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IMPLICATIONS OF VIRTUAL REALITY ON THE TEACHING AND LEARNING OF COMPUTER SCIENCE COURSES IN HIGHER INSTITUTIONS OF LEARNING

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Abstract

Most Computer Science courses are inherently abstract because they are founded on theoretical principles, logical structures and computational processes that are not physically tangible or directly observable. Courses such as Discrete Mathematics, Compiler Design, Automata Theory, and Artificial Intelligence require learners to develop mental models and engage in complex logical reasoning, which makes them difficult to comprehend through traditional teaching approaches. This has adverse implications such as low academic performance and cognitive overload on the teaching and learning of Computer Science courses in higher institutions of learning. Hence, this study highlights the implications of Virtual Reality (VR) as a teaching strategy for Computer Science courses. The study adopted a literature review approach by examining relevant peer-reviewed scholarly articles retrieved from academic databases using keywords related to Virtual Reality, Computer Science, and higher education. Articles were selected based on their relevance to the objectives of the study. The selected studies were reviewed and synthesised using a thematic narrative approach to identify the benefits and challenges associated with the use of VR in teaching abstract Computer Science concepts. The review indicates that VR enhances students' comprehension of abstract Computer Science concepts, improves students' engagement and enhances better retention of complex concepts. The review, however, identified high cost of procurement and maintenance, as well as technical limitations as some of the challenges of VR for teaching and learning of Computer Science courses in higher institutions of learning. The study concludes that VR serves as a promising pedagogical strategy for addressing the challenges posed by the abstract nature of Computer Science courses.

Keywords: Computer Science, Virtual Reality, Higher Institutions of Learning

1. Introduction

Computer Science as a field of study is viewed as the study of computers, computational systems, algorithmic processes and how data is processed, stored, and transformed into meaningful information. It encompasses the theoretical foundations and practical applications of hardware and software design to solve complex real-life problems. Computer Science has often been erroneously seen as a discipline that is limited to coding, however, it is a rigorous academic discipline which involves algorithms and data structures, Database Management, Artificial Intelligence, Cybersecurity, Cryptography and Human-Computer Interaction (HCI) (Grizioti, 2025).

The teaching of Computer Science in Nigeria usually begins at the primary level of Education where it is formally referred to as Basic Digital Literacy (Nigerian Educational Research and Development Council [NERDC], 2025). This subject introduces pupils to basic computer operations, safe use of the computer and common application packages, while

reflecting the curriculum's focus on digital literacy, skills and technology. At the secondary level of the Nigerian Educational System, Computer Science, often referred to as Digital Technology, is compulsory for all students at the Junior Secondary School level to develop computational as well as Information and Communication Technology (ICT) skills. Nonetheless, the subject which is elective at the Senior Secondary School level is designed to advance the creativity, logical reasoning, problem-solving and analytical skills of students. At the tertiary level of the Nigerian Educational system, Computer Science extends far beyond Basic Digital Literacy and Digital Technology. It entails the theories, design, abstraction/modeling and analysis of computational systems while equipping students with the abilities and skills to understand, develop and evaluate both software and hardware solutions (Chakraborty, 2024). Nonetheless, at the tertiary or higher level of Education across different countries in the globe, most Computer Science courses are inherently abstract in nature, unlike the Physical Sciences which focus on phenomena that can be observed and measured in the physical world (Colburn & Shute, 2007). Hence, the teaching and learning of Computer Science courses can be very challenging as students often struggle to connect theory to practice and visualise abstract computational concepts (Mirolo et al., 2021). This difficulty may lead to low comprehension of computational concepts, reduced motivation, low academic performance and increased cognitive load. Consequent upon this, there is a critical need for innovative instructional strategies that can enhance the teaching and learning of Computer Science courses in higher institutions of learning. One such approach is the use of Virtual Reality (VR) as a pedagogical tool.

Succinctly, VR is a simulation system that uses the computer to generate a simulated environment, which allows users to interact and immerse themselves in a three-dimensional (3-D) environment, giving them a more realistic or an exclusively imaginary experience (Piovesan et al., 2012). This technology differs from the conventional desktop simulations, which display virtual environments on a computer screen without creating a sense of immersion (Hamilton et al., 2021). VR usually engages one or more of the five human senses (sight, hearing, touch, smell and taste) to create both realistic and imaginary experiences. Nevertheless, contemporary educational VR systems primarily engage the visual and auditory senses and may incorporate haptic feedback to support tactile interaction. The integration of olfactory and gustatory feedback in educational VR, however, is very rare due to technological complexity and high implementation cost (Richard et al., 2006). Furthermore, these technologies are generally not significant in Computer Science courses because most Computer Science concepts rely on visual, auditory, and interactive representations rather than smell or taste.

