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Exploring the Impact of Virtual Reality on STEM Education in Ghana

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ABSTRACT

The implementation of technology has revolutionised education in recent years by making the learning and teaching experience easier and more enjoyable. The use of virtual reality in STEM education is one of the most promising developments in this area since it offers an immersive and interactive learning experience. However, there is limited research on the impact of VR on STEM education in Ghana. This study seeks to investigate and answer the question of the potential and impact of virtual reality in STEM education in Ghana using the systematic literature review approach. This involved a thorough search across multiple academic databases including Google Scholar, IEEE Xplore, ERIC, ACM Digital Library and Springer Link, examining peer-reviewed articles and reports. The review revealed evidence supporting the positive impact of VR in STEM education as well as some challenges that come with it. The findings suggest that VR can provide a novel and effective way of learning and teaching STEM in Ghana. While certain factors may hinder the implementation of VR in STEM education, certain suggestions mentioned could overcome these barriers and pave the way for a more engaging, stimulating, and effective learning experience for Ghanaian STEM students, fostering a deeper understanding and preparing them to succeed in their future careers.

Keywords: Systematic Review, Virtual reality, STEM education, Ghana, Immersive learning, Interactive learning.

INTRODUCTION

In recent years, the world has been propelled by scientific and technological advancements. Consequently, Science, Technology, Engineering, and Mathematics (STEM) education has evolved in response to these progressions in the various scientific disciplines (Barode, Hayford, Bio, & Gyabeng, 2023). Presently, STEM-related knowledge and skills are the driving force of the global economy, leading to widespread international recognition (Barode, Hayford, Bio, & Gyabeng, 2023). STEM education integrates ideas from science, technology, engineering, and mathematics, making it fundamental for bridging the gaps between these areas by merging them into a single paradigm (Barode, Hayford, Bio, & Gyabeng, 2023). STEM involves understanding the functions of STEM disciplines in contemporary society, grasping core ideas in each field, and applying the knowledge gained (Barode, Hayford, Bio, & Gyabeng, 2023). STEM practices encourage students to explore new ideas, concepts or methods that address 21st-century demands, fostering creative thinking. (Barode, Hayford, Bio, & Gyabeng, 2023). STEM education consists of many abstract and complex concepts. Furthermore, to acquire knowledge in most STEM fields, students need to learn through well-planned instructional methods that offer experimental (practical) activities that closely mimic real-world situations and scenarios (Pellas, Dengel, & Christopoulos, 2020). However, implementing

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

methods to enrich their understanding of these concepts and offer practice-based tasks poses a challenge (Pellas, Dengel, & Christopoulos, 2020). The integration of Virtual Reality technology into STEM education has become a promising tool for solving these issues, thus enhancing the teaching and learning experience (Maheshwari & Maheshwari, 2020).

- **Background**

Virtual Reality refers to the use of computer modelling and simulations to create an artificial and interactive 3D environment perceived by a user wearing specialised devices like goggles, headsets, gloves, or suits (Gandhi & Patel , 2018). This environment, generated through computer graphics, simulates a user's physical presence and offers a realistic and responsive experience. (Gandhi & Patel, 2018).

The primary objective of VR is to provide the user with the perception of occupying a seemingly real and interactive environment, enabling them to carry out specific tasks efficiently and comfortably (Gutiérrez, Vexo, & Thalmann, 2023). Two major characteristics describing the VR experience are immersion and presence (Gutiérrez, Vexo, & Thalmann, 2023). Immersion is linked to the design of the VR application's user interface and can be categorised as fully immersive, semi-immersive, or non-immersive (Gutiérrez, Vexo, & Thalmann, 2023). The category depends on how much the user can sense (vision, hearing, touch) the real world while in simulation. In addition, this category is known as the types of VR (Gutiérrez, Vexo, & Thalmann, 2023). Fully immersive VR systems require the user to put on a head-mounted display (HMD) that tracks the user's head motions and adjusts the view (Gutiérrez, Vexo, & Thalmann, 2023). It envelops the user's auditory and visual senses in a simulated world and blocks out any external or physical stimuli to create a deeply immersive experience. Users have the feeling of being part of the simulated environment (Alqahtani, Dr Daghestani, & Dr Ibrahim, 2017). Semi-immersive VR systems, also known as hybrid systems, use desktop VR with additional hardware like data gloves to create a high level of immersion (Alqahtani, Dr Daghestani, & Dr Ibrahim, 2017). They overlay the simulated environment on the real environment and allow the user to engage with both using different inputs and outputs (Alqahtani, Dr Daghestani, & Dr Ibrahim, 2017). Lastly, non-immersive VR systems use a computer monitor to display the virtual environment without any additional devices. It has low immersion and interaction because the user is aware of the real world, but consists of high graphic quality (Alqahtani, Dr Daghestani, & Dr Ibrahim, 2017).

