

**ASSESSMENT OF CHEMICAL LITERACY OF  
UNDERGRADUATE STUDENTS IN FOUR  
DEPARTMENTS AT THE UNIVERSITY OF IBADAN**

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**Abstract**

*The Nigerian chemistry curriculum at the senior secondary school is designed to provide a complete course for students not proceeding to higher education, while also providing a reasonably adequate foundation for a post-secondary school chemistry course, among other objectives. This objective aims to develop learners' chemical literacy, irrespective of their future careers. The assessment of this objective's attainment has rarely been carried out. This study assessed the chemical literacy among university undergraduates who offered chemistry at the senior secondary school and were currently studying medical and engineering-based courses. A descriptive survey approach was employed, and data were collected from 200 students across the four departments from 100 and 400 level student using a Chemical Literacy Assessment Test (CLAT). The findings showed that the chemistry curriculum objectives related to chemical literacy have been partially achieved, as the respondents' chemical literacy level was below average. Also, there was a significant decline in chemical literacy as students advanced in their education and moved farther from chemistry as a course of study. It was recommended that efforts must be taken to ensure that students exposed to secondary school chemistry curriculum are able to apply the concepts learnt over a long time.*

**Keywords:****Introduction**

Chemistry is a crucial branch of science that shapes our understanding of the world. Learning chemistry involves more than just memorizing facts; it requires students to apply their knowledge to real-life situations, engage with chemical issues, and make informed decisions. The goal of chemistry education should focus on solving real-world problems and empowering students to apply their understanding to develop practical solutions (Gräber et al., 2001). Therefore, chemical literacy has become a vital part of science literacy (Shwartz, Ben-Zvi, & Hofstein, 2006). Science literacy is essential in modern science education and is considered a foundation of an informed society (American Association for the Advancement of Science, 1993). A scientifically literate person understands scientific concepts and can distinguish scientific data from information in other fields (Barlia, 2016). Scholars suggest that scientific literacy encompasses knowledge of science, the ability to apply scientific principles, critical thinking, and awareness of ethical considerations and cultural contexts (Chin, 2005; NRC, 2007). Chemical literacy, a key aspect of scientific literacy (Mozeika & Bilbokaite, 2010), involves effectively activating and applying knowledge and skills, allowing individuals to confidently navigate the complexities of the chemical world.

Formal education contributes to chemical literacy, especially secondary school chemistry being the most significant (Shwartz, 2011). Nevertheless, individuals can also achieve chemical literacy through informal means (Drazic & Devetak, 2025). Evidence abounds that even those without formal education can acquire scientific knowledge through informal learning experiences (Stocklmayer & Gilbert, 2006; Killikely, 2018). The National Science Foundation (2014) found that adults lacking formal science education can gain knowledge through activities such as watching documentaries or participating in discussions. The numerous practical demonstrations of chemical literacy, especially in everyday

life, indicate that the sources of chemical literacy may be informal. For instance, many people use alum for water treatment without a clear understanding of its chemical composition. Similarly, herbal medicine, smelting and blacksmithing, natural dyeing, textile production, and food preservation are widely used, even though the chemical properties of these herbs are often unknown. Despite this lack of knowledge, individuals effectively integrate basic chemistry concepts into their daily lives.

If those without formal education can attain a level of chemical literacy and application, it stands to reason that students trained in structured chemistry curricula should demonstrate an even deeper understanding. The Nigerian policymakers recognise this when they stipulate that the Nigerian chemistry curriculum aims to provide foundational knowledge, support students who are not pursuing higher education, and prepare those intending to continue their studies in chemistry and chemistry related study (Nigerian Education Research and Development Council, 1985; 2007). This underscores that chemical literacy is a crucial measure of the effectiveness of the senior secondary school chemistry curriculum (Kola et al., 2023).

In Nigeria, various studies have investigated the impacts of the chemistry curriculum (Oladejo et al., 2022; Onyinye et al., 2023; Omilani & Zakaria, 2024), primarily emphasizing student achievement and the interrelationships between chemistry and other sciences, while neglecting chemical literacy. Additionally, there is limited information regarding how secondary school students utilize their chemistry knowledge after graduation. On a global scale, gaps in undergraduate students' chemical literacy have been linked to an inability to master core chemistry concepts at the secondary school level (Nnoli & Offiah, 2014; Gwanya, Ncanywa, and Asaleye, 2025).

