UNIOFFA JOURNAL OF INTERDISCIPLINARY STUDIES (U-OJIS)
A Multidisciplinary Journal of Science, Management and Social Sciences
Website: www.unioffajis.com
ISSN:3141-5571
E-ISSN:3141-558X

TRANSFORMING SCIENCE EDUCATION THROUGH TECHNOLOGY AND MENTAL HEALTH-SENSITIVE PEDAGOGIES: THE ROLE OF AUGMENTED REALITY

Bello Zakariyau Adebayo, PhD; Abdulrahim Basira Jibril, PhD; Adeoye Gabriel Ademakinwa, PhD; Maroof Zainab Aliyu; Oba Abdulkadir Ibrahim

Department of Life Science Education, Kwara State University of Education, Ilorin, Nigeria

Corresponding Author: Bello Zakariyau Adebayo, PhD
Department of Life Science Education, Kwara State University of Education, Ilorin, Nigeria
Email: bello.za@kwasued.edu.ng, 08036092412

Volume 1:2

Abstract

Science education in many developing countries continues to face challenges associated with inadequate laboratory facilities, rising costs of scientific equipment, limited practical learning opportunities, and increasing concerns about students' psychological well-being during science instruction. This paper examines the potential of Augmented Reality (AR) as a technology-driven and mental health-sensitive pedagogical approach for transforming Science, Technology, Engineering, and Mathematics (STEM) education. Using a conceptual and narrative literature review approach, relevant studies on AR, virtual laboratories, student engagement, laboratory anxiety, inclusive education, and technology-enhanced learning were synthesized. The review reveals that AR improves students' conceptual understanding, motivation, participation, practical skills development, and confidence through interactive three-dimensional visualization and virtual experimentation. Evidence further suggests that AR can reduce laboratory-related anxiety, support inclusive learning environments, and promote students' psychological well-being. Guided by the Technology Acceptance Model (TAM), the paper argues that AR offers a cost-effective complement to conventional laboratory instruction, particularly in resource-constrained educational settings. The paper concludes that integrating AR into STEM education can improve learning outcomes while simultaneously supporting mental health-sensitive pedagogical practices. Recommendations are provided for policymakers, curriculum developers, educators, and researchers.

Keywords: *Augmented Reality, Science Education, Laboratory Pedagogy, Cost-Effective Instruction, Virtual Experiments, Educational Technology*

Introduction

Globally, science education remains a major driver of innovation, industrial development, and sustainable economic growth. International organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) have consistently emphasized the need to strengthen Science, Technology, Engineering, and Mathematics (STEM) education in order to prepare learners for the demands of the twenty-first century workforce. Despite the growing importance of STEM education, many countries continue to experience challenges relating to inadequate laboratory facilities, limited access to modern instructional technologies, and insufficient opportunities for practical learning. Consequently, educational stakeholders across the world are increasingly exploring innovative technological solutions capable of enhancing science teaching and learning.

ISSN:3141-5571
E-ISSN:3141-558X

The rapid advancement of digital technologies has transformed educational practices globally. Emerging technologies such as Artificial Intelligence, Virtual Reality (VR), Augmented Reality (AR), and simulation-based learning environments are increasingly being integrated into classrooms to improve learners' engagement, understanding, and practical experiences. Among these innovations, Augmented Reality has gained considerable attention because of its ability to combine virtual content with real-world learning environments, thereby making abstract scientific concepts more concrete, interactive, and meaningful for learners.

Within the African context, science education continues to face numerous challenges, particularly in many developing countries where inadequate laboratory facilities, poor funding, shortage of instructional materials, and the digital divide remain major concerns. Across Sub-Saharan Africa, many schools struggle to provide students with adequate practical experiences due to the high cost of scientific equipment and limited technological infrastructure. These challenges have increased the need for affordable and innovative approaches capable of supporting practical science instruction while reducing dependence on expensive laboratory resources.

In Nigeria, the situation is further compounded by economic challenges such as inflation, unstable exchange rates, inadequate funding of education, and the increasing cost of importing scientific and laboratory equipment. These realities have made it difficult for many schools and educational institutions to establish and maintain standard science laboratories, thereby limiting opportunities for effective practical instruction. Consequently, the search for technology-driven and cost-effective alternatives to conventional laboratory practices has become increasingly important in the Nigerian educational system.

Against this background, the importance of science education and the challenges confronting its effective delivery deserve further attention.

Science is a dynamic field built on curiosity, critical thinking, and experimentation, all of which contribute to new discoveries, technological innovations, and practical solutions to everyday challenges facing society. The significance of science education to the growth and technological advancement of every nation cannot be overemphasized because it helps learners to develop knowledge, practical skills, and problem-solving abilities needed to explore scientific ideas, thereby contributing meaningfully to the development of society (Agboola, 2025; Ukozor, 2010). However, the laudable importance of science education cannot be fully achieved without practical learning experiences, which usually require well-equipped science laboratories that are lacking in many Nigerian schools (Abidoye et al., 2022; Kinta & Philip, 2025; Osaiyuwu, 2025).