Presence is a psychological phenomenon that depends on the user's perception of being in a virtual environment. It is when the brain interprets various sensory inputs (such as images, sound, haptic feedback etc.) as a consistent environment where people can do some tasks and interact (Gutiérrez, Vexo, & Thalmann, 2023).

Virtual Reality is being used in a wide range of fields such as entertainment, business, architectural design, museum and art design (Gandhi & Patel , 2018). Beyond these, VR has found practical applications in education, where it facilitates interactive learning experiences for large groups within immersive 3D environments (Gandhi & Patel , 2018). It simplifies complex data visualisation making it both easy and engaging for students (Gandhi & Patel , 2018). For example, surgery simulations for medical students and interactive human anatomy models, where students can examine without any danger are widely used in the UK and other countries (Gandhi & Patel , 2018). Despite the growing research on the use and impact of VR on STEM education, there is a lack of research on its impact and effectiveness in the Ghanaian context. Most of the existing studies focus on developed countries, which have different educational systems and resources than Ghana.

- **Research Question**

The research aims to address the following question:

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

"*How does the integration of Virtual Reality impact Science, Technology, Engineering and Mathematics (STEM) education in the Ghanaian context, and what are the key challenges and opportunities associated with its implementation?*"

A systematic literature review methodology will be utilised in this paper to explore scholarly articles and research studies about the impact of Virtual Reality on STEM Education in Ghana. The scope encompasses investigation into content development, pedagogical strategies, student outcomes, and potential challenges associated with the use of VR technologies in STEM education. By defining the study within these parameters, the review aspires to provide a contextually relevant analysis that can contribute to the literature on Virtual Reality in STEM education in Ghana.

- **Overview of the Paper**

The literature review will thoroughly examine existing research about VR's impact on STEM education, spotlighting research trends, strengths and weaknesses of the studies. The research methodology will outline the data collection processes, search strategies and selection criteria. The results will present both the positive and negative findings from the literature review. Lastly, the discussion will address the research question, limitations and suggestions for future research directions.

LITERATURE REVIEW

This section reviews the existing literature on the impact of VR on STEM education. The selected papers span multiple categories, from the broader domain of VR in education and STEM education, to specific contexts like Computer Science, and Health Sciences. It also features a paper on the opinions of teachers and students on using VR. Each category is critically appraised to provide an analysis of the methodologies, findings and limitations of the studies under each category.

- **VR in Education**

Lege and Bonner (Lege & Bonner, 2020) explored the use, benefits, challenges, and future of using virtual reality as a platform for educational purposes. They did so by conducting a systematic review of VR in education publications from 2017 to 2020, providing a comprehensive overview of the field (Lege & Bonner, 2020). The benefits of VR in education include that it can enhance engagement and motivation for learners, improve spatial memory, and permit both students and teachers to understand and empathise with different perspectives, emotions and situations of others (Lege & Bonner, 2020). To illustrate, many educators have created VR experiences for students to gain more knowledge during events like the Syrian refugee crisis, American political rallies and the Hajj pilgrimage to Mecca (Lege & Bonner, 2020). Teacher trainees also experienced what it is like to be a student and teacher in a classroom, Moreover, the study mentioned that VR has the potential to promote distance learning (Lege & Bonner, 2020). However, VR also poses some challenges to education (Lege & Bonner, 2020). One of the challenges is the lack of VR-specific pedagogy and curriculum. Other challenges comprised cognitive demand and the level to which VR experience can immerse a user that could stem from VR hardware and software (e.g. low-resolution displays, complex visual environments etc.) (Lege & Bonner, 2020). One strength of the study is that it provides a comprehensive overview of VR in education, highlighting both benefits and challenges. A limitation of the study is that it does not address the ethical or social implications of using VR in education, such as privacy, or safety.