Generally, research on the chemical literacy of undergraduate students in Nigeria has predominantly focused on those enrolled in chemistry programs, whose chemical literacy may be attributed to greater exposure to chemistry content (Nnoli & Offiah, 2014; Kola,

Opeyemi, & Olu, 2020; Usman, Aliyu, & Hassan, 2025). Beyond Nigeria, Thummathong and Thathong (2016) evaluated the chemical literacy of engineering undergraduate students in Northeastern Thailand and found it to be lacking. This study aims to assess the chemical literacy of undergraduate students who previously studied chemistry at the senior secondary level but are now pursuing courses in medical science and engineering at the university. The objective is to allow the researcher to distinctly link chemical literacy to the implementation of the chemistry curriculum at the senior secondary school level. While it is acknowledged that the chemical literacy of these students can also be influenced by additional chemistry education, it is typically less formal than that of their peers in chemistry departments who are engaged in core chemistry studies. The key topics covered include environmental chemistry, chemical bonding, organic chemistry, the particulate nature of matter, and industrial chemistry.

### **Theoretical Framework**

Chemical literacy is assessed through several key components. The most widely recognized include an understanding of chemical content and the relationship between chemistry, technology, and society; the application of analytical thinking and reasoning; and a sense of moral awareness and responsibility (Thummanthong & Thathong, 2018). This study will specifically focus on knowledge and comprehension of chemistry content as a means to gauge chemical literacy. The content areas examined in this research include environmental chemistry, chemical bonding, organic chemistry, the particulate nature of matter, and industrial chemistry.

Understanding the concepts of the particulate nature of matter and chemical bonding provides insights into the structure and behavior of matter at the atomic and molecular levels. Proficiency in these areas enables learners to grasp the subatomic properties of matter and their interactions. Additionally, literacy in organic chemistry fosters a deeper appreciation of how chemistry relates to everyday life,

empowering individuals to make informed decisions regarding medicines, fuels, plastic food additives, insecticides, and other biochemical processes. Environmental chemistry addresses pressing issues such as climate change, waste management, water quality, and sustainable practices, while industrial chemistry illustrates how chemical principles are applied on a large scale to enhance the economy and improve daily life. The five selected concepts are pertinent not only to theoretical knowledge but also to practical applications.

### **Research Question**

What is the performance of respondents in chemical literacy tasks related to: environmental chemistry, chemical bonding, organic chemistry, particulate nature of matter, and industrial chemistry?

### **Methodology**

#### **4.1 Research Design**

The study used a descriptive survey research design of the ex post facto type. This research focused on undergraduate students in science-related courses at the University of Ibadan, specifically Nursing, Biochemistry, Civil Engineering, and Mechanical Engineering. The study assessed the chemical literacy of 200 students, with 25 students from each of the 100- and 400-level classes in each department. Nursing and Biochemistry students were selected for their strong foundation in chemistry, while Civil and Mechanical Engineering students were included due to their prior exposure to chemistry in secondary school and university.

#### **4.2 Sample and Sampling Technique**

At the university, the researchers purposively selected faculties where students were likely to have studied chemistry during their senior secondary school education. The faculty of science was excluded. A total of eight faculties that met the criterion were divided into two groups. The first group is the faculties whose programmes are unrelated to chemistry, for example, (faculties of renewable energy resources and Technology) in this group, the faculty of

Technology (engineering) was randomly selected. The second group is the faculties whose courses are chemistry-related. In this group, the faculties of basic medical sciences and nursing were chosen randomly. Two departments from the faculty of Technology (Civil and Mechanical Engineering) were included; students in these departments do not take chemistry courses. The other two departments, from the faculties of basic medical sciences and nursing (Medical Biochemistry and Nursing), offer chemistry, but not as part of their core curriculum. Students in the 100- and 400-level classes in each department were purposively selected to examine whether the duration of stay at the university, relative to their secondary education, influences chemical literacy.

#### *4.3 Instrument for Data Collection*

The self-designed instrument used to evaluate these students' chemical literacy was the Chemical Literacy Assessment Test (CLAT), which consisted of 21 items. The CLAT featured a mix of fill-in-the-blank and multiple-choice questions. It included eight tasks on environmental issues, six on chemical bonding, one on organic chemistry, and four on industrial aspects of chemistry. Responses were categorized as Totally Correct (TC), Partially Correct (PC), Wrong (W), and Blank (B). The CLAT was pilot-tested by administering it to students in the Department of Architecture using a test-retest method over two weeks. Students in the architecture department who had taken chemistry in secondary school took the CLAT, and the data were analyzed using Pearson's Product-Moment Correlation, yielding an r-value of 0.6.

#### *4.4 Procedure for Data Collection*

The instrument for data collection was administered through a course lecturer who volunteered to administer the CLAT in each Department. The researcher ensures that the volunteering lecturer is selected based on access to the two levels (100 and 400 level) students in the Department. The researchers retrieved all the instruments afterwards, and the collected data were analysed using descriptive statistics, including percentages and frequency counts.

