

Impact of Meta Artificial Intelligence on Chemical Literacy of Undergraduate Chemistry Students in Sokoto State University Sokoto

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Abstract

This study investigated the Impact of Meta Artificial Intelligence on Chemical Literacy of Undergraduate Chemistry Students in Sokoto State University. The study was guided by three research objectives, three research questions and three null hypotheses on chemical literacy of students. The study used quasi experimental design with pre test and post test control and experimental group structure and have a population of 169 undergraduate chemistry students out of which 118 were purposively sampled. Data was collected using validated instrument (chemical literacy test CLT) with reliability coefficient of 0.77. The collected data was analyzed using both descriptive including mean, mean difference and standard deviation, and inferential statistics including paired sample t test and independent sample t test. The findings of the research showed that Meta AI has positive impact on students' chemical literacy with comparable outcomes across gender. These findings emphasized the need for integrating Meta Artificial Intelligence technology into chemistry education to improve student chemical literacy.

Keywords: Science Literacy, Chemical Literacy, Meta Artificial Intelligence

Introduction

Scientific literacy is an important skill needed for success in science which formed the bedrock for the development of any nation, and success in science is characterized by having scientific literacy. Students who are exposed to the fundamental of science at the elementary and basic education level are said to be scientifically literates (Yustin & Wiyarsi, 2019). Scientific literacy is essential for students to become well informed on how to perceive science related issues to make decisions in a variety of subject that affect their daily lives (Dierking, 2015). Students who are familiar with scientific ideas, theories and general method associated with scientific research are called science literates (Dibner, & Snow, 2016). The curriculum that inculcates science literacy into the students at the elementary and basic level is the cluster basic

science and technology curriculum, which is prerequisite for the study of the core science subjects (chemistry, physics, and biology) and applied science (Microbiology, Biochemistry, Health Science) etc at tertiary education level (Posselt, 2016). According to Sharon and Baram-Tsabari (2020) people who are literate in science, and can apply concepts of science to their daily lives are considered scientifically literate. Rahayu, Masykuri, and Soeparmi (2018) A person with the science literacy has the ability to understand science and relationship of science with the society and the environment. Turiman (2015) affirmed that students with scientific literacy can comprehend the basic law, and principles in chemistry and can applied the skills in scientific processes.

Chemistry as a course of study is perceived generally to be very interesting, vast mathematical and experimental (Feinberg, 2019). Almost all aspect of life science, both living and non living has something to do with chemistry ranging from physical to biological sciences. It is one of the pre requisite subjects for the study of engineering, technological, medical and other applied science courses in the university. It is at the heart of almost every facet of modern life (Pross, 2016). Chemistry provides training for a vast range of careers faces the world with confidence and knows where to obtain the information they need to complete a task. In view of this (Ababio, 2013) enumerated some careers in chemistry such as teaching service, health service, food processing, manufacturing industry, extractive industry, agriculture and forestry.

Chemistry is a challenging and rewarding subject. It teaches how to think critically, pose questions, and solve problems. Literature indicates that the subject provides graduates with solutions for numerous issues related to chemical studies, (Jegstad, & Sinnes, 2015). Chemical literacy is one of the skills needed in the 21st century among the 16 skills identified by the World Economic Forum (2015). Students that are chemically literate become more creative, critical, and are able to use their knowledge to tackle a variety of challenges on a daily life. As a result, it serves as a precursor to the development of 21st century abilities. The ability to handle complicated and quick changes in day to day problems thus requires a comprehension of chemistry concepts, principles, and theories (Cooper & Stowe, (2018). Therefore, if students are capable of comprehending the framework and applying their knowledge of chemistry to solve issues, they are chemically literate. Chemical literacy is the main goal of chemistry education and requires

students to critically analyze and evaluate their prior knowledge and decision making in daily life issues (Cigdemoglu, 2015)