Another research (Wang & Gu, 2022) describes the application of VR in education. The authors state that VR has interactive features, making students more active and engaged in learning. VR also ensures a safer way to conduct experiments to avoid any risks or hazards (Wang & Gu, 2022). On the other hand, it is noted

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

that VR is not recommended for young children because their 3D vision, hand-eye coordination, and balance are still developing, and could be harmed when VR is used. Besides this, VR does not cover all subject areas (Wang & Gu, 2022).

The study named "A Review of the Virtual Reality Applications in Education and Training" (Smutny, Babiuch, & Foltynek, 2019) reviews the use of VR technologies for supporting teaching and learning, especially on the Oculus Rift platform (Smutny, Babiuch, & Foltynek, 2019). The paper presents a systematic analysis of 171 VR applications from the Oculus Store classified by curriculum content, language, price, size, and user rating (Smutny, Babiuch, & Foltynek, 2019). The paper also lists the top 10 educational VR applications based on a Bayesian average of user ratings (Smutny, Babiuch, & Foltynek, 2019). The findings indicate that STEM-related content accounts for 80% of the applications, with 2 applications for Engineering, 3 for Medicine, 2 for Space, and 1 for Nature (Smutny, Babiuch, & Foltynek, 2019). Table 1 below illustrates this in detail. Subsequently, the paper discusses the benefits of using VR in education such as being beneficial for visual learners, creating a sense of presence (Smutny, Babiuch, & Foltynek, 2019), enabling learning by doing, simulating a virtual laboratory, and triggering emotional reactions, which helps students remember details and increase their interest in the VR environment (Smutny, Babiuch, & Foltynek, 2019). The limitations mentioned in the paper are that it does not cover other distribution channels or platforms for VR applications and an analysis of mobile VR applications is absent (Smutny, Babiuch, & Foltynek, 2019). Although the study provides a comprehensive overview of the uses and benefits of VR in various educational domains, it does not discuss the challenges of using VR in education.

Table 1: Top 10 Educational Virtual Reality Applications Based on User's Ratings on the Oculus Store (Smutny, Babiuch, & Foltynek, 2019)

	Application	Curriculum content	Users' star rating	Number of ratings	Bayesian average
1	1943 Berlin Blitz	History	5	286	4.97
2	Wrench: Engine Building Demo	Engineering	5	143	4.93
3	Vinyl Reality	Music	5	16	4.52
4	Wonderful You	Medicine	4.5	118	4.44
5	Hold The World	Nature	4.5	45	4.35
6	Hoover Dam: IndustrialVR	Engineering	4.5	33	4.30
7	Apollo 11 VR HD	Space	4.5	17	4.16
8	eXPerience· Colorblindness	Medicine	4.5	11	4.03
9	NeuroExplorer	Medicine	5	5	4.00
10	Mars Is A Real Place	Space	4.5	10	4.00

From the table, eight applications are STEM-related Percentage: 8/10×100=80%..

- **VR in STEM Education**

This study (Maheshwari & Maheshwari, 2020) reviews how immersive VR can influence STEM education from primary school to university level (Maheshwari & Maheshwari, 2020). The review includes many case

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

studies such as an educational VR experience named “A Field Trip to Mars” where students can have the feeling of being transported to Mars (Maheshwari & Maheshwari, 2020). Another application developed by a company called “CalcVR” allows students to visualise graphical math problems for better understanding (Maheshwari & Maheshwari, 2020). The authors then go on to point out the advantages and disadvantages of using VR in STEM. For the advantages, VR helps improve cognitive skills, motivates and engages students, makes lessons more personalised to students, minimises distractions, enables visualisation of concepts as well as gives access to inaccessible sites (Maheshwari & Maheshwari, 2020). In contrast, VR technology and framework are costly, extra time is needed to train teachers and students, there is a lack of educational content, there are safety and health concerns (discomfort, nausea, near-sightedness, dizziness), and it’s not always effective for every lesson and subject (Maheshwari & Maheshwari, 2020).