In view of the above, many science teachers rely mainly on teacher-centred instructional practices, which limit students' opportunities to observe experiments, analyse findings, visualize scientific processes, and apply scientific principles to real-life situations. This affects students' interest and performance in Science, Technology, Engineering and Mathematics (STEM) subjects, as many learners find it difficult to understand abstract scientific concepts when they are taught without practical engagement (Hamisu & Ahmad, 2026). In many schools, the lack of functional laboratories, modern instructional materials, and technological resources has made effective science teaching increasingly challenging.

Furthermore, the inadequate funding of science education has limited the ability of many institutions to provide quality laboratory facilities and maintain existing equipment. In addition, the unpredictability of the Nigerian economy occasioned by constant rising inflation and inconsistent exchange rates has immensely contributed to the high cost of technological, laboratory, and scientific materials (Owede, 2026). As such, a large number of schools are unable to procure modern technological and science laboratory equipment because many of these facilities are imported from outside the country. Consequently, both science teachers and learners are often restricted to teaching approaches that focus more on theory rather than hands-on (practical-based) learning in which the teacher mainly serves as a facilitator who guides learning rather than simply delivering information. Hence, the overall flow of effective science instruction is distorted, and students are denied rich practical experiences that are essential for deeper understanding.

ISSN:3141-5571
E-ISSN:3141-558X

The challenges highlighted above have raised the need for alternative and innovative approaches to science teaching and learning. Meanwhile, the revolution in digital technology has introduced new opportunities for improving classroom instruction and making learning more engaging and interactive. One such innovation is Augmented Reality (AR), which stimulates learners' sensory perception and supports digital information through the integration of virtual objects into real-world learning environments (Azhari, 2026). According to Mumtaz et al. (2017), AR offers students the opportunity to interact with three-dimensional models and virtually observe scientific processes, thereby concretizing knowledge and aiding better understanding of difficult concepts without depending entirely on physical laboratory equipment.

The deployment of Augmented Reality in STEM education can facilitate learner-centred and mental health-sensitive pedagogical approaches. This is because many students develop fear and anxiety toward science subjects, particularly when lessons are presented mainly in theory without adequate practical experiences. Such an approach limits students' understanding of scientific concepts and often leads to misconceptions and poor interpretation of scientific ideas (Concannon et al., 2013). By making learning more interactive, practical, and enjoyable, AR can help reduce academic stress, improve students' motivation, and encourage active participation in the learning process.

Hence, this study investigates the transformation of science education through technology and mental health-sensitive pedagogies. It examines the role of Augmented Reality (AR) in Science, Technology, Engineering, and Mathematics (STEM) education, with particular emphasis on how the technology can enhance the teaching and learning of STEM subjects, thereby providing students with meaningful real-time practical experiences despite the shortage of laboratory facilities caused by inadequate funding, harsh economic conditions, and the high cost of imported laboratory equipment.

Statement of the Problem

Science education has remained the building block for the acquisition of scientific and technological skills aimed at improving or enhancing national and technological development. However, a series of constraints affects effective teaching and learning of STEM subjects, which has negatively influenced students' performance, interest, and practical competences. A major challenge is the high cost of laboratory equipment required for practical work, which have made many schools laboratories non-functional or operate with poorly equipped facilities that are insufficient for meaningful experimentation (Oliveira & Bonito, 2023). In such situations, science lessons tend to become largely theoretical, which reduces students' opportunities for hands-on learning and limits their understanding of scientific concepts through direct experience. This submission aligns the finding of Dike and Salisu (2015) which shows that many Nigerian schools experience shortages of laboratory facilities and equipment, resulting in reduced practical activities and over-reliance on theory-based teaching.

Limited funding and economic instabilities further compound this challenge and make the maintenance of standard laboratory illusive. Hence, the need for an affordable and innovative approach such as AR, which has been found to be effective for teaching and learning because it provide interactive simulations that support practical learning even where physical laboratories are limited or unavailable (Aliyu et al., 2025).Literature evidences and empirical studies such as those of Anudu et al. (2025); Udoh et al. (2025); and Nassarawa et al. (2025) has established the effectiveness of AR when deployed in STEM education or related subject areas. However, the present study explores how science education can be transformed through technology and mental health-sensitive pedagogy such as AR

Purpose of the Study

The main purpose of this study is to x-ray how Augmented Reality can be used to transform science education, particularly the teaching and learning of STEM subjects. The study also seeks to propose the use of Augmented Reality as additional supplement to traditional laboratory practices through the introduction of virtual experiments that will simulate hands-on practical activities. Furthermore, the study aims to should be shed light on the how to achieve reduction the cost of purchasing and maintaining laboratory equipments while ensuring that science students gain practical experience, especially in schools with inadequate laboratory facilities, outdated, damage or expired instructional materials.