Chemical literacy is a basic ability to obtain the basic concepts of chemistry macroscopically, microscopically, and symbolically as well as the process for understanding and describing phenomena scientifically (Fahmina, 2019). Students with chemical literacy will learn chemistry more effectively and accurately in the process of teaching and learning chemistry (Avargil, 2019). Learning objectives are achieved if students have the ability or capacity to be chemical literate. By implication, someone is said to be a chemical literate when he/she understand clearly the basic concepts of chemistry, chemical principles that enable macroscopic understanding of the interpretation of symbols and reactions, chemical theories that explain the fundamental principles of our natural world and the applications of chemistry knowledge in our everyday life activities and to other branches of science and technology (Akrosumah, 2016). Chemical literacy is categorized into four domains, the measurement of chemical literacy uses a scale of scientific literacy which is comprised of nominal literacy, functional literacy, conceptual literacy, and multi dimensional literacy (Hofstein, 2016). In spite, the benefits and relevance of scientific literacy in learning chemistry, literature bound that students continue to demonstrate poor performance at secondary school and attribute the problem to teaching approach, (Moran, 2016). Kalani (2023), affirmed that Students see chemistry as challenging, abstract, uninteresting, poor equipped laboratories, and teacher factors.

Transitioning dynamics from secondary schools to the university have implications for effective learning of chemistry (Nkiko, 2021). Emendu and Okoye (2015) aptly demonstrated that basic concepts were poorly learned prior to most students' admission into the university. Other issues associated with this problem, is the students' nature of learning, where they learn chemistry based on memorization as they cannot have the conceptual understanding and need literacy in chemistry (Yildizay & Leman, 2017). To address this problem a technological interventions is required that can enhance students' conceptual understanding of chemical concepts. However, technology are seen as major tool that will help to address the challenges of students towards the developments of literacy in chemistry. Literature bound that, use of emerging technology that include artificial intelligence (AI), virtual reality (VR), and augmented reality (AR), (Jesionkowska, 2020). One of the important emerging technologies that may help towards developing

chemical literacy and help to evaluate some difficulties in learning chemistry is Meta AI

Meta artificial intelligence (AI) refers to a cutting edge artificial intelligence model designed to analyze and generate human like text responses, leveraging meta learning techniques for improved performance across various natural language processing tasks (Liu, 2022). This advanced AI model represents a significant advancement in the field of machine learning, particularly in understanding difficult chemical concepts (Brown, 2020). In the context of enhancing chemical literacy among undergraduate students, Meta AI offers a new methods to developing educational tools and interventions. By utilizing its ability to produce customized educational resources and flexible feedback systems, educators can shape instructional content to individual student needs, thereby potentially improving comprehension and retention of chemical concepts (Yilmaz, 2021). In view of this the present study used Meta AI with hope to enhance stuedents chemical literacy of undergraduate chemistry students.

Significant of the Study

This study on impact of Meta AI on Chemical Literacy of Undergraduate Chemistry Students will have significant implications for various stakeholders, including students, teachers, higher institutions of learning, and policy makers. The findings of this research will be instrumental in shaping educational practices and policies in the field of chemistry education.

The findings of this study will help undergraduate chemistry students to visualize abstract chemistry concepts through interactive simulations and immediate feedback, making it easier for them to understand complex topics and eventually lead to the improvement in their chemical literacy, enabling them to apply chemistry knowledge in real world situations and solve societal problems. It will also benefit teachers in making their teaching more effective and engaging with the introduction of AI enhanced teaching tools.

Furthermore, this study contribute to the improvement of teaching and learning practices within higher institutions of learning. By integrating Meta AI into the chemistry curriculum, institutions can create a more student centered learning environment where technology is used to enhance students chemical literacy. This will not only improve student outcomes but also position these institutions at the forefront of educational innovation. And lastly

the study will have a significant impact on educational policymakers, as it provide evidence based recommendations on how to integrate AI technologies into national and institutional educational frameworks. Policymakers will gain valuable insights into the potential of Meta AI to enhance chemical literacy and improve student engagement in STEM fields. By adopting AI enhanced teaching methods and resources, policymakers can reform existing science curricula to make chemistry more accessible and relevant to modern learners.

Scope and Delimitation

The study was carried out in Sokoto State Nigeria. The study covered 100level undergraduate chemistry students in Sokoto state university, these include chemistry, industrial chemistry, and education chemistry.

