE AS: Turyamureeba Silaji and Kule Ashirafu Masudi (2024). The Impact of Virtual Reality on Science Education in East Africa. RESEARCH INVENTION JOURNAL OF RESEARCH IN EDUCATION 3(3):20-29.