ISSN:3141-5571
E-ISSN:3141-558X

Conceptual Clarifications

Augmented Reality (AR)

Augmented Reality (AR) is a technology that overlays digital information such as images, animations, videos, and three-dimensional objects onto the real-world environment in real time, thereby enhancing users' perception and interaction with their surroundings. According to Azuma (1997), AR is characterized by three essential features: the combination of real and virtual environments, real-time interaction, and three-dimensional registration of virtual objects. Similarly, Billinghurst, Clark, and Lee (2015) described AR as a technology that enriches users' experiences by blending computer-generated content with the physical world. Furthermore, Ibáñez and Delgado-Kloos (2018) defined AR as an emerging educational technology that facilitates visualization, interaction, and engagement in learning processes. In science education, AR enables learners to interact with complex scientific concepts that may be difficult to observe directly, thereby improving understanding and retention.

Science Education Transformation

Science education transformation refers to the systematic improvement and modernization of science teaching and learning practices through innovative pedagogies, learner-centered approaches, and technological integration. According to National Research Council (2012), transformative science education emphasizes active inquiry, critical thinking, problem-solving, and authentic learning experiences. Similarly, UNESCO (2021) emphasized that educational transformation involves redesigning teaching approaches to meet contemporary societal and technological demands. Within this context, the integration of innovative technologies such as AR is increasingly viewed as a catalyst for transforming science classrooms into interactive and engaging learning environments.

STEM Education

STEM Education is an interdisciplinary approach that integrates Science, Technology, Engineering, and Mathematics to foster problem-solving skills, innovation, creativity, and real-world application of knowledge. According to National Science Foundation (2018), STEM education equips learners with competencies required for participation in modern technological societies and future careers. Similarly, Bybee (2013) described STEM education as an integrated instructional framework that prepares students to address complex challenges through scientific inquiry and technological innovation. The significance of STEM education lies in its capacity to develop critical thinking, collaboration, creativity, and technological literacy, all of which are essential competencies in the twenty-first century.

Technology-Enhanced Learning

Technology-Enhanced Learning (TEL) refers to the use of digital technologies to improve teaching, learning experiences, and educational outcomes. According to Kirkwood and Price (2014), TEL involves employing technology not merely as a delivery tool but as a means of transforming learning experiences and promoting deeper understanding. Likewise, Laurillard (2012) argued that technology can facilitate interactive, collaborative, and personalized learning environments. Within science education, AR represents a form of TEL that enables students to visualize abstract concepts, manipulate virtual objects, and engage actively in learning activities, thereby enhancing comprehension and motivation.

Mental Health-Sensitive Pedagogy

Mental Health-Sensitive Pedagogy refers to educational practices that intentionally promote learners' psychological well-being while creating supportive, inclusive, and emotionally safe learning environments. According to Nemiro et al. (2022), educational environments should be responsive to learners' mental health and psychosocial needs through the integration of Mental Health and Psychosocial Support (MHPSS) approaches within teaching and learning processes. Such pedagogical approaches emphasize social and emotional learning, supportive teacher-student relationships, and learning environments that foster safety, participation, and well-being.

Student Well-being

Student well-being refers to learners' overall psychological, emotional, social, and educational

ISSN:3141-5571
E-ISSN:3141-558X

functioning within the learning environment. Nemiro et al. (2022) argued that positive educational environments contribute significantly to learners' mental health, social development, resilience, and academic achievement. Student well-being encompasses positive emotions, healthy relationships, a sense of belonging, and the ability to engage meaningfully in learning activities.

Psychological Safety

Psychological safety refers to a learning climate in which students feel secure, respected, valued, and free from fear of embarrassment, discrimination, or failure. Nemiro et al. (2022) emphasized the importance of creating safe and healing learning environments that support learners' mental health and psychosocial development. Psychological safety encourages participation, creativity, inquiry, and collaborative learning, all of which are essential for effective science learning.

Anxiety Reduction

Anxiety reduction involves educational strategies and learning conditions that minimize stress, fear, and emotional distress among learners. According to Nemiro et al. (2022), integrated mental health and psychosocial support interventions within educational settings can reduce stress, anxiety, and depression while improving academic engagement and overall well-being. Learning environments that incorporate supportive technologies, positive teacher interactions, and learner-centered pedagogies can contribute significantly to reducing academic anxiety.

Inclusive Learning

Inclusive learning refers to educational practices that ensure equitable participation and learning opportunities for all students regardless of gender, disability, socioeconomic background, ethnicity, or other differences. Nemiro et al. (2022) stressed the need for educational systems to respond to the diverse needs of learners, particularly marginalized groups, by promoting participation, accessibility, and supportive learning environments. Inclusive learning recognizes diversity as a strength and seeks to eliminate barriers that hinder effective participation and achievement.

Relationship Between Augmented Reality and Mental Health-Sensitive Learning

The integration of AR into science education aligns with the principles of technology-enhanced learning and mental health-sensitive pedagogy. AR creates interactive, engaging, and learner-centered experiences that can reduce learning anxiety, increase confidence, promote participation, and enhance students' sense of psychological safety. By enabling students to visualize abstract scientific concepts in an accessible and immersive manner, AR contributes to inclusive learning and supports students' cognitive, emotional, and social development. Consequently, AR has the potential to serve as both an instructional innovation and a tool for promoting student well-being within contemporary science education environments.