However, the study is confined to Sokoto State University, excluding students from other institutions, this is because of the need to maintain a manageable scope within the available timeframe and resources. And also it served as a basic investigation, upon which future research may build on. It specifically focused on 100level chemistry students, without including students from other levels. The study specifically focused on 100level chemistry students because the level was considered to be the basic level in the university, hence the intellectual capacity of students at this level is lower than that of other levels and also building chemical literacy is most critical at this level. The study is limited to the use of Meta AI as the primary technological tool for enhancing learning, with no consideration of other AI models or technologies. Because of the easy accessibility of Meta AI as it can be found in social media platforms like Facebook, WhatsApp, and Instagram where most of the students spend their time without any academic benefit. Furthermore, the research is geographically restricted to Sokoto State, and as such, the findings may not be generalized to students in other regions or universities.

Concept of Chemical Literacy

Chemical literacy is an important skill needed in the 21st century for national development. In view of this literature indicate that, students and general public need chemical literacy toward societal development and nation at large (Avargil, 2018). However, the question is what concept of chemical literacy is? Chemical literacy refers to the understanding and application of fundamental chemical concepts, principles, and processes. It includes the ability to interpret and use chemical knowledge in various contexts, make

informed decisions based on chemical information, and appreciate the role of chemistry in everyday life and in broader societal issues (Rungrat, & Thummathong, 2018). Chemical literacy among undergraduate chemistry students encompasses their proficiency in recognizing chemical phenomena, solving chemical problems, and effectively communicating chemical ideas.

Components of Chemical Literacy

There are basically three major components of chemical literacy these includes chemical concepts, principles and processes (Mozeika & Bilbokaita, 2010)

1. **Chemical Concepts:** Knowledge of chemistry concepts forms the basic layer of chemical literacy. It encompasses an understanding of basic and advanced principles of chemistry, including the structure of atoms, chemical reactions, periodic table trends, and the properties of matter. Recent studies emphasize that a deep comprehension of these concepts is crucial for students to apply chemistry knowledge in real world contexts (Coope, 2021). Moreover, integrating interdisciplinary approaches enhances students' understanding of chemical concepts, making chemistry more applicable to everyday life (Lewis, 2023).
2. **Principles:** This component involves critical thinking, problem solving skills, and the practical use of chemical principles in laboratory settings and daily life. For instance, students must be able to predict the outcomes of chemical reactions, design experiments, and interpret data effectively. Recent advancements in educational technology, such as virtual labs and simulations, have proven effective in enhancing students' ability to apply chemical knowledge (Gagnon & Fisher, 2022). Critical thinking and problem solving are essential for navigating complex chemical phenomena and making informed decisions. This component involves analyzing data, evaluating evidence, and constructing coherent arguments based on chemical knowledge. Research highlights that promoting these skills in chemistry education leads to improved academic performance and better preparedness for scientific careers (Tsaparlis & Zoller, 2022). Teaching strategies that encourage inquiry based learning and problem based learning have shown significant positive impacts on developing students' critical thinking abilities (Overton & Potter, 2021).

3. **Processes:** The integration of technology into chemistry education has transformed the way students learn and engage with chemical processes. Technologies such as augmented reality (AR), virtual reality (VR), and artificial intelligence (AI) have provided an interactive learning experiences that enhance understanding and retention of chemical knowledge (Cheung, 2023). These tools not only make learning more engaging but also help in visualizing complex chemical structures and reactions, thus improving students' scientific attitude and chemical literacy (Rodriguez, 2022).

Concept of Artificial Intelligence

Artificial intelligence (AI) refers to the capability of computational systems to perform tasks typically associated with human intelligence, such as learning, reasoning, problem solving, perception, and decision making. It is a field of research in computer science that develops and studies methods and software that enable machines to perceive their environment and use learning and intelligence to take actions that maximize their chances of achieving defined goals (Russell, 2021).

