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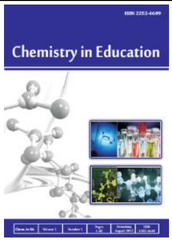

Perceived Influence Of Augmented Reality On The Learning Of Chemistry Osogbo Local Government Area, Osun State, Nigeria

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Abstract

Augmented reality (AR) technology is becoming increasingly prevalent in chemistry education. AR is regarded as an essential pedagogical resource that facilitates the comprehension of complex concepts at all educational levels. Despite the numerous reported advantages of AR in education, research is yet to be conducted on the influence of AR on secondary school chemistry education in the Nigerian state of Osun. Thus, this study was conducted to determine the impact of an AR system used to teach secondary school pupils about material structures and chemical equilibrium on their motivation, cognitive burden, and technology acceptance. Material structures and chemical equilibrium is an essential subtopic in chemistry education, particularly for high school students; however, this can be difficult to grasp as it is abstract. Augmented Reality (AR) technology , considered an added value compared to traditional learning materials such as textbooks, two-dimensional images, and video, is one way to facilitate this learning process. A class of 14- to 16- year-old (eleventh-grade) students in the Osogbo Local Area of Osun State, Nigeria, evaluated the impact of augmented reality on chemistry learning. This study employed a mixed -methods survey research design with an ex-post facto methodology. Twenty secondary institutions in Osogbo Local Government will be chosen using a simple random sampling technique, yielding 300 pupils. The data were collected using an achievement test, a cognitive burden scale, and a semi-structured interview form. After analyzing the results , we can conclude that these students favorably viewed this augmented reality (AR) application in the learning process. Numerous students need help to comprehend chemistry's symbolic and molecular representations. This may have enhanced their comprehension of chemical symbols and concepts. In addition, the results indicate that computerized models can serve as a means for students to generate mental images.

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INTRODUCTION

In the field of natural science education, students explore the laws governing natural phenomena through observation, logical thinking, and experimentation (Gooding, 2012). However, due to the influence of exam-oriented education, teachers often demonstrate experiments rather than allowing students to conduct them, or they simply describe experimental principles and results. This approach deprives students of direct observation and experimentation, leading to difficulties in understanding essential scientific concepts. To address this challenge, advanced 3D computer programs have been integrated into traditional chemistry teaching (Capel, Rimington, Lewis, & Christie, 2018), allowing students to observe chemical bonds and the transformations reactants undergo during chemical reactions.

Deep learning occurs when new knowledge is connected to real-life situations. This can be achieved by designing open-ended questions, allowing students to make assumptions based on prior knowledge and verifying them through experimentation (Sawyer, 2006). Without experimental processes and logical reasoning, knowledge remains unconnected to prior learning, leading to isolated memory nodes that fade over time (Tarng, Tseng, & Ou, 2022). Although experimentation is essential in science education, certain scientific concepts remain highly abstract and challenging to comprehend within a short observation period. Examples include lunar phases, stellar movements, and seasonal changes in Earth science. In chemistry, many theories and concepts originate from experimental observations, yet some remain difficult to grasp due to their submicroscopic nature (Tarng, Lin, & Ou, 2021).

Chemistry, as a fundamental natural science, examines the properties, composition, structure, and transformations of matter (Jespersen & Hyslop, 2021). It plays a crucial role in advanced scientific developments and emphasizes both theoretical understanding and practical experimentation. Well-designed experimental courses not only stimulate students' interest but also cultivate skills in experimental design, operation, and observation. Through hands-on learning (Reese, 2011), students can actively engage in scientific discovery, test hypotheses, and convert theoretical knowledge into problem-solving abilities.

