



Assessing the Impact of Virtual Reality on Senior Secondary Students' Conceptual Understanding of Simple AC Circuits in Kwara State, Nigeria

*¹Yahaya, Q., ¹Shehu, A., ²Abdulkadir, S. A., ³Yahaya, O. W., & ¹Yusuf, M. O.

¹Department of Physical Science Education, Kwara State University of Education, Ilorin, Nigeria.

²Department of Physics, Federal College of Education (Technical), Bichi, Nigeria.

³Department of Science Education, University of Ilorin, Nigeria.

*Corresponding author email: yahaya.q@kwasued.edu.ng

Abstract

This research assessed the impact of virtual reality on students' conceptual understanding of simple alternating current circuits in Kwara State, Nigeria, and examined its effects on students' self-efficacy and motivation. The study used a quasi-experimental pretest–posttest single-group design. Senior School II (SS II) Physics students from Kwara State public secondary schools formed the population, and 163 students were selected through a multistage sampling technique from three intact classes across Kwara Central, Kwara North, and Kwara South. Three validated instruments were used for data collection: the Simple Alternating Current Circuit Conceptual Understanding Test, the Physics Self-Efficacy Scale, and the Students' Academic Motivation Questionnaire, having reliability coefficients of 0.95, 0.77, and 0.93, respectively. The treatment involved exposing students to virtual reality-based instruction for four weeks using immersive simulations and interactive learning environments to facilitate understanding of Simple alternating current circuit concepts. Data collected were analysed using descriptive statistics mean and standard deviation and inferential statistics: a paired-samples t-test at the 0.05 level of significance. The findings revealed that virtual reality instruction significantly improved students' conceptual understanding, self-efficacy, and motivation, as posttest mean scores were higher than pretest scores in all cases. The results indicated that pretest and posttest scores differed significantly, rejecting the null hypotheses. The study found that virtual reality is a useful teaching tool for improving physics learning outcomes and suggests incorporating it into classroom education.

Keywords: Virtual Reality, Conceptual Understanding, Self- Efficacy, Motivation, Simple Alternating Current Circuit.

Introduction

Virtual Reality is transforming education by introducing interactive learning experiences going beyond the limitations of conventional teaching methods (Mudi et al., 2025). In many advanced countries, virtual reality is already part of the curriculum and has been connected to better student results (Mudi et al., 2025). These improvements are often linked to virtual reality's capacity to visualise complex or invisible phenomena, simulate hazardous or inaccessible events, and sustain learners' engagement and focus.

The use of virtual reality in physics education is growing, in particular in the teaching of difficult concepts such as simple alternating current circuits. The use of virtual reality in this area is currently supported by famous learning theories and specific virtual reality models. A robust theoretical foundation is necessary as past virtual reality studies have been criticised for lack of theoretical congruence in instructional design and evaluation (Matovu et al., 2022; Lui

et al., 2023). There are a number of related theories that give a complete framework for addressing students' intellectual comprehension as well as affective variables such as self-efficacy and motivation.

Virtual reality in physics education is based on constructivist learning theory, which states that learners gain knowledge via interaction with their surroundings, not by passively collecting information. Students have difficulties understanding abstract ideas in simple alternating current circuits, such as alternating current flow, phase relationships, impedance and behaviour of the circuit. The settings of virtual reality enable learners to interact with parts of circuits, see the flow of current in real-time, and see the dynamic changes in voltage and resistance. Interactive experiences are conducive to meaningful conceptual knowledge according to constructivist and social constructivist concepts (Maroukcas et al., 2023).

This method is directly tied to experiential learning theory: Kolb's learning cycle, which emphasises acquiring knowledge through phases of concrete experience, reflective observation, abstract conceptualisation and active experimentation. Students can learn by experience, by reality-based simulations for a simple alternating current circuit, constructing virtual circuits, testing configurations and witnessing consequences, all without the risks of real laboratories. These immersive experiences assist learners to comprehend issues by connecting theoretical knowledge with real-world uses (Maroukcas et al., 2023; Asad et al., 2021).