## Results

What is the performance of respondents in chemical literacy tasks related to: environmental chemistry, chemical bonding, organic chemistry, particulate nature of matter, and industrial chemistry?

### A. ENVIRONMENTAL ASPECT

	TC	PC	W	B
<i>Ability to predict pollution in electric cars charged with fossil fuel and normal automobiles powered with fossil fuel</i>	-	33 (16.5%)	145 (72.5%)	22 (11%)
<i>Ability to predict pollution in use of firewood to cook and use of gas turbine to generate electricity</i>	-	26 (13%)	158 (79%)	16 (8%)
<i>Knowledge of the process by which plants convert sunlight into energy</i>	183 (91.5%)	-	5 (2.5%)	12 (6%)
<i>Ability to judge of the impacts of chemistry on the environment</i>	104 (52%)	-	92 (46%)	4 (2%)
<i>Awareness of the process of cement-making and prediction of hazards associated with the process and usage</i>	22 (11%)	38 (19%)	37 (18.5%)	103 (51.5%)
<i>Ability to predict pollution in the use of aluminium foil and plastics as containers for food</i>	3 (1.5%)	13 (6.5%)	143 (71.5%)	41 (20.5%)
<i>Ability to identify which is hazardous between steel utensils and copper utensils for cooking</i>	69 (34.5%)	71 (35.5%)	28 (14%)	32 (16%)
<i>Ability to recall the definition of an atom</i>	166 (83%)	-	33 (16.5%)	1 (0.5%)
<i>Ability to recall types of bond between elements</i>	172 (86%)	-	25 (12.4%)	3 (1.5%)

<b>B. CHEMICAL BONDING ASPECT</b>				
	<b>TC</b>	<b>PC</b>	<b>W</b>	<b>B</b>
<i>Aptitude to identify valences of elements and predict the compound formed</i>	75 (37.5%)	86 (43%)	14 (7%)	19 (9.5%)
<i>Ability to recognise elements based on their physical and chemical properties, and then predict outcomes of reactions I</i>	46 (23%)	72 (36%)	40 (20%)	41 (21%)
<i>Ability to recognise elements based on their physical and chemical properties, and then predict outcomes of reactions II</i>	39 (19.5%)	72 (36%)	21 (10.5%)	68 (34%)
<i>Ability to recall the definition of an element</i>	154 (77%)	-	33 (16.5%)	13 (6.5%)
<b>C. ORGANIC CHEMISTRY</b>				
<i>Ability to identify functional group, physical property of compounds and reaction process</i>	7 (3.5%)	32 (16%)	136 (68%)	25 (12.5%)
<b>D. PARTICULATE NATURE OF MATTER</b>				
<i>Ability to identify and predict the form of molecules during and after separation</i>	43 (21.5%)	127 (63.5%)	16 (8%)	14 (7%)
<i>Ability to recognise elements based on physical properties</i>	186 (93%)	-	10 (5%)	4 (2%)
<b>E. INDUSTRIAL ASPECT</b>				
<i>Awareness of the contribution to agriculture</i>	186 (93%)	-	9 (4.5%)	5 (2.5%)
<i>Awareness of the chemistry to pharmaceuticals</i>	161 (80.5%)	-	35 (17.5%)	4 (2%)
<i>Awareness of the contribution of chemistry to development of energy sources</i>	150 (75%)	-	34 (174%)	16 (8%)

The performance of respondents across the five domains of chemical literacy, environmental chemistry, chemical bonding, organic chemistry, particulate nature of matter, and industrial chemistry was analyzed using the response categories Totally Correct (TC), Partially Correct (PC), Wrong (W), and Blank (B).

### **Environmental chemistry**

The results from the environmental chemistry items indicated varied levels of understanding among the respondents. When inquired about the process by which plants convert sunlight into energy, a significant majority of 183 respondents (91.5%) provided correct answers, while 5 respondents (2.5%) answered incorrectly and 12 respondents (6%) left the question unanswered. In a similar assessment of the ability to evaluate the environmental impacts of chemistry, 104 respondents (52%) answered correctly, 92 (46%) answered incorrectly, and 4 (2%) left the question blank.

Despite overall performance, there was a notable decline in responses regarding the application of chemical knowledge to environmental scenarios. When asked about pollution associated with electric cars charged using fossil fuels and conventional fossil-fuel vehicles, 145 respondents (72.5%) answered incorrectly, while 33 respondents (16.5%) provided partially correct answers, and 22 respondents (11%) left the question unanswered. A similar pattern emerged regarding pollution linked to the use of firewood for cooking and gas turbines for electricity generation, with 158 respondents (79%) answering incorrectly, 26 (13%) providing partial answers, and 16 (8%) not responding.