The integration of technology, particularly *Augmented Reality (AR)*, offers new opportunities in science education. *Computer-Assisted Learning (CAL)* supports learning through digital tools without direct human instruction, enhancing classroom engagement and making abstract concepts more tangible (Clark, 2020). AR technology, which overlays virtual objects onto real-world environments, enables students to interact with chemical structures in a dynamic and immersive manner (Habig, 2020). AR possesses three key characteristics: (1) combining virtual and real-world elements, (2) enabling real-time interaction, and (3) functioning in three-dimensional environments (Azuma, 1997). Historically, AR required specialized head-mounted displays, but with the widespread adoption of smartphones and tablets, it has become more accessible in educational settings (Nielsen, Brandt, & Swensen, 2016; Nechypurenko, Starova, Selivanova, Tomilina, & Uchitel, 2018).

Freeman (2014) emphasized that students who actively engage in learning activities achieve better outcomes. To promote student-centered learning, instructional strategies must shift from traditional teacher-led approaches to inquiry-based methods, encouraging knowledge construction through active exploration (Bazan, 2007). Understanding chemical reactions requires visualizing changes at the molecular level, such as electron transfer and bond formation, which are challenging due to their abstract nature. AR technology helps bridge this gap by enabling students to visualize submicroscopic chemical interactions, thereby improving conceptual understanding and logical reasoning (Herga, Glazar, & Dinevski, 2015).

The interactive nature of AR offers a learning experience distinct from traditional instruction. By leveraging 3D modeling and animation, AR allows students to explore chemical concepts in a more engaging and intuitive way. The development of AR-based instructional tools is guided by *Johnstone's Triangle Model*, *Predict-Observe-Explain (POE) Strategy*, and *Multimedia Learning Theory* (Mayer & Moreno, 2002, 2005). This study investigates the impact of AR technology on students' learning effectiveness, motivation, and cognitive load. Additionally, a questionnaire survey was conducted to assess students' acceptance of AR as a learning tool.

To understand why a chemical reaction occurs, it is essential to examine how reactants' structures change at the molecular level, including electron transfer and bond formation. These submicroscopic changes correlate with macroscopic phenomena, influencing the observable properties of substances. However, abstract chemical concepts are often difficult for students to grasp due to their complexity and the limitations of spatial reasoning. AR technology provides a potential solution by expanding students' learning experiences and enhancing their ability to visualize molecular transformations (Herga, Glazar, & Dinevski, 2015).

To address the limitations of traditional chemistry instruction, this study develops an AR-based learning system designed to assist high school students in comprehending chemical reactions. Through interactive AR applications on smartphones or tablets, students can conduct virtual experiments, manipulate reactants, and visualize molecular changes in real time. The integration of AR in chemistry education enhances conceptual understanding and fosters active learning. The study also explores the impact of AR on students' learning motivation, cognitive load, and overall technology acceptance.

Purpose of the Study and Research Questions

The primary objective of this study is to examine the influence of *Augmented Reality (AR)* on chemistry learning in Osogbo Local Government Area, Osun State, Nigeria. Specifically, the study aims to explore the effectiveness of AR in teaching material structures and chemical equilibrium, determine students' motivation when using AR for learning chemistry, assess students' cognitive load when engaging with AR-based learning materials, and evaluate students' acceptance of AR technology as a chemistry learning tool. To address these objectives, the study is guided by the following research questions: (1) How effective is the AR system in teaching material structures and chemical equilibrium to high school students? (2) How does AR influence students' motivation in learning chemistry? (3) What is the cognitive load experienced by students when using AR-based learning materials? (4) How do students perceive the acceptance of AR technology in chemistry learning?

By addressing these questions, this study aims to contribute to the growing body of research on technology-enhanced chemistry education and provide insights into the potential of AR in improving learning outcomes.

METHODS

The research methodology adopted in this study encompassed several key components, including the research design, study population, sample selection, research instrument, validity and reliability of the instrument, data collection procedure, and methods of data analysis. A survey research design using an ex-post facto approach was employed, as the study did not involve manipulation of independent variables. The study population comprised all secondary school students in Osogbo Local Government Area of Osun State, and a simple random sampling technique was applied to select twenty secondary schools. From each school, fifteen students were randomly chosen, resulting in a total sample of 300 students. The distribution of participants is shown in Table 1.