Theories of gamification and flow are applied to elucidate the role of incentives in virtual reality learning environments. Furthermore, the interactive feature of VR apps, including quick feedback, challenges, and exploratory tasks, contributes to the promotion of engagement and intrinsic motivation. These elements can make difficult and abstract content more approachable and fascinating when learning about simple alternating current circuits, thus improving students' motivation to take part actively in the learning. Flow experience, marked by strong focus and delight, improves persistence and facilitates conceptual learning (Lampropoulos & Kinshuk, 2024; Maroukcas et al., 2023).

From a cognitive perspective, the cognitive theory of multimedia learning and cognitive load theory are significant to describe the processing of information by students in virtual reality environments. The study of basic alternating current circuits involves unifying schematics, waveforms and mathematical relationships. The virtual reality has a dual-channel processing, which includes visual simulation and spoken explanation. But too much sensory information might lead to cognitive overload when not managed well. Therefore, an effective virtual reality design for teaching simple alternating current circuits should reduce extraneous information, focus learners' attention, and combine visual and textual elements for the best conceptual understanding (Ateş & Kölemen, 2024; Lui et al., 2023; Maroukcas et al., 2023).

In addition to the general learning theories, models unique to virtual reality provide greater insight into how immersive environments impact learning outcomes. The cognitive affective model of immersive learning highlights the relevance of presence and agency in virtual reality. In physics instruction, presence makes students feel like they are in a virtual laboratory, while agency allows them to manipulate circuit factors and observe outcomes. These affordances affect psychological characteristics such as motivation, self-efficacy and cognitive engagement. For example, when students complete virtual circuit assignments, they experience an increase in confidence in their own abilities (self-efficacy), which in turn increases their conceptual knowledge of simple alternating current circuits (Makransky & Petersen, 2021).

Similarly, as inferred from the theory of cognitive-affective learning, immersion improves students' learning experience, but enhancement in accomplishment is more closely associated with improved motivation and cognitive engagement. In basic alternating current circuit learning, virtual reality environments that actively include students and keep their interest are more likely to succeed in terms of meaningful learning outcomes than those that only rely on immersive elements (Huang et al., 2021).

Empirical design principles further highlight that successful virtual reality learning occurs when instructional settings afford learners control, minimise cognitive burden, and incorporate reflective activities. For example, if students are allowed to experiment with different circuit configurations and this reflects on the outcomes can deepen their

conceptual understanding. Additionally, aligning virtual reality tasks with students' prior knowledge and abilities helps to strengthen both learning outcomes and self-efficacy (Lui et al., 2023).

Recent theoretical breakthroughs recommend integrated frameworks of constructivism and experiential learning with cognitive theories as the most successful way for virtual reality-based science education. These frameworks recognise that students' conceptual understanding of physics is enhanced by active engagement with content, reflection on experiences, and support from well-designed instructional environments. Besides, it is known that affective variables like self-efficacy and motivation are important mediators that affect students' engagement with online reality and their learning outcomes (Mallek et al., 2024; Algerafi et al., 2023; Maroungkas et al., 2023).

Theoretical underpinnings of virtual reality in physics education suggest that students learn when they are fully engaged in immersive, experiential and cognitively supported settings. Virtual reality helps students better understand concepts while teaching topics such as simple alternating current circuits. Utilising virtual reality also increases students' confidence and motivation, which are vital for further academic success. The combination of the theoretical viewpoints provides a strong foundation for exploring the effect of virtual reality on students' learning results. Research in science education shows that virtual reality and similar extended reality tools can improve students' academic performance, confidence, self-regulation, and motivation. In one quasi-experimental study of eighth-grade students, the use of virtual reality was significantly linked to improvements in all these areas (Nikpour & Dastjerdi, 2025). Supporting evidence shows that desktop-based virtual reality is positively correlated with self-regulation skills, predicting higher satisfaction and increased motivation among learners (Nikpour & Dastjerdi, 2025). Also, experiential virtual reality treatments have been found to affect self-efficacy and learning motivation, with students' motivation increasing after virtual reality interventions compared to other pedagogical conditions (Nikpour & Dastjerdi, 2025).