Literature review

Theoretical Framework

This study is anchored on the Technology Acceptance Model (TAM), which explains how individuals accept and use information systems and emerging technologies. The model postulates that the acceptance of technology is predicted by users' behavioural intention, which is influenced by their perceptions and attitudes toward the technology. TAM has been widely applied in studies relating to educational technology because it provides insight into how users respond to innovative digital tools within learning environments.

The acceptance and use of information technologies can produce both immediate and long-term benefits at individual and organisational levels, including improved performance, time efficiency, convenience, and enhanced learning experiences. The capacity of technology to deliver these benefits has continued to motivate research in information systems and educational technology, particularly in understanding users' willingness to adopt new technological innovations (Foley Curley, 1984; Sharda, Barr & McDonnell, 1988).

In this study, TAM is considered suitable because it explains how students may accept and utilise Augmented Reality tools in science learning environment, Research on technology adoption became prominent in the 1980s alongside the rapid growth in the use of personal computers. However,

ISSN:3141-5571
E-ISSN:3141-558X

one of the major challenges during this period was the limited empirical understanding of users' responses to information system performance. Prior to the development of TAM, several technological and organizational perspectives attempted to explain technology usage, but these approaches did not adequately capture users' perceptions and behavioral intentions toward emerging technologies.

In the context of this study, the Technology Acceptance Model is relevant in explaining students' and educators' acceptance of Augmented Reality (AR) in science education. The integration of AR into STEM learning environments has the potential to improve engagement, simplify abstract scientific concepts, reduce laboratory-related anxiety, and support mental health-sensitive pedagogies. Through interactive and immersive learning experiences, AR can promote students' confidence, motivation, participation, and psychological well-being during science learning activities.

Furthermore, the application of TAM in this study provides a framework for understanding how perceived usefulness and perceived ease of use of AR technologies may influence learners' attitudes, behavioral intentions, and actual usage in science education. This is particularly important in transforming science education through innovative pedagogical practices that are both technology-driven and supportive of students' emotional and psychological needs.

Global Perspectives on Augmented Reality in STEM Education: Virtual and Physical Laboratories in Developing Countries

Augmented Reality has become an important technological innovation in education, especially in science and STEM learning. It refers to technology that combines virtual objects with the real environment in real time, enabling learners to interact with digital information within physical settings (Al-Ansi et al., 2023). Augmented Reality (AR) refers to a technology those overlays digital objects such as images, videos, animations, and 3D models onto the real-world environment in real time. It integrates virtual content with physical surroundings to improve interaction and learning experiences (Godoy, 2021). In recent years, AR has gained attention because of its ability to improve visualization, engagement, and practical learning experiences in classrooms and laboratories. It evolution has accelerated significantly in STEM education because it simplifies difficult scientific concepts and supports experiential learning through the use of smart phones, tablets, and wearable devices in classrooms (Zhang et al., 2024).

In biology education, AR applications are used to visualize anatomy, cellular structures, genetics, and ecological systems. Students can interact with 3D biological models, which improve understanding and retention of complex concepts (Zhang et al., 2024). In chemistry education, AR simulations assist learners in visualizing molecular structures, chemical bonding, and laboratory procedures. AR-based chemistry simulations reduce risks associated with dangerous experiments and improve practical understanding (Ajit, 2020).In same vein, Physics education has also benefited from AR integration. AR supports modeling of abstract concepts such as light waves, electricity, motion, and magnetism through interactive visualization and real-time simulations (Windha et al., 2025). Studies reported that AR enhances conceptual understanding, critical thinking, and problem-solving skills in physics classrooms.

Studies have shown that AR positively influences students' academic performance, motivation, and participation. Evidence across studies suggests that AR consistently improves student engagement, conceptual understanding, and laboratory participation. For instance, Akçayır et al. (2016), Algerafi et al. (2023), and Beyoglu et al. (2020) reported improvements in learners' interaction with scientific concepts through immersive visualization technologies. However, despite these positive outcomes, challenges relating to infrastructure, implementation cost, and teacher preparedness remain significant barriers in developing countries.

Akçayır et al. (2016) investigated the effects of AR in science laboratories among university students and found that AR improved laboratory skills and enhanced students' attitudes toward science laboratories. The study revealed that AR-supported laboratory activities helped students better understand scientific procedures and reduced difficulties associated with conducting practical experiments. The researchers concluded that AR creates more interactive and meaningful learning environments compared to traditional teaching methods. Also, Algerafi et al. (2023) explored the educational potential of AR and VR technologies. Their findings

ISSN:3141-5571
E-ISSN:3141-558X

indicated that AR improves students' understanding of difficult concepts through interactive 3D visualization and real-time feedback. The authors also emphasized that AR enhances creativity, critical thinking, and problem-solving skills among learners. Despite these benefits, the study identified challenges such as inadequate technological infrastructure, high implementation costs, and limited teacher training, especially in developing countries. Beyoglu et al. (2020) reported that mixed reality applications enhanced students' interest and participation in science lessons by making abstract concepts more visible and engaging. Bhagat et al. (2021) further observed that AR improved students' motivation and learning processes in mathematics by supporting interactive visualization and real-time feedback. Similarly, Cai et al. (2020) demonstrated that AR-based probability learning improved students' achievement and attitudes toward mathematics.