Table 1. Respondent Distribution by Gender (N=300)

Gender	**F**	**%**
Male	148	49.3
Female	152	50.7
Total	300	100.0

The research instrument used was a questionnaire titled Questionnaire on Technology Acceptance by Venkatesh and Bala (2008), which was structured into three sections (A, B, and C) and formatted on a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). To ensure the validity of the instrument, experts in measurement evaluation and chemistry education reviewed the items for necessary modifications, establishing construct validity. Reliability was determined using a test-retest method, where the instrument was administered to fifty students outside the study sample within a two-week interval, and the reliability coefficient was assessed using Cronbach's alpha. Data collection involved school visits where permission was obtained from principals and class teachers, and respondents' consent was secured. The researcher, assisted by two research aides, conducted the data collection over two weeks, ensuring completion and retrieval of the instruments. The collected data were analyzed using bivariate and multiple regression statistical methods.

RESULT

Effectiveness of AR System in Learning Chemical Structure and Equilibrium Material for High School Students

Table 2. Analysis to know the effectiveness of the AR system on learning material structures and chemical equilibrium for high school students

S/N	ITEMS	RESPONSE									
		Strongly Agree		Agree		Undecided		Disagree		Strongly Disagree	
		F	%	F	%	F	%	F	%	F	%
1	The teaching method makes me feel interested in the subject content	176	58.7	118	39.3	6	2.0	0	0.0	0	0.0
2	I think the teaching method and subject content are lively	109	36.3	179	59.7	11	3.7	0	0.0	0	0.0
3	The arrangement of teaching activities enhances my learning engagement	103	34.3	162	54.0	32	10.7	0	0.0	0	0.0
4	I am clear about what knowledge I should learn after each class	123	41.0	98	32.7	78	26.0	0	0.0	0	0.0
5	The course is related to my expected learning content	120	40.0	127	42.3	27	9.0	12	4.0	14	4.7
6	I have enough time to practice	93	31.0	153	51.0	43	14.3	10	3.3	1	0.3
7	The difficulty of learning activities moderate, not too easy	84	28.0	133	44.3	54	18.0	20	6.7	9	3.0
8	I believe I can receive good grade in class	162	54.0	96	32.0	25	8.3	16	5.3	1	0.3
9	I need good luck to receive a good grade in this subject	107	35.7	85	28.3	53	17.7	45	15.0	10	3.3
10	I am satisfied with the knowledge learned in class	91	30.3	130	43.3	44	14.7	25	8.3	10	3.3
11	The AR system allows me to learn better by repetitive practice	116	38.7	125	41.7	34	11.3	25	8.3	0	0.0
12	I am willing to engage myself in the subject content	93	31.0	152	50.7	34	11.3	14	4.7	6	2.0

The items the respondents agreed with were; the teaching method makes me fee interested in the subject content(98.00%), I think the teaching method and subject content are lively (96.00%), the arrangement of teaching activities enhances my learning engagement(88.30%), I am clear about what knowledge I should learn after each class (73.70%), the course is related to my expected learning content (82.30%), I have enough time to practice (82.00%), the difficulty of learning activities moderate, not too easy (72.30%), they believe I can receive good grade in class (86.00%), I need good luck to receive a good grade in this subject(64.00%), I am satisfied with the knowledge learned in class (73.60%), the AR system allows me to learn better by repetitive practice (80.40%), I am willing to engage myself in the subject content(81.70%).