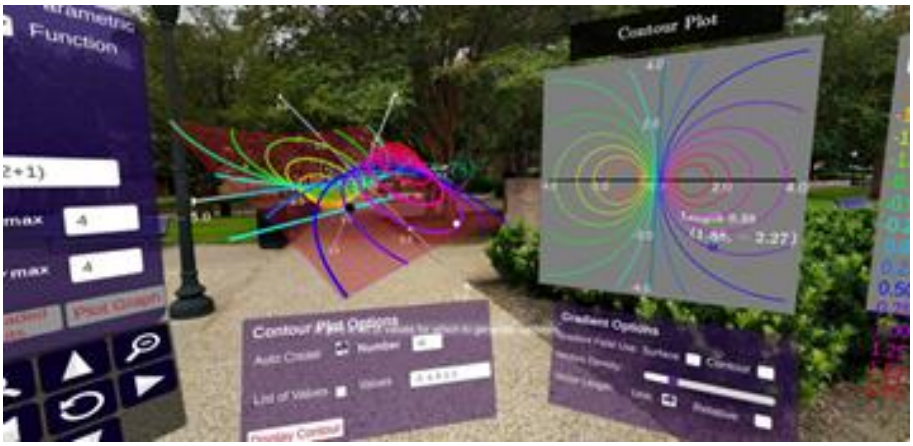

Fig. 1: CalcVR Application Screenshot (Maheshwari & Maheshwari, 2020)

- **VR in Secondary Schools**

A study by Truchly et al. named “Virtual Reality Applications in STEM Education” (Truchly, Medvecký, Podhradský, & Vančo, 2018), contributes to the literature on implementing VR in STEM education by providing a concrete example of how VR can be used to teach computer-networking concepts, which are often abstract and complex (Truchly, Medvecký, Podhradský, & Vančo, 2018). To demonstrate this, they developed and evaluated two VR games for teaching computer networking concepts to secondary school students. The first game, called ‘TCP/IP Protocol Stack’, allows students to learn about the protocol stack by shooting at a protocol “balloon” at the right protocol layer using a weapon (Truchly, Medvecký, Podhradský, & Vančo, 2018). The second game called ‘Firewall’ simulates the firewall concepts and decision process by having students inspect and then accept or reject freight items at a castle gate based on a set of rules. For their research methodology, 52 students in total participated in this research. Twenty-three (23) students were assigned to an experimental group (using the VR games) and twenty-nine (29) students were assigned to the control group (using only self-directed learning) (Truchly, Medvecký, Podhradský, & Vančo, 2018). Pre-test and post-test assessments were used to measure the student’s knowledge gains. Interviews and observations were conducted as well (Truchly, Medvecký, Podhradský, & Vančo, 2018). The study found that the experimental group outperformed the control group in terms of knowledge gains, with an average increase of 22% for the experimental group compared to -13% for the control group concerning lesson 1 (Truchly, Medvecký, Podhradský, & Vančo, 2018). Regarding lesson 2, the average increase for the experimental group was 29% compared to 10% for the control group (Truchly, Medvecký, Podhradský, & Vančo, 2018). The comparison can be found in Figure 2 below. Moreover, the observations and interviews reported that the learners appreciated the technology because it made their practical classes more active (Truchly, Medvecký, Podhradský, & Vančo, 2018). In addition, student engagement and motivation increased as they enjoyed the immersive and interactive environment (Truchly, Medvecký, Podhradský, & Vančo, 2018). The study also noted that the teacher’s guidance and feedback were required

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

to facilitate the student's self-directed learning (Truchly, Medvecký, Podhradský, & Vančo, 2018). This paper demonstrates the positive impact virtual reality has on STEM education. However, it does not discuss the limitations of its methodology and the sample size was quite small. A more thorough discussion of the limitations of the methodology and a larger sample size would provide more detail to the study.