Psychological Benefits of AR in STEM Learning: Laboratory Anxiety Reduction, Inclusive Education, and Student Well-being

Anxiety has been widely examined across the three major branches of science, both in classroom settings and laboratory environments. It usually results from various causes, including fear of chemicals, difficulties in conducting experiments involving living specimens, unclear biological concepts, and inadequate handling of laboratory equipment (Chandni S. 2025). Students having anxiety before going into the laboratory can impede their performance, concentration, and attitude during laboratory activities, thereby negatively affecting learning outcomes. Many students enter the laboratory with fears such as fear of failure, fear of damaging laboratory equipment, and fear of embarrassment in front of their peers or instructors. These fears often create tension, nervousness, and emotional discomfort that interfere with effective participation in practical activities.

Chandni S. (2025) highlighted the causes of laboratory activities as the fear of laboratory activities, poor handling of laboratory equipment, past bad experiences in science classes, exposure to science-anxiousteachers who are teaching science in elementary and secondary schools, lack of role models, gender and racial stereotyping, and scientists' stereotyping in the popular media.These identified factors provide a clear explanation to why many students develop laboratory anxiety, which in turn affects their confidence and participation during science practical sessions.

Augmented reality significantly benefits student learning in STEM by increasing engagement through heightened interest and enjoyment, reducing extraneous cognitive load by integrating digital information directly into physical tasks to prevent split attention, reducing stress, improving learning outcomes by facilitating the transfer of knowledge between abstract concepts and real-world applications and boost student confidence (Ogunjobi et al 2025).All these benefits rendered can take off anxiety and make students anticipate laboratory activities. Augmented reality enhances students' engagement, motivation, attention, interactivity, participation, concentration, knowledge retention, and spatial abilities (Alzahrani 2020).

The use of Augmented Reality (AR) in inclusive education offers diverse benefits by tailoring learning experiences to the specific needs of various student groups. For slower learners and remedial students, ARprovides procedural guidance for complex tasks and uses immersive storybooks to increase commitment, ultimately allowing students to understand concepts faster and more effectively. Students with learning difficulties, such as those with dyslexia, ADHD, or intellectual disabilities, benefit from AR-enhanced interactive textbooks that use multimedia to boost motivation and help them tolerate frustration while independently acquiring knowledge. AR increases student confidence and fosters social skills by helping students recognize emotional expressions, which can facilitate better participation in collaborative environments (Quintero et al 2019).These benefits of augmented reality in STEM learning do not stand in isolation; rather, they help explain why AR is increasingly seen as a powerful educational tool across different learning environments. When students are more engaged, less overwhelmed by complex information, less stressed during learning tasks, and more confident in their abilities, they are naturally better positioned to understand and apply scientific concepts. In other words, AR creates a more supportive learning experience that makes difficult STEM ideas easier to grasp for the average learner.

AR is identified as a solution to facilitate gender-based learning demands, ensuring that the learning environment is equitable for all participants regardless of gender (Tamam & Corebima2023). The

ISSN:3141-5571
E-ISSN:3141-558X

implementation of STEM-integrated Augmentedrealityhas been shown to significantly boost student motivation and confidence. This technology-based approach is deemed effective in enhancing the overall quality of the learning process and encouraging more active involvement in science education (Dwi Putri et al. 2025). These findings suggest that AR not only promotes equity and inclusion but also creates a more supportive and engaging learning atmosphere that encourages all students to participate more confidently in STEM activities

Methodology

This study adopted a conceptual paper and narrative review approach to examine the role of Augmented Reality (AR) in transforming science education through technology-enhanced and mental health-sensitive pedagogical practices. The study did not involve the collection of primary data; rather, it synthesized existing scholarly evidence on the application of AR in Science, Technology, Engineering, and Mathematics (STEM) education.

Relevant literature was identified through systematic searches of major academic databases, including Google Scholar, Scopus, ERIC, and Web of Science. These databases were selected because they provide extensive coverage of peer-reviewed educational technology, science education, and psychology-related publications. The literature search was guided by key search terms such as “Augmented Reality,” “STEM Education,” “Science Education,” “Virtual Laboratories,” “Laboratory Anxiety,” “Mental Health-Sensitive Pedagogy,” “Student Well-being,” “Technology-Enhanced Learning,” and related combinations of these terms.

To ensure relevance and quality, only peer-reviewed journal articles, conference papers, and scholarly publications published in English between 2015 and 2026 were included in the review. Studies were selected based on their relevance to AR applications in education, STEM teaching and learning, laboratory-based instruction, student engagement, inclusive education, psychological well-being, and mental health-sensitive pedagogical practices. Publications that lacked direct relevance to the study objectives, duplicate records, and non-scholarly sources were excluded from the review.