Motivation of Students When the AR System is Used for Learning Material Structures and Chemical Equilibrium

Table 3. Analysis to know the motivation of students when the AR system is used for learning material structures and chemical equilibrium

S/N	ITEMS	RESPONSE									
		Strongly Agree		Agree		Undecided		Disagree		Strongly Disagree	
		F	%	F	%	F	%	F	%	F	%
1	I thought material structure and chemical equilibrium are easy before learning.	74	24.7	118	39.3	75	25.0	22	7.3	11	3.7
2	I didn't need to process a lot of information during the learning process	60	20.0	115	38.3	59	19.7	52	17.3	14	4.7
3	I could find related information during the learning process.	134	44.7	130	43.3	17	5.7	10	3.3	9	3.0
4	I had enough thinking time during the learning process.	67	22.3	154	51.3	45	15.0	26	8.7	8	2.7
5	I have confidence on material structures and chemical equilibrium after the class.	88	29.3	131	43.7	56	18.7	14	4.7	11	3.7
6	I only spent a little effort to understand the course content	69	23.0	121	40.3	66	22.0	26	8.7	18	6.0
7	After the class, I feel material structures and chemical equilibrium easy to understand	90	30.0	134	44.7	52	17.3	14	4.7	10	3.3
8	I had no pressure during the learning process of this course	83	27.7	138	46.0	46	15.3	26	8.7	7	2.3

Table 3 presents the analysis to know the motivation of students when the AR system is used for learning material structures and chemical equilibrium. The items the respondents agreed with were; I thought material structure and chemical equilibrium are easy before learning (64.0%), I didn't need to process a lot of information during the learning process (58.3%), I could find related information during the learning process (88.0%), I had enough thinking time during the learning process (73.6%), I have confidence on material structures and chemical equilibrium after the class (73.0%), I only spent a little effort to understand the course content (63.3%), After the class, I feel material structures and chemical equilibrium easy to understand(74.7%), they had no pressure during the learning process of this course (73.7%).

Cognitive Load of Students When The AR System is Used for Learning Material Structures and Chemical Equilibrium

Table 4. Analysis to know the cognitive load of students when the AR system is used

S/N	ITEMS	RESPONSE									
		Strongly Agree		Agree		Undecided		Disagree		Strongly Disagree	
		F	%	F	%	F	%	F	%	F	%
1	I have the intention to use the AR system.	125	41.7	138	46.0	29	9.7	3	1.0	5	1.7
2	I am likely to use the AR system in the next month.	67	22.3	139	46.3	82	27.3	10	3.3	2	0.7
3	I am willing to continue using the AR system.	69	34.3	145	48.3	74	24.7	11	3.7	1	0.3
4	Using the AR system allows me to learn the subject more easily.	103	35.3	143	47.7	47	15.7	4	1.3	3	1.0
5	Using the AR system allows me to obtain more detailed knowledge.	106	34.0	135	45.0	48	16.0	10	3.3	1	0.3
6	Using the AR system makes learning more effective.	102	25.7	137	45.7	44	14.7	13	4.3	4	1.3
7	My interaction with the AR system does not require a lot of mental effort	77	35.7	148	49.3	49	16.3	20	6.7	6	2.0
8	I find the AR system easy to me.	107	27.7	134	44.7	43	14.3	7	2.3	9	3.0

Table 4 presents the analysis to know the cognitive load of students when the AR system is used for learning material structures and chemical equilibrium. The items the respondents agreed with were; I have the intention to use the AR system (87.7%), I am likely to use the AR system in the next month (68.6%), I am willing to continue using the AR system (71.3%), Using the AR system allows me to learn the subject more easily (82.0%), Using the AR system allows me to obtain more detailed knowledge (80.3%), Using the AR system makes learning more effective (79.7%), My interaction with the AR system does not require a lot tos\ mental effort (75.0%), I find the AR system easy to me (80.4%).

DISCUSSION

Ex post facto research is a type of quasi-experimental research that investigates the effect of an independent variable, such as age, sex, familial environment, or socioeconomic status, on a dependent variable.

Table 2 demonstrates that the AR application aided in increasing students' knowledge of material structures and chemical equilibrium. This may have something to do with technical characteristics and distinctive chemical properties.