Concept of Meta AI

Artificial Intelligence (AI) is a field of computer science dedicated to creating systems capable of performing tasks that typically require human intelligence. These tasks include reasoning, learning, problem solving, understanding natural language, and perception. AI aims to develop machines and software that can mimic or surpass human cognitive abilities. (Hospedales, 2021). Meta AI is a branch of artificial intelligence focused on improving the ability of AI systems to learn and adapt to new tasks quickly with minimal additional data. It emphasizes the development of models that can generalize from past experiences to efficiently handle new, unseen tasks. (Zhai, 2021; Hariri, 2023).

Integration of Meta AI in Chemistry Education

Meta AI's integration into chemistry education enhances the learning experience by providing adaptive, individualized and manage solutions that benefit both students and chemistry educators. The ongoing advancements in this field promise even more impactful innovations in the future. Personalized learning refers to shaping educational experiences to meet individual students'

needs, strengths, and preferences. Meta AI facilitates this by supporting data to adapt chemistry content and methods by providing adaptive learning platforms, customized learning paths and recommendation system which can be used to create customized learning paths by suggesting relevant learning materials, such as articles, videos, and exercises, based on students' interests and previous interactions. Meta AI help students with feedback based on their questions. It can diagnose errors, suggest improvements, and guide students through problem solving processes, enhancing the learning experience.

Social Constructivism Learning theory

Social Constructivism, grounded in the work of Lev Vygotsky (1930), emphasizes the importance of social interactions and cultural context in the learning process. According to this theory, knowledge is constructed through collaboration and dialogue with others. Vygotsky introduced the concept of the Zone of Proximal Development (ZPD), which represents the gap between what learners can achieve independently and what they can achieve with guidance. Learning is seen as a social process where peers and more knowledgeable others play a crucial role in helping learners advance their understanding. In alignment with these principles, Meta AI, with its advanced capabilities, can create collaborative and interactive learning environments. By integrating Meta AI into chemistry education, educators can shape social interactions and support learners within their ZPD, thereby enhancing their level of chemical literacy and improving their scientific attitude.

The integration of Social Constructivism and Meta AI in chemistry education offers a powerful approach to enhancing students' chemical literacy. By facilitating collaborative learning, providing guided support and connecting students with expert resources, Meta AI creates a rich, interactive learning environment. This team work between social constructivist principles and Meta AI technology not only supports students in constructing knowledge through social interaction but also cultivates a positive attitude towards scientific inquiry and learning.

Review of Empirical Studies

SiAhmed (2019), conducted research titled "enhancing chemical literacy through ai powered educational tools." This study involved 180 high school students and used a mixed methods approach. The results showed that AI

powered tools significantly enhanced students' chemical literacy by providing interactive and personalized learning experiences.

Akinola (2022), explored "the role of ai in promoting chemical literacy among university students." The study included 160 undergraduate students from two universities in Ibadan and used a quasi-experimental design. The findings revealed that AI tools improved chemical literacy by facilitating a deeper understanding of chemical concepts and processes.

Williams, (2020) examined "AI and its influence on chemical literacy in higher education." This study involved 140 undergraduate chemistry students and used a pretest/posttest control group design. The findings indicated that AI enhanced learning environments significantly improved students' chemical literacy, particularly in terms of critical thinking and problem-solving skills in chemistry.

Statement of Problem

Chemical literacy at undergraduate is essential for learner to grasp most of the course content. The literacy enable them to interact, identify and describe chemical phenomena, such as the particulate nature of matter, symbol formula and equation atomic and mass number, chemical bonding chemical equilibrium as well as chemical reactions etc. It is however regrettable that undergraduate students of lack basic chemical literacy to understand or apply in understanding other chemistry and science concepts. Thus, which may lead chemistry graduates not been able to use a basic chemical literacy to solve societal problems, provide information in science and technology that could help to bring development in Nigeria and globally.