The major objective of VR is to create an illusion of the physical presence of a user within a computer-generated environment. It can therefore be said that VR replicates the real world in its appearance and phenomena by simulating the user's physical presence in an artificially generated environment. This illusion is achieved through the use of a head-mounted display (HMD) system worn on the head of the user with built-in display and lenses which enables the user to have a view of the virtual world (Zhang, 2017). It is however important to note that VR is not the only immersive technology used in Education. Other immersive technologies used in Education include Augmented Reality (AR) and Mixed Reality (MR). AR is a technology which overlays digital information, such as images, text, or animations, onto the real-world environment while allowing users to remain aware of their physical environment. MR, on the other hand, combines elements of both VR and AR by enabling virtual objects to interact with real-world objects in real time. VR has however been found to be suitable for visualising complex and abstract concepts that are difficult to demonstrate using traditional instructional methods because of its high level of immersion and interactivity (Hamilton et al., 2021).

VR has been applied in various fields such as in healthcare where it has been used in the treatment of phobias, management of pain and surgical training (Seymour, 2002). It has also been deployed in digital marketing, urban and regional planning and Education. The introduction of VR in Education in recent times has made it possible for students to learn in an immersive and engaging way usually through real-life scenarios. It also improves knowledge retention, enhances motivation, provides easier comprehension of abstract concepts as well as providing simulation training. VR is therefore fast becoming an emerging technology in Education. Nonetheless, there is very limited research on the implications of VR on the teaching and learning of Computer Science courses in higher institutions of learning. Hence, this study examines the implications of VR on the learning outcomes of students studying Computer Science in higher institutions of learning. This is with the aim of evaluating the effectiveness of VR in enhancing students' understanding of abstract Computer Science concepts, improving students' engagement and students' performance in Computer Science.

2. Literature Review

2.1. Theoretical Framework

This study relies on two theoretical perspectives which include the Constructivist Learning theory and David Kolb's Experiential Learning theory. These theories were considered appropriate for this study because they provide a robust

theoretical foundation for understanding how VR can enhance students' comprehension and engagement as well as improve learning outcomes in abstract Computer Science courses.

Several proponents such as Jean Piaget, Lev Vygotsky, Jerome Bruner and John Dewey have been associated with the Constructivist Learning theory which emphasises active, experiential and socially mediated learning (Daodu et al., 2024). Nevertheless, this study aligns with Lev Vygotsky's social constructivist learning theory. Lev Vygotsky (1978) argued that learning is socially constructed and that knowledge is constructed by interacting with others, making use of tools and providing guided support for learners. This theory also emphasises that learners create an environment of shared meanings with their peers when they learn in a collaborative manner. The key components of this theory include social interaction, Zone of Proximal Development (ZPD), scaffolding, More Knowledgeable Other (MKO) and cultural tools. These components are briefly described below:

a) Social Interaction: Vygotsky (1978) opines that learning is a collaborative process that is achieved through interaction with other individuals which include teachers, peers and experts.

b) Zone of Proximal Development (ZPD): This component of the theory refers to the gap between the learner's ability to solve a problem independently and the potential to resolve the problem under the guidance of an adult or in collaboration with his peers. This zone is the zone of potential development and learning is said to be most effective at this level (McLeod, 2025).

c) More Knowledgeable Other (MKO): This refers to individuals with a higher level of knowledge than the learners. The MKO can be a teacher, a parent or a peer. The MKO helps the learner to surpass the ZPD level.

d) Scaffolding: Scaffolding refers to the temporary support that the MKO gives to the learner. Scaffolding comes in different forms which include the use of visual aids, demonstration, hints and cues, prompting or the use of guided questions and explanations.

e) **Cultural Tools:** This refers to the cultural artefacts that aid the learning process. They typically include language, symbols and technology. They differ across different countries, thereby resulting in different cognitive developments among learners across different environments (McLeod, 2025). VR is a cultural tool which mediates learning by enabling students to visualise and interact with abstract Computer Science concepts within immersive learning environments.