In the item assessing awareness of the hazards associated with cement production, 22 respondents (11%) provided completely correct answers, while 38 respondents (19%) gave partially correct responses. Additionally, 37 respondents (18.5%) answered incorrectly, and 103 respondents (51.5%) left the question blank. Similarly, when evaluating predictions about pollution linked to the use of aluminum foil and plastics as food containers, only 3

respondents (1.5%) offered completely correct answers, 13 respondents (6.5%) gave partially correct responses, 143 respondents (71.5%) responded incorrectly, and 41 respondents (20.5%) left that item blank.

Better performance was observed when respondents were asked to identify hazardous cooking utensils. In this item, 69 respondents (34.5%) gave totally correct responses, 71 respondents (35.5%) gave partially correct responses, 28 respondents (14%) gave wrong responses, and 32 respondents (16%) left the item blank.

### **Chemical bonding**

The analysis of the chemical bonding items indicates that respondents generally excelled in recalling basic definitions but struggled with application-based questions. When asked to define an atom, 166 respondents (83%) provided entirely correct answers, while 33 respondents (16.5%) offered incorrect responses, and 1 respondent (0.5%) left the question blank. Similarly, when inquiring about the types of bonds between elements, 172 respondents (86%) answered correctly, 25 respondents (12.5%) responded incorrectly, and 3 respondents (1.5%) left the item blank.

In identifying the valences of elements and predicting the resulting compounds, a total of 75 respondents (37.5%) provided completely correct answers, while 86 respondents (43%) offered partially correct responses, 14 respondents (7%) gave incorrect answers, and 19 respondents (9.5%) left the item blank. Performance decreased further when participants were asked to recognize elements based on their physical and chemical properties and to predict reaction outcomes. In the first scenario, 46 respondents (23%) provided correct responses, 72 respondents (36%) gave partial answers, 40 respondents (20%) answered incorrectly, and 41 respondents (21%) left the item blank. In a related question, 39 respondents (19.5%) gave completely correct responses, 72 respondents (36%) provided partial answers, 21 respondents (10.5%) answered incorrectly, and 68 respondents (34%) left the question blank.

In recalling the definition of an element, 154 respondents (77%) answered correctly, while 33 respondents (16.5%) provided incorrect responses, and 13 respondents (6.5%) left the item blank.

### **Organic chemistry**

The results for the organic chemistry item indicate generally low levels of performance among respondents. When tasked with identifying functional groups, physical properties of compounds, and reaction processes, only 7 respondents (3.5%) provided completely correct answers, while 32 respondents (16%) offered partially correct responses. In contrast, 136 respondents (68%) submitted incorrect answers, and 25 respondents (12.5%) left the item unanswered.

### **Particulate nature of matter**

The results on the particulate nature of matter indicate relatively strong performance among respondents. When asked to identify and predict the forms of molecules during and after separation, 43 respondents (21.5%) provided entirely correct answers, while 127 respondents (63.5%) gave partially correct responses. Additionally, 16 respondents (8%) submitted incorrect answers, and 14 respondents (7%) left the question unanswered. In the assessment of the ability to recognize elements based on their physical properties, an impressive 186 respondents (93%) answered correctly, whereas 10 respondents (5%) gave incorrect answers, and 4 respondents (2%) left the item blank.

### **Industrial chemistry**

The findings in industrial chemistry indicate a relatively high level of awareness of chemistry's role in societal development. In the assessment of chemistry's contribution to agriculture, 186 respondents (93%) provided completely correct answers, whereas 9 respondents (4.5%) answered incorrectly, and 5 respondents (2.5%) left the question unanswered. Similarly, 161 respondents (80.5%) answered correctly regarding chemistry's contribution to pharmaceuticals, while 35 (17.5%) gave incorrect responses and 4 (2%) chose not to answer. When evaluating chemistry's impact on

food processing, 171 respondents (85.5%) answered correctly, 13 (6.5%) answered incorrectly, and 16 (8%) left the item blank. Finally, in relation to chemistry's contributions to energy development, 150 respondents (75%) answered correctly, while 34 respondents (17%) offered incorrect responses.

### **Discussion**

The findings of this study reveal variations in students' chemical literacy across the five conceptual domains examined. Overall, the results suggest that respondents perform better in items that require recall of basic concepts or recognition of familiar applications of chemistry, but show weaker performance when required to apply chemical knowledge to interpret or predict phenomena. On the other hand, some respondents did not answer certain items. This indicates the ability to recall. This implies that some students fail to recall the concepts while writing incorrect answers.