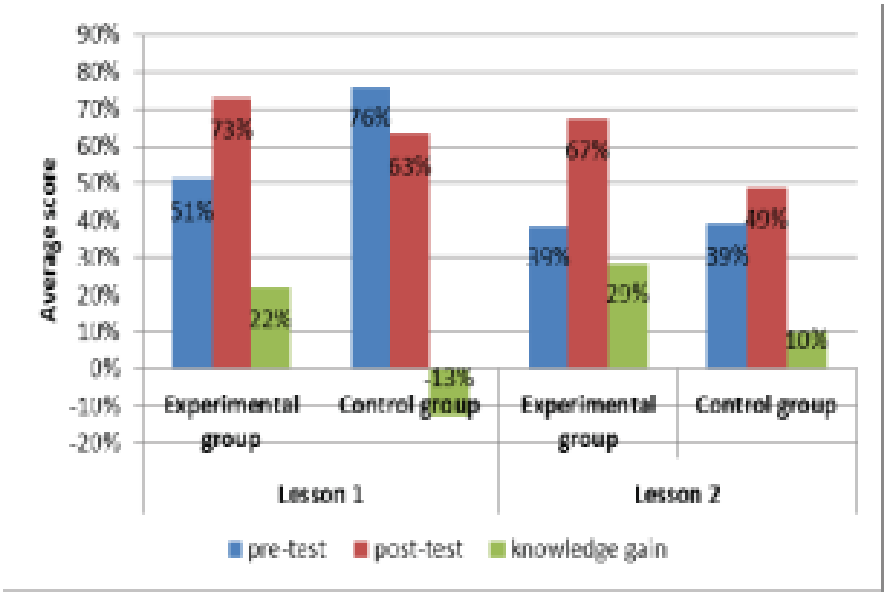

Fig. 2: Average pre and post-test scores and the knowledge gain for Lesson 1 and 2 (Truchly, Medvecký, Podhradský, & Vančo, 2018)

- **VR in Computer Science**

A study named "Using Virtual Reality in Education of Programming" (Konecki, Konecki, & Vlahov, 2023) discusses the potential of using virtual reality in programming education (Konecki, Konecki, & Vlahov, 2023). It highlights the challenges in programming, such as students' lack of problem-solving skills and the gap between students' way of thinking and algorithmic thinking necessary for programming (Konecki, Konecki, & Vlahov, 2023). The paper emphasizes the factors contributing to student's success in their programming courses, which are motivation to learn programming, fostering problem-solving skills, visualisation of complex programming, as well as learning through engaging and interactive programming content (Konecki, Konecki, & Vlahov, 2023). The authors believed that virtual reality could be used to develop a novel educational environment that enhances both the intellectual and emotional aspects of learning programming (Konecki, Konecki, & Vlahov, 2023). To support their statement, they created a questionnaire to discover students' attitudes towards using VR in their programming education. One hundred and thirty-four (134) Information Technology students took part in the questionnaire-based study (Konecki, Konecki, & Vlahov, 2023). They first answered the questions to get an overview of their knowledge of VR (Konecki, Konecki, & Vlahov, 2023). They were then provided with a customised VR programming lesson and were asked to answer the same questionnaire after the VR experience (Konecki, Konecki, & Vlahov, 2023). The findings indicate a significant positive change in students' perceptions of VR technology and its usefulness in programming education after engaging in the VR programming lesson (Konecki, Konecki, & Vlahov, 2023). The paper also addresses the challenges of implementing VR in programming education, including the high cost of VR headsets, the complexity of usage, and the need for VR education-related content development (Konecki, Konecki, & Vlahov, 2023). The paper concludes by stating that students should be informed about this type of education to raise awareness about how they can benefit from it as well and more research is needed on the teaching models, teachers' opinions of VR, and infrastructural requirements of VR in educational settings (Konecki, Konecki, & Vlahov, 2023). The strengths of this paper include its focus on an innovative approach to programming education, the

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

presentation of research findings, and the identification of challenges related to VR integration. However, the paper could benefit from a more in-depth quantitative approach and addressing the identified challenges. Additionally, a more extensive review of existing literature on VR in education could provide a stronger theoretical foundation for the discussion.