Lev Vygotsky's theory of constructivism is depicted in Figure 1. Within this framework, a learner's Actual Development Level represents what they can do on their own independently. VR serves as a computer-mediated tool that shapes cognitive development by providing an interactive, guided, and collaborative environment for learning. Thus, VR complements the MKO by providing technological scaffolding which enhances students' engagement. This assists learners to acquire more knowledge, skills and competence that were previously beyond their learning potentials. This moves them into the Zone of Proximal Development, and what they learn eventually becomes part of their actual developmental level.

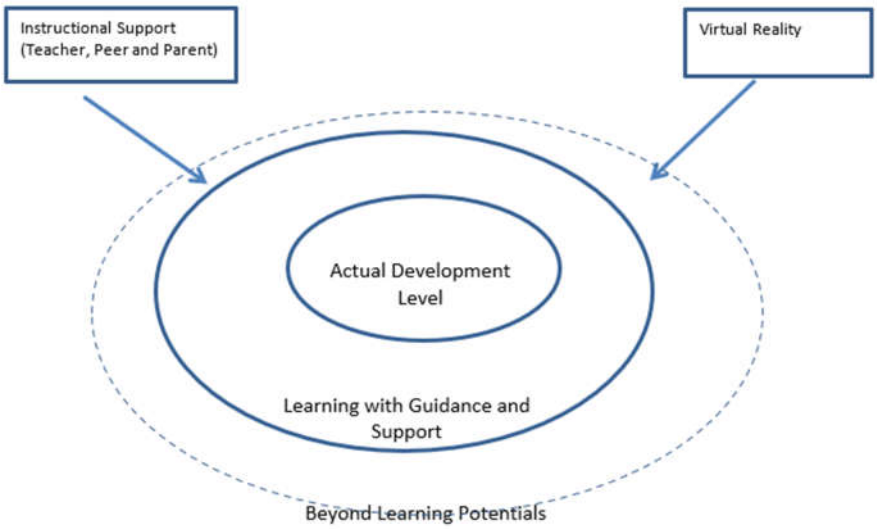


Figure 1: *Lev Vygotsky's social constructivist theory (Adapted from McLeod, 2025)*

David Kolb's experiential learning theory is a widely recognised framework that focuses on perception, cognition, behaviour and how people learn through experience (Kolb, 1984; Sims, 1983). Kolb (1984) outlines four stages of learning in his experiential learning theory. These stages are briefly described below:

a) **Concrete Experience:** Concrete experience occurs when a learner actively acquires a new experience or interprets a previous experience in a new way.

b) **Reflective Observation:** As the name implies, reflective observation occurs when a learner reflects on the new experience in order to have a full comprehension of the meaning of the experience and connects the experience to its meaning. This enables the learner to develop a deeper understanding of the experience.

c) **Abstract Conceptualisation:** This stage helps the learner to construct new ideas, theories or concepts based on their reflection.

d) **Active Experimentation:** At this stage, the learner adapts their experiences to real-life situations to check if they work and see if changes need to be made.

From the foregoing, David Kolb's theory of experiential learning allows learners to apply their learning experiences to real-life situations, thereby supporting knowledge retention, improving motivation as well as promoting learning. This theory can be applied to this research because VR provides immersive environments where students can learn abstract Computer Science concepts in interactive and simulated environments which enhance concrete experiences. This theory can also be linked to this research because VR allows learners to review recorded sessions, reflect on their previous experiences, form new ideas, generalisations, or models based on their reflections and also test their models in real-life.

2.2. Conceptual Review

This study reviews two basic concepts which include Computer Science and Virtual Reality.

The term computer is derived from the English verb *compute*, which originates from the Latin word *computare*, meaning "to calculate", "to reckon", or "to sum up" (Oxford English Dictionary, 2024). Historically, before the advent of electronic computers, the term computer referred to highly skilled individuals who performed mathematical calculations manually for scientific, commercial, engineering, and military purposes (Bruderer, 2021; Grier, 2001). They also played vital roles in performing complex manual computations during the First World War. These include calculations of ballistics, stresses and loads on military equipment, navigation of the troops and statistical and logical analysis (Grier, 2005). However, these procedures were time-consuming, labour intensive and prone to errors as the complexity of the calculations increased. As the demands for computations increased across industrial, military and scientific fields, the limitations of the manual computations became more evident. Hence, there was an urgent need for a more reliable, faster and accurate computational method which ultimately contributed to the development of mechanical and electronic computing devices. Hence, the field of Computer Science evolved as a result of the growing demand for computational efficiency, management of the exponential growth of data and information as well as harnessing technological advancements. Computer Science is therefore a broad scientific and academic discipline of study that entails the study of the theory, design, development, and application of computer systems and computational processes and how they are applied to solve real-life problems in all human endeavours. Mathematics, Mathematical Logic, Electrical Engineering, Philosophy and Physics laid the groundwork for Computer Science. However, Computer Science has a stronger link with Mathematics because Computer Science is fundamentally built on mathematical principles which include logic, algorithms, and discrete structures. In addition, both disciplines share the concept of computation which is the bedrock of Computer Science.