The selected literature was analyzed using thematic synthesis. This involved carefully reviewing the identified studies, extracting key findings, and organizing them into recurring themes. Major themes that emerged from the literature included: (i) the role of AR in improving conceptual understanding and practical learning experiences; (ii) AR and student engagement in STEM education; (iii) AR as a tool for reducing laboratory anxiety and supporting student well-being; (iv) AR in promoting inclusive and gender-responsive learning environments; and (v) challenges and opportunities associated with the adoption of AR in developing countries.

The Technology Acceptance Model (TAM) served as the theoretical framework underpinning the study. The model provided a useful lens for understanding how perceived usefulness and perceived ease of use influence learners’ and educators’ acceptance of AR technologies in science learning environments. Through thematic synthesis and conceptual analysis of the reviewed literature, the study provides evidence-based insights into how AR can contribute to the transformation of science education while supporting mental health-sensitive pedagogical practices.

Conceptual Discussion

The following discussion synthesizes evidence from reviewed literature rather than reporting empirical findings generated from primary data

Why AR improves understanding

AR improves students’ understanding in STEM because it makes learning more practical and easier to visualize. Students are able to interact with 3D models, virtual objects and simulations, which helps them to understand concepts that are usually difficult when taught only through theory. In Biology, AR helps students to study anatomy, genetics, cells and ecological systems in a more practical way. In Chemistry, it helps students to understand molecular structures, chemical bonding and laboratory procedures. In Physics, AR supports the teaching of concepts such as electricity, motion, magnetism and light waves through visual demonstrations and simulations. All these make students understand scientific concepts better and also improve retention and problem-solving skills.

ISSN:3141-5571
E-ISSN:3141-558X

Why AR increases engagement

AR increases students' interest and participation during science lessons because the learning process becomes more interactive and realistic. Students do not just listen to explanations alone, they also interact with animations, virtual models and instant feedback during lessons. The use of virtual objects, animations and instant feedback made students more interested in STEM subjects. AR also supports learner-centred teaching where students participate actively during classroom activities instead of depending completely on the teacher. This makes students more motivated and willing to participate during science practicals and classroom discussions.

Why AR reduces anxiety

Many students develop fear toward science practicals because of poor laboratory exposure, fear of handling equipment, fear of failure and difficulty in understanding science concepts. AR helps to reduce this fear because students can practice experiments virtually before carrying out the real practical activities. Students can repeat simulations many times without fear of damaging laboratory equipment or being embarrassed before others. This makes students feel more relaxed and confident during practical lessons. AR also supports a more friendly and supportive learning environment, which can improve students' confidence and participation in STEM learning.

Why adoption matters now

The adoption of AR in science education is important now because many schools do not have adequate laboratory facilities and modern instructional materials. Poor funding, inflation, unstable exchange rates and the high cost of imported laboratory equipment have made science practicals difficult in many schools, especially in developing countries like Nigeria. Because of these challenges, many science teachers depend more on theory-based teaching with little or no practical activities. AR can help to provide virtual practical experiences without depending completely on physical laboratory equipment. This can help schools reduce the cost of maintaining laboratories while students still gain meaningful practical learning experiences.

Conclusion

Science education remains very important for scientific and technological development because it helps students to develop hands-on practical skills, intellectual problem-solving abilities, and concrete scientific understanding needed for any national development especially a developing nation like Nigeria. But, the shortage of functional laboratories, inadequate funding, outdated instructional materials/ teachings aids, a very high cost of laboratory equipment and high cost of importation, inflation, and unstable exchange rates have continued to affect effective teaching and learning of STEM subjects in many schools, especially in developing countries like Nigeria.

The literature reviewed suggests that Augmented Reality (AR) can serve as an alternative and supportive approach to traditional laboratory instruction through the use of virtual experiments, simulations, animations, and interactive learning environments. AR supports the teaching of abstract scientific concepts by making learning more practical, visual, interactive, and engaging for students. The study also established that AR can improve students' motivation, participation, confidence, understanding, and practical learning experiences in STEM education.

The study also revealed that AR supports mental health-sensitive pedagogies by helping to reduce laboratory anxiety, fear of handling equipment, and stress associated with science practical activities. Through virtual laboratory experiences, students can practice scientific activities repeatedly in a safer and more flexible learning environment. Therefore, the integration of AR into science education can help schools address the challenges associated with inadequate laboratory facilities while improving the quality of STEM teaching and learning.

Recommendations

1. Government should provide support for the integration of Augmented Reality technologies into science education, especially in public schools where laboratory facilities are inadequate.
2. Schools and educational institutions should encourage the use of AR-based instructional

ISSN:3141-5571
E-ISSN:3141-558X

materials and virtual laboratory applications for the teaching of STEM subjects.

3. Science teachers should be trained through workshops, seminars, and professional development programmes on the use of AR technologies for classroom instruction and practical teaching.
4. Educational stakeholders should support the development of locally designed AR software and virtual laboratory applications that align with the Nigerian science curriculum.
5. Schools should combine conventional laboratory activities with AR-supported practical learning in order to improve students' understanding and participation in science subjects.
6. Curriculum planners and educational policymakers should include digital and AR-supported learning approaches in science education curricula at different levels of education.
7. Researchers should carry out more empirical studies on the effectiveness of AR in improving students' academic performance, practical skills, motivation, and psychological well-being in STEM education.