In Nigeria, using virtual reality in schools is still developing, and this is often limited by funding and infrastructure issues, even though its benefits are clear (Mudi et al., 2025). Despite these challenges, studies from the Southwestern States show that bringing virtual reality into the classroom can boost student engagement and participation, improve performance, and help educators better understand both the opportunities and challenges of using the technology (Mudi et al., 2025). In a Chemistry practical, students who learned with virtual reality performed better than those who did not, indicating that it plays a significant role in improving academic outcomes (Neji et al., 2025).

Despite these favourable outcomes, there is still a limited body of context-specific evidence on the use of virtual reality to teach abstract physics concepts in Nigerian senior secondary schools. Many science and mathematics topics at this level, including simple alternating current circuits, are conceptually demanding because they involve invisible processes and complex spatial or temporal relationships. It has been demonstrated that immersive technologies, such as virtual reality, help learners perceive abstract ideas and intricate spatial linkages, making learning more interesting and understandable. (Olaronke & Olusola, 2024). However, much of the Nigerian research focused on Mathematics and Chemistry or on virtual reality more broadly, leaving a gap regarding virtual reality-based instruction for simple alternating current circuits and the psychological processes through which it may operate.

In addition, contemporary virtual reality research in science education highlights the importance of self-efficacy and academic motivation as key variables associated with virtual reality-enhanced learning outcomes (Nikpour & Dastjerdi, 2025). Studies have shown that virtual reality-supported self-regulation and cognitive strategies are linked to higher satisfaction and increased motivation, and that augmented or virtual reality can positively impact academic self-efficacy and motivation across educational levels (Nikpour & Dastjerdi, 2025). Yet, empirical investigations that explicitly examine how self-efficacy and motivation shape or moderate the effect of virtual reality on Nigerian students' conceptual understanding in physics are scarce.

Given this, the current study evaluates the effect of virtual reality on Kwara State students' conceptual understanding of simple alternating current circuits, examining the efficacy of virtual reality-based instruction for teaching a crucial but difficult physics topic while accounting for how students' motivation and confidence may influence learning outcomes.

Aim and Objectives of the Study

This study assessed the impact of virtual reality instruction on students' conceptual understanding of simple alternating current circuits in Kwara State. Specifically, the research investigated:

1. The impact of virtual reality on students' conceptual understanding of simple alternating current circuits.
2. The impact of virtual reality on students' self-efficacy
3. The impact of virtual reality on students' motivation

Research Questions

1. Is there a difference in students' conceptual understanding of simple alternating current circuits before and after instruction using virtual reality?
2. What is the difference in students' self-efficacy before and after instruction using virtual reality?
3. Is there a difference in students' motivation before and after instruction using virtual reality?

Research Hypotheses

H0₁: There is no significant difference between pretest and posttest mean scores of students' understanding of simple alternating current circuits when taught with the virtual reality method.

H0₂: There is no significant difference between pretest and posttest mean scores of students' self-efficacy when taught with the virtual reality method.

H0₃: There is no significant difference between pretest and posttest mean scores of students' motivation when taught with the virtual reality method.

Methodology

This study used a single-group, quasi-experimental pretest-posttest research design. The approach was selected because it allowed the researcher to compare students' motivation, self-efficacy, and conceptual grasp of simple alternating current circuits before and after they were exposed to virtual reality instruction. The posttest was used to assess the impact of the intervention, whereas the pretest supplied baseline data. The research was carried out in Kwara State, Nigeria, covering three geopolitical districts: Kwara Central, Kwara North, and Kwara South. These districts ensured a broad and representative distribution of schools across the state. The population consisted of all physics students in public secondary schools in Kwara State, while the target population comprised Senior School II (SS II) students offering physics in these schools. SS II students were selected because simple alternating current circuits form part of their prescribed physics curriculum. A total of 176 students initially participated in the research; however, only 163 students were included in the final analysis due to attrition, as some participants were present for the pretest but absent during the posttest. A multistage sampling technique was used to select the participating students. First, one school was chosen from each of the three geopolitical districts. Subsequently, one intact class was selected from each school, resulting in three intact classes. All students in the selected classes were included in the research to preserve the natural classroom setting and minimise disruption to normal school activities.