Computer Science emerged as an academic field of study in the 20th century, specifically in the early 1960s. Purdue University established its Department of Computer Science in 1962, making it one of the earliest dedicated Computer Science Departments in the United States (Rice & Rosen, 2004; Purdue University, 2025). Computer Science courses taught in higher institutions of learning across the globe include Software Engineering, Artificial Intelligence, Automata Theory, Discrete Mathematics, Computer Architecture, Database Management Systems, Data Structures and Operating Systems. Nonetheless, most Computer Science courses are abstract, as practical and systems-based courses vary in their levels of abstraction. Hence, the teaching and learning of these courses can be very challenging because they involve logical reasoning, symbolic representations, mental models and theoretical ideas which are not easily visualised. This no

doubt has adverse implications such as difficulty in comprehension, low academic performance and increased cognitive load on students of Computer Science. Consequently, this study explores the implications of Virtual Reality (VR) as a teaching strategy for Computer Science courses in order to facilitate students' comprehension of abstract Computer Science concepts, improving students' engagement and performance in Computer Science.

The term Virtual Reality (VR) is formed from two distinct words: virtual and reality. In the context of Computer Science, virtual means a concept or an object that does not physically exist but is made to appear as if it exists by software while reality refers to objects or concepts that physically exist in the environment. From the foregoing, the term Virtual Reality can be described as a computer-generated simulation of the reality which users can interact with as though they were real. Concisely, VR can be generally viewed as a computer-generated, 3-D environment which immerses users completely in a simulated environment, replacing their physical environment. There are several tools that are used for achieving VR. These tools include head-mounted display or a VR headset, motion sensors or trackers, input devices, computers or consoles, headphones or speakers, VR applications and 3-D modelling objects. The functions of each of these devices are briefly described below:

a) **Head Mounted Display or VR Headset**: The Head Mounted Display is a device which is usually worn on the head of the user and positioned close to the user's eyes. It incorporates visual technology, motion tracking and optical systems to display digital contents within a user's field of view, presenting a 3-D environment which immerses the user in the simulated world by completely blocking out the physical environment (Yue et al., 2023). The head-mounted display also includes the lenses through which the virtual environment is displayed. Figure 2 shows Teenage students wearing virtual reality goggles in a Computer Science class.



Figure 2: *Teenage students wearing VR headset in a Computer Science Class (Halfpoint, 2022)*

b) **Motion Trackers:** The basic goal of the motion trackers is to detect users' movements in the physical space and transfer them into the virtual environment, ensuring that the interaction between the user and the computer generated environment is realistic and immersive.

c) **Input Devices:** The function of the input devices is to capture physical actions such as gestures, movement and voice. Typical examples of input devices include joysticks, data gloves and microphones.

d) **Computers or Consoles:** The computer or console in VR is responsible for processing, controlling, rendering and managing the 3-D environment in real-time. It also runs the VR applications, receives signals from the input devices and synchronises all the other components of the VR while ensuring that they enhance realism.

e) **Headphones and Speakers:** These devices are responsible for producing 3-D spatial audio, reducing noise from the physical environment as well as improving immersion.

f) VR Applications: These are software or programmes that enable the computer or console to run VR applications.