References

Abidoye, F., Adebisi, A. M., Rihanat, A. A., & Aliyu, M. Z. (2022). Availability of laboratory facilities on students' performance in upper basic schools in Kwara State, Nigeria. *International Journal of Educational Research Review, 7*(4), 262-267. https://doi.org/10.24331/ijere.1151372

Agboola, O. S. (2025). *Science education in Nigeria: the emergence, challenges and expectations. Inaugural Lecture Series 392.*Ile-Ife: Obafemi Awolowo University Press Limited. Retrieved from https://oauife.edu.ng/wp-content/uploads/2025/02/392nd-Inaugural.pdf

Ajit, G. (2020). A systematic review of augmented reality in STEM education. *Studies of Applied Economics, 39*(1), 1–15.

Akçayır, M., Akçayır, G., Pektaş, H. M., & Ocak, M. A. (2016). Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. *Computers in Human Behavior, 57*, 334–342. https://doi.org/10.1016/j.chb.2015.12.054

Al-Ansi, A. M., Jaboob, M., Garad, A., & Al-Ansi, A. (2023). Analyzing augmented reality (AR) and virtual reality (VR) recent development in education. *Social Sciences & Humanities Open, 8*(1), 100532.

Algerafi, M. A. M., Zhou, Y., Oubibi, M., & Wijaya, T. T. (2023). Unlocking the potential: A comprehensive evaluation of augmented reality and virtual reality in education. *Electronics, 12*(18), 3953. https://doi.org/10.3390/electronics12183953

Aliyu, Z., Lawal, A., Auwal, A. A., & Zakari, O. J. (2025). Impact of augmented reality (ar) on conceptual understanding and interest in physics, mathematics, biology, and chemistry among senior secondary students. *Global Journal of Health Related Researches, 7*(2), 68 - 72. Retrieved fromhttp://journals.abu.edu.ng/index.php/gjhrr/article/view/816/330

Alzahrani, N. M. (2020). Augmented reality: A systematic review of its benefits and challenges in e-learning contexts. *Applied Sciences, 10*(16), 5660. https://doi.org/10.3390/app10165660

Anudu, A. P., Odimkpa, C. O., Anyigor, C. P., Nweke, C. O., Mezieobi, K. C., Nwankwo, A. C., Ukor, D. D., Eneasato, O. S., &Ugwu, A. U. (2025). Efficacy of augmented reality (AR) and virtual reality (VR) technologies on secondary school students' engagement in science education. *Cuestiones De Fisioterapia, 54*(5), 4966-4977. Retrieved from https://cuestionesdefisioterapia.com/index.php/es/article/view/3844/2823

Azhari, N. P., Nugraha, F. A., Sumini, & Widowati, A. (2026). Biofun AR: Enhancing Primary Student's Engagement in Science Learning through Augmented Reality. *Jurnal Didaktika Pendidikan Dasar, 10*(1), 19-40. https://doi.org/10.26811/didaktika.v10i1.2085

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments, 6*(4), 355–385.

ISSN:3141-5571
E-ISSN:3141-558X

Beyoglu, D., Hursen, C., & Nasiboglu, A. (2020). Use of mixed reality applications in teaching of science. *Education and Information Technologies, 25*(5), 4271–4286. https://doi.org/10.1007/s10639-020-10166-8

Bhagat, K. K., Yang, F. Y., Cheng, C. H., Zhang, Y., & Liou, W. K. (2021). Tracking the process and motivation of math learning with augmented reality. *Educational Technology Research and Development, 69*(6), 3153–3178. https://doi.org/10.1007/s11423-021-10066-9

Billinghurst, M., Clark, A., & Lee, G. (2015). A survey of augmented reality. *Foundations and Trends in Human–Computer Interaction, 8*(2–3), 73–272.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA Press.

Cai, S., Liu, E. R., Shen, Y., Liu, C. H., Li, S. H., & Shen, Y. H. (2020). Probability learning in mathematics using augmented reality: Impact on student's learning gains and attitudes. *Interactive Learning Environments, 28*(5), 560–573. https://doi.org/10.1080/10494820.2019.1696839

Chandni S. (2025), Laboratory Anxiety: Prevalence and Overcoming the Challenges among Indian Secondary School Students. (2025). *SciEd Journal, 5*(2), 47–55. https://journal.qitepinscience.org/index.php/sej/article/view/167/68

Dike, N., & Salisu, S. (2015). Inadequate laboratory facilities and utilization: pedagogicalhindrance to students' academic performance in biology in seniorsecondary certificate examination in Zaria Metropolis, Kaduna State, Nigeria. *International Business Research, 8*(9), 124 – 134.