The underlying causes of these problems, are abstract nature of chemistry, making it challenging for students to comprehend and connect to practical applications. This could have resulted from the nature of instruction utilized by chemistry teachers which is mostly traditional despite recent technologies such as Meta AI that could support better literacy in learning, students may find it difficult to examine ideas outside the classroom or develop their independent research abilities if they do not have proper access to textbooks, reference materials, technological resources, and instructional software. Integrating Meta AI into chemistry education may bridge the gap between theoretical knowledge and practical applications, making chemistry more accessible and engaging. It provides a solution to the abstract nature of

chemistry, and gives students the resources they need to build their chemical literacy, (Alasadi & Baiz, 2024). With the help of Meta AI, chemistry graduates will be better equipped to use their knowledge to address societal challenges, contributing to the development of science and technology both in Nigeria and globally. In view of this, the present study aimed at using Meta AI to enhance students' of chemical literacy.

Research Objectives

The aim of the study is to provide an insight into the level of chemical literacy of undergraduate chemistry students. However, the specific objectives are to:

1. Examine the difference in chemical literacy of undergraduate chemistry students' of Sokoto State University between before and after using Meta AI.
2. Investigate the difference in chemical literacy between undergraduate chemistry students of Sokoto State University learned using Meta AI and those who do not used Meta AI.
3. Examine the difference in chemical literacy between male and female undergraduate chemistry students of Sokoto State University who learned using Meta AI

Research Questions

The aim of the study is to provide an insight into the level of chemical literacy of undergraduate chemistry students. However, the following research questions will guide the study:

1. Is there any mean difference in chemical literacy of undergraduate chemistry students of Sokoto State University before and after learning using Meta AI?
2. Is there any mean difference in chemical literacy of undergraduate chemistry students of Sokoto State University who learned using Meta AI and those who learned without Meta AI?
3. Is there any mean difference in chemical literacy between male and female undergraduate chemistry students of Sokoto State University who learned using Meta AI?

Research Hypotheses

To answer the above questions the following null hypotheses were tested:

- H₀₁:** There is no significant difference in the chemical literacy of undergraduate chemistry students of Sokoto State University before and after learning using Meta AI.
- H₀₂:** There is no significant difference in the chemical literacy of undergraduate chemistry students of Sokoto State University who learned using Meta AI and those who learned without Meta AI.
- H₀₃:** There is no significant difference on the chemical literacy of male and female undergraduate chemistry students of Sokoto State University who learned using Meta AI.

Methodology

This section contained the research methodology employed to investigate the impact of Meta AI on chemical literacy. For this study quasi experimental research designed was used with pre test post test, control group and experimental group structure. The population of the study comprise of 169 100level undergraduate chemistry students in Sokoto State University in 2024/2025 academic session out of which 118 students were sampled using purposive sampling technique. The chosen sample were then divided equally in to control and experimental group where pure chemistry (59 students) served as the experimental group, industrial chemistry and education chemistry (59 students) served as the control group. The control group were taught using traditional method while the experimental group were taught with the intervention of Meta AI. Both groups were taught basic chemistry topics including particulate nature of matter, periodic table, electronic configuration of element, chemical reaction, mass volume relationship, acid base and salt, and chemical bonding in five different lessons. The instrument used was chemical literacy test (CLT) which was designed to evaluate students' understanding of fundamental chemistry concepts and their ability to apply these concepts in their day to day activities. This test include thirty (30) multiple choice questions, short answers, and problem solving tasks that reflect real world chemical scenarios. The test was validated by three experts in science education, and it was piloted before the main study. The result of

the pilot study was used to calculate the reliability of the instrument using Test retest method after which the reliability coefficient was found to be 0.77 which indicates a moderate to strong positive correlation between the test and retest scores. The data collected was analyzed using mean, standard deviation and mean difference to answer the research questions and independent sampled t test to test hypothesis.

Data Analysis

Data collected was analyzed based on the research questions.

Research Question One: What is the mean difference in chemical literacy of undergraduate chemistry students of Sokoto State University before and after learning using Meta AI?

Table 1: Difference in Chemical Literacy Before and After Intervention

Group	N	Mean	Std. Dev.	Mean Difference
Pretest	118	9.38	4.202	6.55
Post Test	118	15.93	5.038	

Table 1 present difference in chemical literacy of the respondents before and after the intervention. The results show that average mean score of the students before the intervention is 9.38 with a standard deviation of 4.202, while after the intervention the students had a higher average mean score of 15.93 with a standard deviation of 5.038. The mean difference between before and after the intervention is 6.55, indicating students performed better in chemical literacy test after the intervention of Meta AI. This suggests that Meta artificial intelligence have a positive impact on students' chemical literacy.