VR has been applied in various fields of life including healthcare, military and in Education (Radianti et al., 2020; Jensen & Konradsen, 2018). VR has been applied in Education to enhance virtual field trips. This enables students to visit places they may never have the opportunity to physically access, such as museums, historical sites, oceans, and the outer space. VR has also been used to enhance Virtual Science Laboratories where students perform experiments in a safe and simulated environments (De Jong et al., 2013). It has also facilitated medical and healthcare training which helps medical students to practice surgical procedures, patient examinations, and emergency responses before working with real patients (Kyaw et al., 2019). Different VR applications common in the field of Education include:

a. **Google Expeditions/Tour Creator:** This educational VR application enabled students to take virtual field trips to historical sites, museums, underwater environments, and the outer space. The platform was deactivated by Google in 2021, although, it provided students with the opportunity of immersive virtual field trips which enriched classroom instruction through experiential learning.

b. **ClassVR**: ClassVR is a classroom-focused VR platform that provides teachers with educational content and lesson plans.

c. **ENGAGE:** ENGAGE is a social VR platform that provides a platform for teachers and students to meet in virtual classrooms and collaborate on projects.

d. **Labster:** This provides immersive virtual laboratory simulations for conducting safe experiments in Biology, Chemistry, Physics, and other sciences.

e. zSpace: This provides interactive 3-D learning experiences that allow students to manipulate virtual objects and models.

2.3. Benefits of Virtual Reality on the Teaching and Learning of Computer Science Courses in Higher Institutions of Learning

This section highlights the benefits of VR in the teaching and learning of Computer Science courses in higher institutions of learning. These benefits are highlighted below:

a. **Improved Comprehension of Abstract Concepts:** Most Computer Science courses taught in higher institutions of learning are associated with abstract concepts that are not easily visualised. The learning of these abstract concepts can be challenging and may create a sense of ambiguity for Computer Science students. However, the use of VR to teach and learn abstract concepts in Computer Science courses will enhance the understanding of these concepts by enabling students to visualise these concepts in a 3-D environment. This helps to simplify the complex ideas and improve the learners' comprehension of the abstract concepts (Pirker et al., 2020; Radianti et al., 2020).

b. **Interactive and Immersive Learning:** VR provides an immersive and interactive learning environment for students to actively participate in the teaching and learning of Computer Science courses. Through 3-D visualisation, simulation, and real-time interaction, VR allows students to explore abstract Computer Science concepts such as data structures, AI, computer architecture, computer networks, and programming in a more intuitive and engaging manner (Parong & Mayer, 2018). This no doubt enhances students' comprehension of abstract concepts which in turn leads to increased motivation to learn as well as improved learning outcomes (Radianti et al., 2020). However, it should be noted that VR learning outcomes vary by instructional design and learners' characteristics.

c. **Improved Retention of Computing Concepts and Ideas:** VR helps students to easily recall computing ideas and concepts by enabling students to visualise these concepts in a 3-D environment. This visualisation experience promotes deeper understanding of Computing ideas and concepts, which reduces confusion and improves long-term recall (Makransky & Lilleholt, 2018).

d. **Improved Creativity and Problem-Solving Skills**: Computer Science as an academic discipline in higher institutions of learning entails both creativity and problem-solving skills which are essential for effectively addressing complex computational problems (Adeoye & Jimoh, 2023). VR helps Computer Science students develop their creativity and problem solving skills by allowing learners to manipulate virtual objects as if they were

real. This capability enhances hands-on experience, encourages trial-and-error experimentation and design, improves innovative thinking, and allows learners to explore alternative solutions.

e. **Safe Simulation of Real-Life Scenarios:** VR enables Computer Science students to simulate real-life computing scenarios in a safe virtual environment without posing risks to the actual systems. This enables students to test different computing scenarios in a secured virtual environment which provides a platform for experiential learning and skill development.

f. **Encourages Self-Paced Learning:** VR enables students to learn at their own pace by encouraging students to repeat experiments, designs and simulations as long as they desire. This enhances personalised learning and accommodates diverse learners with different learning rates and abilities.

g. **Enhanced Collaborative Learning:** Computer Science is a highly collaborative field of study because most of the tasks performed in Computer Science are usually too large for a single individual to handle (Sommerville, 2011). Hence, Computer Scientists usually work in teams where each person handles different components of the tasks in order to build and maintain complex computing systems. VR facilitates collaboration in the teaching and learning of Computer Science courses by creating a shared and virtual platform where different students can communicate, interact and work together as if they are in the same physical environment. This fosters teamwork and collaborative learning.