Three instruments were used for data collection:

- (i) Simple Alternating Current Circuit Conceptual Understanding Test (SACCUT): This researcher-developed instrument was designed to assess students' conceptual understanding of simple alternating current circuits. It covered key topics such as alternating current, waveform, frequency, and circuit behaviour.
- (ii) Physics Self-Efficacy Scale (PSES): This instrument was adapted from the standardised self-efficacy questionnaire developed by Midgley (2000). It consisted of 25 Likert-scale items measuring students' confidence in learning and applying physics concepts.
- (iii) Students' Academic Motivation Questionnaire (SAMQ): Adapted from Harter's Scale (1981), the instrument included items that are rated on a five-point Likert scale comprising Never, Rarely, Sometimes, Often, and Almost Always, to assess students' motivation toward learning physics.

Experts in physics education and educational measurement conducted face and content validation of all instruments. The researchers incorporated their feedback to improve clarity, relevance, and alignment with the research objectives. Reliability was established as follows: the SACCUT was tested using the test-retest method with the Pearson Product Moment Correlation (PPMC), yielding a reliability coefficient of 0.95. The PSES and SAMQ were tested using

Cronbach's alpha, with coefficients of 0.77 and 0.93, respectively. These indicated that the instruments were sufficiently reliable for the research.

The treatment involved the use of virtual reality instructional modules in teaching simple alternating current circuits over a period of four weeks. The SACCUT, PSES, and SAMQ were first administered to obtain baseline data on students' conceptual understanding, self-efficacy, and motivation. Students were then exposed to virtual reality-based instruction using head-mounted displays and interactive simulations. The virtual environment enabled learners to visualise and manipulate A.C. circuit components, observe current flow, and explore concepts such as frequency and voltage within an immersive setting. Instruction was facilitated by the researcher in collaboration with the classroom physics teacher. Upon conclusion of the treatment session, the instruments were re-administered to evaluate changes in students' conceptual knowledge, self-efficacy, and motivation.

Descriptive and inferential statistics were used for analysing the data. The research questions were answered using means and standard deviations, and the hypotheses were tested at the 0.05 level of significance using a paired-sample t-test. The relevant school authorities granted ethical permission before any data collection. To ensure transparency and understanding, participants received sufficient information about the goals, methods, and aims and objectives of the study. Additionally, participants were informed that participation was entirely optional and that they could stop at any time without repercussions. The researchers rigorously upheld confidentiality and anonymity; no personal identifiers were recorded, and all data were used exclusively for academic and research purposes.

Results

Table 1: Descriptive Statistics and paired-sample t-test on the difference in students' conceptual understanding, self-efficacy and motivation before and after instruction using virtual reality

Variable	Pretest, M (SD)	Posttest, M (SD)	Mean difference	t(df)	p	Effect size, dz
Conceptual understanding	43.12 (8.45)	70.38 (7.88)	27.26	24.57 (162)	<.001	1.925
Self-efficacy	48.27 (9.14)	72.65 (8.36)	24.38	22.11 (162)	<.001	1.732
Motivation	50.18 (8.78)	74.92 (7.91)	24.74	23.45 (162)	<.001	1.836

The results indicate a clear difference in students' conceptual understanding of simple alternating current circuits before and after virtual reality instruction. The pretest mean score of 43.12 and SD of 8.45 show that students initially had a relatively low level of understanding. However, after exposure to virtual reality instruction, the posttest mean score increased substantially to 70.38, with an SD of 7.88. The mean difference of 27.26 reflects a notable improvement in students' performance. This suggests that students' conceptual understanding of simple alternating current circuits improved considerably following the virtual reality instruction. Therefore, students' pretest and posttest scores differ clearly, with posttest scores significantly higher, indicating the effectiveness of virtual reality as an instructional tool.