Moreover, to have clear picture of the responses of the respondents the result was subjected to independent sample t-test to test hypothesis one (H_{01})

Table 2: Significant Difference in chemical literacy before and after the intervention

Group	Mean	Std. Dev.	df	t	p-values	Decision
Pretest	9.38	4.202	117	-11.238	0.000	H_1 rejected
Post Test	15.93	5.038				

The test indicated that there is a statistical significant difference before and after exposing the students to Meta AI intervention, ($t = -11.238$, $df = 117$, $p\text{-value} < 0.05$). An inspection of the means shows that students before the intervention have less chemical literacy (Mean = 9.38, SD = 4.202) than after

the intervention (Mean = 15.93, SD = 5.038), based on which the hypothesis was therefore, rejected.

In addition to determine how far is the significance the data was further subjected to effect size calculator, the effect was found to be (ES=1.3) which indicated there is high level of significance between students exposed to Meta Artificial Intelligence and those exposed to traditional approach.

Research Question Two: What is the difference in chemical literacy of undergraduate chemistry students of Sokoto State University who learned using Meta AI and those who learned without Meta AI?

Table 3: Difference in Chemical Literacy Between Control and Experimental Group

Group	N	Mean	Std. Dev.	Mean Difference
Experimental	59	18.09	5.19	4.31
Control	59	13.78	3.84	

Table 3 present the analysis of chemical literacy of the respondents in both control and experimental groups. The results show that the control group had an average mean score of 13.78 with a standard deviation of 3.84, while the experimental group had a higher average mean score of 18.09 with a standard deviation of 5.19. The mean difference between the two groups is 4.31, indicating that the experimental group, which was exposed to Meta artificial intelligence, demonstrated significantly chemical literacy compared to the control group that used traditional methods. This suggests that Meta artificial intelligence have a positive impact on students' chemical literacy.

Moreover to have clear picture of the responses of the respondents the result was subjected to independent sample t-test to test hypothesis three (H₀₃).

Table 4: Significant difference in chemical literacy between experimental and control group

Group	Mean	Std. Dev.	df	t	p-values	Decision
Experimental	18.09	5.19	116	-5.116	0.000	H ₃ rejected
Control	13.78	3.84				

The analysis of the result indicates significant difference between student's exposed to Meta Artificial Intelligence and those exposed to traditional method ($t = -5.116$, $df = 116$, $p\text{-value} < 0.05$). Therefore, null hypothesis was rejected and conclude a significant difference between experimental and control group.

Moreover, to determine how much is the significance the data was further subjected to effect size calculator, the effect was found to be (ES=0.83) which

indicated there is high level of significance between students exposed to Meta Artificial Intelligence and those exposed to traditional approach (Cohen, 1988).

Research Question Three: What is the difference in chemical literacy between male and female undergraduate chemistry students of Sokoto State University who learned using Meta AI?

Table 5: Gender Differences in Chemical Literacy

Group	N	Mean	Std. Dev.	Mean Difference
Male	95	15.66	5.056	1.38
Female	23	17.04	4.913	

Table 5 present gender differences in chemical literacy of male and female students in the study. The results show that male students (N = 95) had an average mean score of 15.66 with a standard deviation of 5.056, while female students (N = 23) had a slightly higher mean score of 17.04 with a standard deviation of 4.913. The mean difference of 1.38 suggests that female students performed slightly significant in chemical literacy than the male students. However, the difference may not be considerable and would require further statistical analysis to determine its significance.