2.4. Challenges of Virtual Reality in the Teaching and Learning of Computer Science Courses in Higher Institutions of Learning

The following are some of the challenges of VR in the teaching and learning of Computer Science courses in higher institutions of learning:

a. **High Cost of Procurement and Maintenance:** The procurement and maintenance of VR devices require substantial financial investments. Unfortunately, many higher institutions of learning, especially in developing countries, often operate under limited financial resources and inadequate technological infrastructure (Afolabi & Oketunbi, 2023; Shehu, 2025). This poses a significant challenge to the adoption of VR equipment in higher institutions in developing countries. Consequently, most higher institutions of learning in developing countries may find it difficult to establish and sustain VR-based learning environments. This ultimately restricts the accessibility of VR as an instructional strategy for teaching and learning Computer Science courses in developing countries.

b. **Lack of Technical Skills:** VR requires adequate technical skills to be effectively deployed for teaching and learning of Computer Science courses in higher institutions of learning. Many teachers, especially in developing countries, are not trained in the use of VR for teaching and learning. Nonetheless, without adequate training and technical skills, VR cannot be effectively deployed for teaching and learning of Computer Science courses.

c. **Health Concerns:** VR results in health-related issues such as eyestrain, cyber-sickness, headaches and mental fatigue particularly during prolonged use (LaViola, 2000; Kourtesis et al., 2023). One of the reasons for these health concerns is that the VR headset is worn very close to the eyes. The lenses in the VR headset makes the 3-D images appear farther than they are in the physical space. This phenomenon confuses the eye and the brain, thereby resulting in health-related problems.

d. **Cognitive Overload:** The use of VR for teaching and learning Computer Science courses may result in cognitive overload, particularly when learners are required to process complex concepts and interact with an immersive virtual environment concurrently. Nevertheless, Sweller et al. (1998) in their Cognitive Load Theory emphasised that effective learning will only take place when the amount of information presented to the learners does not exceed their mental processing capabilities. Hence, excessive visual and auditory interactive elements or poorly designed VR elements may result in an increase in the mental effort of students while navigating virtual environments. Consequently, learners may experience reduced concentration, poorer comprehension, and lower knowledge retention. The concept of cognitive overload is, however, quite different from the novelty effect which is a term that refers to the temporary excitement that a learner experiences when using a new technology. This feeling, however, increases learners' motivation and engagement but often decreases once the technology becomes familiar (Clark,1994). The novelty effect can, however, contribute to cognitive overload by imposing additional

mental demands on learners as their attention is divided when exploring the new technology and processing the instructional content simultaneously.

e. **Distraction During Academic Activities:** VR provides features which promote excitement, entertainment and engagement in Computer Science classes. Nonetheless, Computer Science students taught with VR may be distracted when their attention is more focused on the entertaining or immersive features of the VR environment than on the actual learning contents or objectives. This phenomenon, known as entertainment-related distraction often reduces learning effectiveness and contributes to cognitive overload as learners spend their mental processing capabilities processing distractions rather than the instructional content. Hence, immersive features in VR should be designed to support learning in Computer Science classes (Makransky & Petersen, 2021).

3. Conclusion

This study examined the implications of VR on the teaching and learning of Computer Science courses in higher institutions of learning. The study relied on existing literature to reveal the benefits and challenges of VR in the teaching and learning of Computer Science courses in higher institutions of learning. The reviewed literature suggested that VR enhances students' comprehension of abstract concepts in Computer Science courses. The reviewed literature also suggested that VR increases students' engagement and motivation as well as collaboration amongst Computer Science students. However, the study revealed that high cost of procuring, installing and maintaining VR equipment hinders the widespread use of the technology for teaching and learning of Computer Science courses especially in developing countries. The study also revealed that VR equipment can pose significant health challenges during prolonged use, foster cognitive overload and can cause distraction during academic activities. The study concluded that since VR is a promising and innovative instructional tool, stakeholders in higher institutions of learning should invest in resources and formulate policies that will engender its sustainable implementation for teaching and learning Computer Science courses in higher institutions of learning.

4. Recommendations

Based on the literature reviewed so far, the following recommendations are hereby made to facilitate the effective integration of VR in the teaching and learning of Computer Science courses in higher institutions of learning:

a) Capacity Building for Computer Science Students and Teachers: Computer Science students and lecturers should be adequately trained on the use of VR for pedagogy rather than for entertainment.

b) Investment in VR Technology: Stakeholders in higher institutions of learning should invest in VR technology by providing adequate funds for procurement, installation and maintenance of VR technology.

c) Policy Support: Government and other stakeholders in higher institutions of learning should formulate and support policies that will encourage the integration of VR into the teaching and learning of Computer Science courses across universities, polytechnics, colleges of education and other higher institutions of learning.

d) Blended Learning Approach: VR should not be seen as a replacement of the conventional teaching methods but as a complementary approach.

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