- **VR in Health Sciences**

A research study investigated the impact of VR on pharmacology education and evaluated students' perception of VR as an educational tool (Kim, Xie, Hammersmith, Berrocal, & Roni, 2023). Thirty-two (32) medical students at the University Of Illinois College Of Medicine, Peoria, participated in the research. The participants completed a pre-test assessment, engaged in a 10-minute VR module on the pharmacology of cardiovascular drugs associated with the autonomic nervous system, and then completed a post-test assessment and perception survey (Kim, Xie, Hammersmith, Berrocal, & Roni, 2023). The results showed that the majority of participants responded positively to the VR module, finding it easy to use and time efficient, while some experienced discomfort and preferred traditional learning formats (Kim, Xie, Hammersmith, Berrocal, & Roni, 2023). In addition, the assessment scores indicate that the VR module improved knowledge acquisition and confidence in pharmacology amongst the medical students who participated in the study (Kim, Xie, Hammersmith, Berrocal, & Roni, 2023). One strength of the study is that it provides quantitative data and students' positive and negative perceptions of their use of VR. On the contrary, the study does not extensively discuss the content and design of the VR module, which could have given more insight into its effectiveness.

Fig. 3: (A) A study participant is interacting with the VR environment using an HMD and controller (left) and (B) The VR interface of the cardiovascular pharmacology module (right) (Kim, Xie, Hammersmith, Berrocal, & Roni, 2023).

PERCEPTIONS OF VR IN STEM EDUCATION

- *Students:* A paper titled "Student Thoughts on Virtual Reality in Higher Education — A Survey Questionnaire"(Cicek, Bernik, & Tomicic, 2021) explored the potential benefits and student perceptions of using VR technology in higher education (Cicek, Bernik, & Tomicic, 2021). It reviews the history, definitions, and evolution of VR and its growing use for training and education due to improved visualisation, interaction, and immersion capabilities (Cicek, Bernik, & Tomicic, 2021). A 27-question survey was conducted with 55 respondents to test three hypotheses related to preferences for VR over 2D displays (Hypothesis 1), increased student interest in VR (Hypothesis 2), and learning outcomes of VR systems in education (Hypothesis 3) (Cicek, Bernik, & Tomicic, 2021). The results

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

showed that for hypothesis 1, 68.25% of the respondents preferred using VR head-mounted displays over 2D displays (Cicek, Bernik, & Tomicic, 2021). They noted that two (T2 and T3) statements were not taken into account due to data inconsistencies (Cicek, Bernik, & Tomicic, 2021). For hypothesis 2, 66.1% of the respondents believed that VR would increase student interest and engagement in course content (Cicek, Bernik, & Tomicic, 2021). They mentioned that social interaction between students and teachers is still important (Cicek, Bernik, & Tomicic, 2021). With hypothesis 3, 63.27% of the respondents thought introducing VR in curriculums would improve learning outcomes (Cicek, Bernik, & Tomicic, 2021).

- *Teachers:* This research article (Çoban, Akçay, & Çelik, 2022) focused on investigating ICT (Information and Communication Technology) pre-service teacher's opinions, and expectations using VR technologies as a teaching and learning tool in STEM education. Forty-four (44) ICT pre-service teachers participated in the study(Çoban, Akçay, & Çelik, 2022). The data was collected through a questionnaire and analysed using descriptive statistics, t-tests, and content analysis. Most of the ICT pre-service teachers did not have any experience using VR (Çoban, Akçay, & Çelik, 2022). Nevertheless, they expressed intent to use VR when teaching (Çoban, Akçay, & Çelik, 2022). Most of them felt it would have positive impacts like increased immersion, facilitating learning of complex topics, providing realistic environments, as well as exploring experiences and places inaccessible in real life (Çoban, Akçay, & Çelik, 2022). A few teachers expressed concerns about costs, technical issues, student isolation, as well as safety and health issues with VR (Çoban, Akçay, & Çelik, 2022). One strength of the study was the use of ICT teachers for the research, while the weakness included the use of only questionnaire data, considering that the teachers had a lack of VR experience.