The paired-samples t-test results ($t(162) = 24.57$, $p = 0.00$) indicate that this difference is statistically significant at the 0.05 significance level. The p-value is less than 0.05; therefore, the null hypothesis, which states that there is no significant difference between pretest and posttest mean scores, is not retained. This implies that virtual reality instruction had a significant improvement in students' understanding of simple alternating current circuits.

Students recorded a mean pretest score of 48.27 (SD = 9.14), indicating a moderate level of self-efficacy before the intervention. After the virtual reality instruction, the posttest mean score increased to 72.65 (SD = 8.36). The mean difference of 24.38 indicates improved self-efficacy following the instructional treatment. This suggests that exposure to virtual reality learning experiences positively influenced students' confidence in their ability to understand and engage with physics concepts, particularly simple alternating current circuits. Therefore, pretest and posttest self-efficacy scores differed, with posttest scores significantly higher, indicating that virtual reality instruction enhanced students' self-efficacy.

The paired-samples t-test yielded a t-value of 22.11, 162 degrees of freedom, and a p-value of 0.00. The p-value is less than the significance level of 0.05, the null hypothesis, which states that there is no significant difference between pretest and posttest mean scores of students' self-efficacy, is not retained. This finding implies that virtual reality instruction had a statistically significant improvement in students' self-efficacy. The increase in mean scores suggests that the immersive and interactive nature of virtual reality may have enhanced students' confidence in their ability to understand and apply concepts related to simple alternating current circuits.

Students recorded a mean motivation score of 50.18 and a standard deviation of 8.78, suggesting moderate motivation before the intervention. After the intervention, the posttest mean score increased to 74.92 with a standard deviation of 7.91. The mean difference of 24.74 shows a substantial gain in students' motivation following the instructional treatment. This suggests that virtual reality instruction positively influenced students' motivation toward learning. Therefore, pretest and posttest motivation scores differ, with posttest scores higher, indicating that virtual reality instruction enhanced students' motivation.

The paired-samples t-test yielded a t-value of 23.45, 162 degrees of freedom, and a p-value of 0.00. This indicates a statistically significant difference between pretest and posttest mean motivation scores. The null hypothesis, which states that there is no significant difference between pretest and posttest mean motivation scores, is rejected because the p-value is less than the 0.05 level of significance. This finding implies that the educational intervention, rather than chance variance, caused the increase in students' motivation. As a result, virtual reality instruction positively affected students' motivation in a statistically meaningful way.

In summary, conceptual understanding increased significantly from pretest to posttest, $t(162) = 24.57$, $p < .001$, $dz = 1.93$. Self-efficacy also increased significantly, $t(162) = 22.11$, $p < .001$, $dz = 1.73$, and motivation showed a significant increase, $t(162) = 23.45$, $p < .001$, $dz = 1.84$.

Discussion

The findings provide strong empirical support for the effectiveness of virtual reality instruction in improving students' conceptual understanding of simple alternating current circuits, as well as their self-efficacy and motivation. Across all three variables, posttest mean scores were significantly higher than pretest scores, and the null hypotheses were rejected in each case. This indicates that the virtual reality-based instructional intervention contributed to the observed improvements.

The significant improvement in conceptual understanding aligns with constructivist learning theory, which posits that learners actively construct knowledge through interaction with their environment. Virtual Reality environments provide students with opportunities to visualise abstract Simple alternating current circuit phenomena, manipulate circuit components, and observe real-time changes in current and voltage. These interactive experiences likely bridged the gap between theoretical concepts and observable phenomena, enhancing meaningful learning. This supports earlier assertions that immersive technologies improve understanding of complex, invisible scientific processes (Olaronke & Olusola, 2024; Maroukias et al., 2023).