Moreover, to examine whether there is a significant difference between male and female students' chemical literacy the responses were further subjected to independent sample t-test where hypothesis five (H₀₅) was tested

Table 6: Significant difference in chemical literacy between male and females after the intervention

Group	Mean	Std. Dev.	df	t	p-values	Decision
Male	15.66	5.056	116	-1.191	0.810	H ₅
Female	17.04	4.913				Accepted

The result from Table 6 indicated that the mean score for male students was 15.66 with a standard deviation of 5.056, while the mean score for female students was slightly higher at 17.04 with a standard deviation of 4.913. The calculated t-value of -1.191 at 116 degrees of freedom (df) yielded a p-value of 0.810, which is greater than the 0.05 significance level. Since the p-value is greater than 0.05, the null hypothesis is accepted, indicating that there is no significant difference in chemical literacy between male and female 100level undergraduate chemistry students.

Discussion

Firstly, is to examine the chemical literacy of undergraduate chemistry students' of Sokoto State University before and after using Meta AI, the analysis of the pretest and post-test scores of chemical literacy of students indicates a significant improvement in the chemical literacy of the students following the Meta AI intervention. This suggests that the use of Meta AI had a positive impact on students 'chemical literacy. The difference in mean scores reveals a marked shift in learning outcomes, of the students. This finding aligns with recent studies that emphasize the role of Meta AI in improving chemical literacy. Zawacki (2019) noted that Meta AI offer personalized learning experiences, which help bridge individual gaps in understanding, particularly in science related subjects. Similarly, Holmes, (2021) found that Meta AI can enhance chemical knowledge. Moreover, the improvement observed supports the conclusions of Chen (2022), who reported that Meta AI provide immediate feedback, adapt to learners' needs, and promote a more interactive learning environment. By integrating Meta AI, students likely experienced enriched peer to peer and student content interaction, which impact their chemical literacy.

Secondly, to investigate the difference in chemical literacy between undergraduate chemistry students using Meta AI and those do not used Meta AI, the comparison of chemical literacy between the experimental and control groups reveals a significant difference, with the experimental group showing greater improvement than the control group. This indicates that students exposed to Meta AI outperformed those who experienced traditional instruction, emphasizing the added value of Meta AI. This result is consistent with the findings of Tang (2021) who reported that Meta AI enhance students' chemical literacy by guiding problem solving skills, and promoting metacognitive awareness. These features are built in Meta AI and may explain the observed improvement in the experimental group. The result also aligns with the Social Constructivist Theory, which emphasizes the importance of interaction, collaboration, and contextualized learning. META AI, by offering interactive simulations and adaptive instruction, likely promoted these essential elements, giving the experimental group a learning advantage.

Thirdly, to difference in chemical literacy between male and female undergraduate chemistry students of Sokoto State University, the analysis of gender differences in chemical literacy revealed no statistically significant difference between male and female students, as both experimental and control groups demonstrated comparable chemical literacy. This suggests that

the intervention of Meta AI, had an equal impact on both male and female students, irrespective of gender. This finding aligns with the research of Baker (2019), who observed that Meta AI is equally effective for all learners, regardless of gender. Furthermore, Miller and Katz (2021) found that the use of Meta AI in educational settings eliminates many gender based disparities. Meta AI neutrality in delivering content ensures that both male and female learners are exposed to the same learning opportunities and resources, contributing to comparable chemical literacy.

Summary of the Major Findings

1. There is significant difference in chemical literacy of undergraduate chemistry students of Sokoto state university before and after using Meta AI. Students demonstrated high chemical literacy after using Meta AI.
2. There is significant difference in chemical literacy between undergraduate chemistry students of Sokoto State University learn using Meta AI and those do not Used Meta AI. The experimental group which used Meta AI demonstrated significant improvement in chemical literacy than the control group which used traditional method.
3. There is no significant difference in chemical literacy between male and female undergraduate chemistry students of Sokoto State University who learn using Meta AI.

Conclusion

The findings highlight the potential impact of Meta Artificial Intelligence in chemical literacy among undergraduate chemistry students of Sokoto State University. Based on the findings of the research Meta AI was seen to have positive impact on students' chemical literacy. Based on gender analysis the findings also indicates that both male and female students benefited from the Meta Artificial Intelligence intervention. These results emphasized the need for integrating Meta Artificial Intelligence technology into chemistry education to improve student chemical literacy.

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