Dwi Putri, M., Mufit, F., Hidayati, H., &Riyasni, S. (2025). Impacts of STEM-integrated Cognitive Conflict-based Augmented Reality as a 21st Century Learning Strategy on Student Learning Motivation. *Journal of Innovative Physics Teaching, 3*(1), 1–11. https://doi.org/10.24036/jipt/vol3-iss1/88

Foley Curley, K. (1984). Are there any real benefits from office automation?. Business Horizons, 27 (4), 37-42.

Godoy, C. H. Jr. (2022). *A review of augmented reality apps for an AR-based STEM education framework*. arXiv.

Hamisu, S., & Ahmad G. I. (2026). Enhancing biology teaching through effective curriculum implementation in Nigeria: implications for students' academic performance and attitude. *Journal of Educational Studies Trends and Practice, 12*(8), 13-29. https://doi.org/10.70382/sjestp.v12i8.089

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education, 123*, 109–123.

Kinta, M. J., & Philip, J. (2025). Effects of inadequate laboratory resources on academic achievement and learning attitudes in Biology among senior secondary school students in Kontagora, Niger State, Nigeria. *Kontagora Journal of Science and Technology, 18*(1-2), 154–159. https://doi.org/10.5281/zenodo.18012422

Kirkwood, A., & Price, L. (2014). Technology-enhanced learning and teaching in higher education: What is enhanced and how do we know? *A critical literature review*. Learning, Media and Technology, 39(1), 6–36.

Laurillard, D. (2012). *Teaching as a design science: Building pedagogical patterns for learning and technology*. Routledge.

Mumtaz, K, Iqbal, M. M., Khalid, S., Rafiq, T., Owais, S. M., &Al Achhab, M. (2017). An E-assessment framework for blended learning with augmented reality to enhance the student learning.*EURASIA Journal of Mathematics Science and Technology Education, 13*(8), 4419-4436. DOI 10.12973/eurasia.2017.00938a

Nassarawa, H. S., Bashir, I., &Aminu, E. H. (2025). Integrating emerging technologies into Science, Technology, Engineering, and Mathematics (STEM) curriculum for enhanced skills acquisition in Kano State

ISSN:3141-5571
E-ISSN:3141-558X

science and technical schools. Science Journal of Education, 13(6), 206 – 212. https://doi.org/10.11648/j.sjedu.20251306.14

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Nemiro, A., Hijazi, Z., O'Connell, R., Coetzee, A., & Snider, L. (2022). Mental health and psychosocial wellbeing in education: The case to integrate core actions and interventions into learning environments. *Intervention, 20*(1), 36–45.

Ogunjobi, D. T., Abu, S., Ajayi, A. B., Emenike, M. I., Obong, E. E., & Mensah, T. K. (2025). A Systematic Review of Augmented and Virtual Reality for STEM Learning: Engagement, Cognitive Load, and Transfer Outcomes. *Australian Journal of Biomedical Research*, 1(2), aubm010. https://doi.org/10.63946/aubiomed/

Osaiyuwu, R. (2025). The impact of inadequate laboratory facility onstudents' academic performance in integrated science in Federal College of Education (Technical), Omoku, Rivers State. *International Journal of Innovative Social & Science Education Research, 13*(4), 297-310.

Owede, A. (2026, April 20). Parents groan over rising cost of education as schools resume today. *The Guardian.*https://guardian.ng/news/parents-groan-over-rising-cost-of-education-as-schools-resume-today/

Quintero, J., Baldiris, S., Rubira, R., Cerón, J., & Velez, G. (2019). Augmented Reality in Educational Inclusion. A Systematic Review on the Last Decade. *Frontiers in Psychology, 10*, 1835. https://doi.org/10.3389/fpsyg.2019.01835

Sharda, R., Barr, S.H. & McDonnell, J.C. (1988). Decision Support System Effectiveness: A Review and an Empirical Test. Management Science, 34 (2), 139-159.

Tamam, B., &Corebima, A. D. (2023). Implementing augmented reality to improve students' biology learning outcomes: Gender-based effect. *International Journal of Evaluation and Research in Education (IJERE), 12*(4). http://doi.org/10.11591/ijere.v12i4.25645

Udoh, N. M., George, M. S., & Ekpo, U. R. (2025). Effectiveness of augmented and virtual reality teaching methods on biology students' achievement on microorganisms in Ikot Ekpene Municipality, Akwa Ibom Sate-Nigeria. *International Journal of Developmental Research in Education, 5*(1), 189 – 201. Retrieved from https://journals.benchmarkjournals.com/index.php/IJDRE/article/view/205/207

Ukozor, F. I. (2010). Role of Science Education in Technological and NationalDevelopment of a New Nigeria. *Nigerian Journal of Functional Education, 6*(1), 16-24.

UNESCO. (2021). *Reimagining our futures together: A new social contract for education*. UNESCO Publishing.

Windha, W., Marlina, L., & Siahaan, S. M. (2025). Augmented reality as an interactive learning media on light wave material: A literature review. *EduFisika: Jurnal Pendidikan Fisika*.

Zhang, Y., Feijoo-Garcia, M. A., Gu, Y., Popescu, V., Benes, B., & Magana, A. J. (2024). Virtual and augmented reality in STEM education: An umbrella review. *Information, 15*(9), 515.