The significant increase in students' self-efficacy is also consistent with the cognitive-affective model of immersive learning, which emphasises the role of presence and agency in virtual reality environments. When students successfully interact with virtual circuit simulations, they experience a sense of control and achievement, which enhances their confidence in handling physics concepts. This finding corroborates empirical evidence suggesting that virtual reality experiences can strengthen learners' belief in their capabilities to understand and apply scientific knowledge (Nikpour & Dastjerdi, 2025; Makransky & Petersen, 2021).

Similarly, the observed improvement in students' motivation supports gamification and flow theory perspectives. The immersive, interactive, and engaging nature of virtual reality likely sustained students' attention and interest, making learning more enjoyable and stimulating. This is consistent with prior empirical studies indicating that virtual reality environments enhance intrinsic motivation by promoting engagement, curiosity, and active participation (Lampropoulos & Kinshuk, 2024; Maroukias et al., 2023).

Furthermore, these findings align with broader empirical evidence showing that virtual reality positively influences academic performance, self-efficacy, and motivation in science education (Nikpour & Dastjerdi, 2025; Neji et al., 2025). The results also support the Cognitive Theory of Multimedia Learning and cognitive load theory, as virtual reality integrates visual and interactive elements that facilitate dual-channel processing and reduce abstraction in learning complex physics concepts (Ateş & Kölemen, 2024; Lui et al., 2023).

The research confirmed that virtual reality not only enhances cognitive outcomes but also plays a crucial role in improving affective variables such as self-efficacy and motivation. These variables, in turn, reinforce each other and contribute to deeper conceptual understanding. The findings therefore align with both theoretical frameworks and empirical literature, reinforcing the position that immersive, interactive, and well-designed VR environments can significantly improve teaching and learning outcomes in physics education.

Conclusion

The findings suggest that virtual reality instruction significantly improves senior students' learning outcomes in simple alternating current circuits. The results showed that students' conceptual understanding improved significantly after exposure to virtual reality-based instruction, indicating that immersive, interactive learning environments support better comprehension of abstract physics concepts. The research also found that virtual reality instruction significantly enhanced students' self-efficacy. This suggests that engaging with virtual reality simulations helped students build confidence in their ability to understand and apply physics concepts, particularly those related to simple alternating current circuits. In addition, students' motivation to learn physics also improved significantly, suggesting that virtual reality environments foster greater interest, engagement, and willingness to participate actively in the learning process. The research demonstrates that virtual reality is an effective instructional tool that not only improves cognitive outcomes but also strengthens affective factors such as self-efficacy and motivation, which are essential for sustained academic success in physics.

Recommendations

The following were therefore recommended:

1. Physics teachers should incorporate virtual reality tools into classroom instruction, especially when teaching abstract and conceptually difficult topics such as simple alternating current circuits, to enhance students' understanding.
2. Educational authorities and school administrators should organise training programmes and workshops to equip teachers with the skills required to effectively design and implement virtual reality-based lessons,
3. Government and stakeholders in education should invest in the provision of virtual reality equipment and infrastructure in secondary schools to support technology-driven teaching and learning.
4. Curriculum planners should consider integrating virtual reality-based instructional strategies into the physics curriculum to promote active learning and improve student outcomes,
5. Teachers should adopt learner-centred approaches that allow students to interact with VR simulations, explore concepts independently, and engage in hands-on virtual experiments
6. Future studies should explore the long-term effects of virtual reality on students' academic achievement across different science subjects and investigate its effectiveness in larger and more diverse populations.