METHODOLOGY

- **Research Design**

This study employs a systematic literature review approach to examine the impact of Virtual Reality on STEM Education in the Ghanaian context. It consists of an in-depth process to identify, select, and critically evaluate all relevant studies on the topic of VR in STEM Education.

- **Search Strategy**

The literature search was conducted using reputable academic databases and search engines like Google Scholar, IEEE Xplore, ERIC (Education Resources Information Center), ACM Digital Library and Springer Link. The search terms derived from the research question consisted of terms such as Virtual Reality, STEM Education, Ghana, Immersive Learning, and Interactive Learning. Studies included in the review must be journal articles, conference proceedings, book chapters or any relevant reports published between 2013 and 2023. It must focus on VR in STEM education, STEM education in Ghana, or any similar context. The studies must be written in English and there must be full-text availability. Studies not meeting these criteria were excluded.

- **Study Selection**

The literature search and selection process resulted in a total of nine (9) studies published between 2018 and 2023. The breakdown of the selected studies by publication year is as follows:

- 2018: 1 study
- 2019: 1 study
- 2020: 2 studies
- 2021: 1 study
- 2022: 2 studies

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

- 2023: 2 studies

- **Data Extraction**

The following data was extracted from each study:

- Bibliographic details: author(s), title, publication year, publication type, number of pages, publisher etc.
- Methodology: research design, data collection methods
- Results and findings
- Limitations and conclusion

- **Quality Assessment**

The quality of included studies will be assessed using established criteria tailored to the nature of the studies. Criteria will encompass a clear research question or objective, appropriate research design, reliable data collection methods, satisfactory reporting of results, satisfactory discussion of results, as well as the presence of implications and recommendations.

RESULTS

- **Positive**

The literature review identified several advantages and positive influences of VR on STEM education:

1. Enhances student motivation and engagement(Maheshwari & Maheshwari, 2020) (Lege & Bonner, 2020) (Wang & Gu, 2022) (Truchly, Medvecký, Podhradský, & Vančo, 2018).
2. Improves cognitive skills and spatial memory(Maheshwari & Maheshwari, 2020) (Lege & Bonner, 2020).
3. Provides access to explore inaccessible places and experiences(Maheshwari & Maheshwari, 2020) (Çoban, Akçay, & Çelik, 2022).
4. Offers a safer alternative to conducting experiments(Wang & Gu, 2022).
5. Makes practical classes more active(Truchly, Medvecký, Podhradský, & Vančo, 2018).
6. Facilitates visualisation of complex concepts(Maheshwari & Maheshwari, 2020) (Çoban, Akçay, & Çelik, 2022).
7. Easy to use and time efficient(Kim, Xie, Hammersmith, Berrocal, & Roni, 2023).
8. Personalises lessons for students(Maheshwari & Maheshwari, 2020).
9. Minimises distractions(Maheshwari & Maheshwari, 2020). `
10. Allows understanding of different perspectives.(Lege & Bonner, 2020) (Smutny, Babiuch, & Foltynek, 2019).
11. Promotes distance learning(Lege & Bonner, 2020).
12. Benefits visual learners(Smutny, Babiuch, & Foltynek, 2019).
13. Creates a sense of presence(Smutny, Babiuch, & Foltynek, 2019).
14. Enables learning by doing(Smutny, Babiuch, & Foltynek, 2019).