Table 2 also reveals that the AR system improves learning engagement, knowledge clarity, moderate difficulty, and willingness to engage with subject content. This finding is consistent with (Dunleavy et al., 2009), in which teachers and students reported that the AR simulation's technology-mediated narrative and interactive problem-solving capabilities were highly engaging, especially for students who had previously exhibited behavioral and academic difficulties.

Bacca-Acosta et al., (2014) Concur that augmented reality has successfully enhanced learning performance, motivation, pupil engagement, and attitudes. By superimposing computer-generated virtual information in real-time, augmented reality affords new opportunities for designing engaging learning environments (Phon et al., 2014).

In (Table 3). Respondents agreed that material structures and chemical equilibrium were uncomplicated before learning, that they had sufficient time to deliberate during the learning process, were confident after the class, and were not under any duress while learning.

AR cards assist students in learning chemistry by displaying the submicroscopic view of a chemical reaction by the law of conservation of mass (Wernhuar Tarng et al., 2022).

This finding indicates that an augmented reality (AR) system has been developed to aid high school students in their study of Material structures and chemical equilibrium. Cognitive load theory suggests that knowledge is subdivided into biologically primary and secondary knowledge that is processed similarly to how information is processed by biological evolution. Instructional procedures have been generated using this architecture (Sweller, 2011).

Table 4 displays the cognitive fatigue that students experience when using AR to investigate material structures and chemical equilibrium. Respondents concurred that the AR system facilitates quicker, more effective, and more comprehensive learning. It is straightforward and requires little effort.

According to Cook, (2006), learners have a limited working memory; therefore, instructional representations should strive to reduce cognitive load.

Table 4 demonstrates that Augmented Reality (AR) technology adds value to textbooks, two-dimensional graphics, video, and other learning aids, with nearly 70 per cent of respondents indicating they are likely to use the system within the next month.

Three-dimensional augmented reality technology provides students a safe environment to simulate chemical processes and other vital activities (Ewais, 2019).

CONCLUSION

After implementing the AR system for learning chemistry in several secondary schools in Osun State, Nigeria, students' learning effectiveness, motivation, cognitive burden, and technology acceptance were examined through an ex-post facto study. The findings indicated that the AR system was more effective than conventional teaching methods, particularly benefiting low-achieving students. Although the motivation to learn was slightly higher when using the AR system compared to traditional methods, the difference was not statistically significant. However, further analysis showed that the AR system contributed to increased student confidence in learning. There was no significant difference in cognitive burden between the AR system and traditional methods, but students using AR reported a greater sense of accomplishment. The AR system was widely accepted by high school students regardless of gender or cognitive ability, with an overall acceptance rate of 5.4%. Observations during the learning process revealed that the experimental group exhibited more interaction and feedback than the control group, as the AR system enabled students to actively explore knowledge rather than passively receive it. This increased engagement fostered higher motivation to learn. Additionally, augmented reality offers flexibility unrestricted by space or time and provides an interactive user interface that promotes autonomous exploration, supporting conceptual change and cognitive development. Students can access the AR system beyond the classroom for continued learning and practice, making it a valuable tool for understanding the abstract concepts underlying chemical reactions.

RECOMENDATIONS

Even though interaction and collaboration have emerged as significant advantages of augmented reality, many evaluation mechanisms have not been explored because the technology is not sufficiently mature, resulting in a gap between the affordances of augmented reality, its advantages, uses of research methodologies, and evaluation mechanisms employed.

In this study, only the high school chemistry learning elements "material structures" and "chemical equilibrium" were covered by the AR system. Due to the limited time spent instructing and the small sample size, the results cannot be generalized to all high school students. Both cooperative learning among peers through conversation and competitive learning between distinct groups are suggested as future research avenues. Instructors should explain and provide immediate corrections when students have concerns or misunderstandings. Using augmented reality (AR) systems, experiment results can be verified.

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