References

- Aliyu, Z., Lawal, A., Auwal, A., & Zakari, O. (2025). Impact of augmented reality (AR) on conceptual understanding and interest in physics, mathematics, biology, and chemistry among senior secondary students. *Global Journal of Humanities and Religious Research*, 7(2), 68–72.
- 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.
- Asad, M., Naz, A., Churi, P., & Tahanzadeh, M. (2021). Virtual reality as a pedagogical tool to enhance experiential learning: A systematic literature review. *Education Research International*, 2021, 7061623. <https://doi.org/10.1155/2021/7061623>
- Ateş, H., & Kölemen, C. (2024). Integrating theories for insight: An amalgamated model for gamified virtual reality adoption by science teachers. *Education and Information Technologies*, 30, 2123–2153.
- Huang, W., Roscoe, R., Craig, S., & Johnson-Glenberg, M. (2021). Extending the cognitive-affective theory of

- learning with media in virtual reality learning: A structural equation modelling approach. *Journal of Educational Computing Research*, 60, 807–842.
- Lampropoulos, G., & Kinshuk. (2024). Virtual reality and gamification in education: A systematic review: G. Lampropoulos and Kinshuk. *Educational technology research and development*, 72(3), 1691-1785.
- Lui, A., Not, C., & Wong, G. (2023). Theory-based learning design with immersive virtual reality in science education: A systematic review. *Journal of Science Education and Technology*, 32, 390–432.
- Makransky, G., & Petersen, G. (2021). The cognitive affective model of immersive learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality. *Educational Psychology Review*, 33, 937–958.
- Mallek, F., Mazhar, T., Shah, S. F. A., Ghadi, Y. Y., & Hamam, H. (2024). A review on cultivating effective learning: Synthesising educational theories and virtual reality for enhanced educational experiences. *PeerJ Computer Science*, 10, e2000. <https://doi.org/10.7717/peerj-cs.2000>
- Maroungkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023). Virtual reality in education: A review of learning theories, approaches and methodologies for the last decade. *Electronics*, 12(13), 2832. <https://doi.org/10.3390/electronics12132832>
- Matovu, H., Ungu, D., Won, M., Tsai, C., Treagust, D., Mocerino, M., & Tasker, R. (2022). Immersive virtual reality for science learning: Design, implementation, and evaluation. *Studies in Science Education*, 59, 205–244.
- Midgley, C., Maehr, M. L., Huda, L. Z., Anderman, E., Anderman, L., Freeman, K. E., Gheen, M., Kaplan, A., Kumar, R., Middleton, M. J., Nelson, J., Roeser, R., & Urdan, T. (2000). *Manual for the Patterns of Adaptive Learning Scales (PALS)*. University of Michigan.
- Mudi, A., Inalegwu, A., & Friday, A. (2025). Investigative impact of virtual reality (VR) on education in the southwestern states of Nigeria. *International Journal of Modelling & Applied Science Research*, 7(9), 53–78.
- Neji, H. A., Anari, M. I., Bayim, B. A., Agube, C. C., & Arorim, O. O. (2025). Effects of virtual and augmented reality teaching strategies on students' understanding of chemistry practical activities. *Faculty of Natural and Applied Sciences Journal of Mathematics and Science Education*, 7(2), 1–8.
- Nikpour, A., & Barat Dastjerdi, N. (2025). The impact of virtual reality on self-efficacy, self-regulation, motivation, and academic performance in sciences. *Journal of Turkish Science Education*, 22(4), 724–742.
- Olaronke, I., & Olusola, O. (2024). Impact of augmented reality on the academic performance of senior secondary school students in mathematics in Ile-Ife, Nigeria. *Asian Journal of Education and Social Studies*, 50(8), 379–392.
- Song, C., Shin, S.-Y., & Shin, K.-S. (2023). Optimising foreign language learning in virtual reality: A comprehensive theoretical framework based on constructivism and cognitive load theory (VR-CCL). *Applied Sciences*, 13(23), Article 12557. <https://doi.org/10.3390/app132312557>
- Wehrmann, F., & Zender, R. (2024). Inclusive virtual reality learning: Review and “best-fit” framework for universal learning. *Electronic Journal of e-Learning*, 23(3), 74–89.