- **Negative**

The literature also identified several challenges and disadvantages of using VR in STEM education:

1. Lack of VR-specific pedagogy and curriculum(Lege & Bonner, 2020).
2. Need for the development of VR educational content(Maheshwari & Maheshwari, 2020) (Konecki,

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

Konecki, & Vlahov, 2023).
3. High cost of VR technology and framework(Maheshwari & Maheshwari, 2020) (Konecki, Konecki, & Vlahov, 2023) (Çoban, Akçay, & Çelik, 2022).
4. Extra time is needed to train students and teachers(Maheshwari & Maheshwari, 2020).
5. Complexity of VR usage(Konecki, Konecki, & Vlahov, 2023).
6. Health issues like discomfort, nausea, dizziness(Maheshwari & Maheshwari, 2020) (Kim, Xie, Hammersmith, Berrocal, & Roni, 2023) (Çoban, Akçay, & Çelik, 2022).
7. Not suitable or effective for every lesson and subject(Maheshwari & Maheshwari, 2020) (Wang & Gu, 2022).
8. Not recommended for younger children(Wang & Gu, 2022).
9. Student isolation(Çoban, Akçay, & Çelik, 2022).

DISCUSSION

This paper aimed to answer the research question: **"How does the integration of Virtual Reality impact Science, Technology, Engineering and Mathematics (STEM) education in the Ghanaian context and what are the key challenges and opportunities associated with its implementation?"**

To answer this question a systematic literature review was conducted, which identified and analysed nine relevant studies from various sources.

- **Threats to Validity**

It is vital to acknowledge certain gaps present in the literature reviewed the major gap lies in the limited number of studies directly conducted within the Ghanaian context. While efforts were made to include relevant literature, the scarcity of localised research poses a limitation to this study.

A quasi-experimental study comparing the impact of VR to the classroom norm of conventional methods could not be conducted due to limited resources and time.

- **Recommendations and Future Research**

In future studies, a quasi-experimental study comparing the impact of VR to the classroom norm of Conventional methods will be conducted.

Despite the valuable insights gained, the literature review identifies several areas warranting further investigation. One area for future research is to conduct more empirical studies on the impact of Virtual Reality on STEM education in Ghana, as the current literature is scarce and limited. Another area for future research is to investigate the development of a pedagogical approach specifically tailored for VR integration in STEM education. Examine effective instructional strategies, content, and assessment methods, and develop a VR-specific curriculum and pedagogy that aligns with the learning objectives and standards of different STEM subjects at the various levels. Moreover, the research could focus on creating and testing VR content that is relevant, appropriate, and diverse for education and covers a wide range of STEM topics, especially for the Ghanaian context and culture.

Also, investigate and develop VR environments that encourage teamwork among students to tackle the challenge of student isolation. Research on Cost-effective VR solutions suitable for educational settings like mobile VR headsets and encourage collaboration between the government, private sector and NGOs to make VR technology more accessible to schools. In addition, explore innovative training methods that minimise the time required to become proficient in using VR technology.

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Future research could also monitor and troubleshoot the usage and performance of VR applications, and ensure that it is reliable, functional, and user-friendly. Usability studies and feedback can help with this. Focus on simplifying the integration process and developing guidelines for educators to implement VR seamlessly into their teaching methods. To address the health issues, carry out studies to understand the causes of health issues associated with VR usage. Investigate hardware and software modifications that reduce comfort, motion sickness and other adverse effects as well as develop guidelines for safe and comfortable VR experiences in educational settings.

Furthermore, conduct research to identify the most effective use cases for VR in different STEM subjects. Develop a framework for selecting appropriate lessons and subjects for VR integration based on learning objectives, student preferences, and content suitability. Lastly, investigate the developmental appropriateness of VR for different age groups. Conduct studies on the impact of VR on younger children's cognitive and emotional development and provide evidence-based guidelines for age-appropriate VR integration in educational contexts.

CONCLUSION

To conclude, this paper presented a systematic literature review on the impact of VR on STEM education in Ghana. The findings showed that VR has a positive impact on STEM education such as increased engagement and motivation, improved cognitive skills, and many more. On the other hand, there were a few challenges stated like cost and health issues that need to be addressed and researched in the future before fully implementing it in the STEM curriculum in Ghana. The paper also contributes to the existing knowledge of VR in STEM education, particularly within the Ghanaian context. Using VR in STEM education is still in its developing stages but has the potential to enhance STEM education in Ghana if the right actions are taken to address the challenges and hence, it will become a tool for equitable access to knowledge for Ghanaian students.

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