In the environmental chemistry domain, students demonstrated strong recall of the photosynthesis process but showed limited ability to analyse the environmental implications of technological and industrial activities, such as energy generation, pollution sources, and material use. The high proportions of incorrect and blank responses on these items indicate that many students struggle to apply chemical knowledge in environmental decision-making contexts. This aligns with the findings of Broman & Parchmann (2014) that upper secondary school students in Sweden could not apply environmental chemistry topics to real-life contexts.

The findings of this study indicate significant variations in students' chemical literacy across the five conceptual domains examined. The overall results suggest that respondents perform better on items requiring the recall of fundamental concepts or the recognition of familiar applications of chemistry. In contrast, their performance declines substantially when tasked with applying chemical knowledge to interpret or predict various phenomena.

### **Undergraduates Chemical Literacy in Environmental Concept**

In the domain of environmental chemistry, students demonstrated a robust ability to recall the process of photosynthesis; however, they exhibited a notable deficiency in analyzing the environmental implications of technological and industrial activities, such as energy generation, pollution sources, and material usage. The substantial proportions of incorrect and unanswered responses to these items indicate that many students struggle to integrate chemical knowledge into environmental decision-making contexts. This finding resonates with the observations of Broman and Parchmann (2014), who noted that upper secondary school students in Sweden faced challenges in applying chemistry related to environmental issues in real-life contexts.

### **Undergraduates' Chemical Literacy in Chemical Bonding**

A comparable pattern was observed within the chemical bonding domain. Students demonstrated strong recall of basic definitions, including atoms, elements, and types of chemical bonds; however, their performance declined when asked to apply bonding concepts to predict compounds or reaction outcomes. The significant prevalence of partially correct answers suggests that while students possess some foundational knowledge, their conceptual understanding of bonding principles may be incomplete. For instance, some students struggled to identify elements with  $+2$  and  $-2$  charges and frequently miswrote chemical formulas, such as representing calcium oxide as  $\text{CaO}_2$  instead of the correct formula  $\text{CaO}$ . Furthermore, respondents demonstrated an inadequate ability to use the physical properties of elements or compounds to make accurate predictions, as evidenced by their confusion between  $\text{SO}_2$ , which has a pungent odor, and  $\text{H}_2\text{S}$ , which has a distinctive rotten-egg smell. Nevertheless, students successfully recalled the definition of an element, indicating the efficacy of repetition and drilling as teaching methods.

Moreover, Yustin and Wiyarsi (2019) reported that students' chemical literacy concerning bonding is notably low, a finding that aligns with

the results of the present study. They emphasized that many students struggle to apply concepts related to chemical bonds and to effectively connect with and analyze chemical information.

The findings from the organic chemistry section further illustrate the challenges students face with structurally complex chemical concepts. The extremely low percentage of totally correct responses suggests that many respondents experience difficulty identifying functional groups and linking molecular structures to chemical behaviour. This may be related to the abstract and symbolic nature of organic chemistry, which requires learners to interpret molecular representations and reaction patterns. These findings echo the research by Salame, Patel, and Suleman (2019), which identified similar challenges in organic chemistry and highlighted existing knowledge gaps that contribute to low chemical literacy levels.

#### **UndergraduatesΔ Chemical Literacy in the Particulate Nature of Matter**

In the particulate nature of matter domain, students demonstrated relatively strong performance in recognising elements based on observable physical properties. However, the large proportion of partially correct responses when predicting molecular forms suggests that many students still have difficulty connecting macroscopic observations to microscopic particle-level explanations. Such difficulties are commonly reported in research on chemistry education due to the abstract nature of particle-level reasoning. This finding aligns with the observations of Singer et al. (2003), who noted that students often face challenges related to the particulate nature of matter, including understanding atoms, molecules, and the various states of matter. Additional studies, such as those by Adbo and Taber (2009) and Othman et al. (2008), have found that learners at all educational levels struggle to comprehend the nature of matter.

#### **Undergraduates Chemical Literacy in Industrial Chemistry**

The industrial chemistry section recorded the highest levels of correct responses among the respondents. Most students

demonstrated awareness of chemistry's contributions to agriculture, pharmaceuticals, food processing, and energy development. These findings suggest that students are more able to recognise applications of chemistry that are visible in everyday life and societal development. However, Diez-Ojeda et al. (2021) noted that while students grasp the connection between chemistry and real-world applications, they need further development of 21st-century skills. This may be due to greater media focus on industrial chemistry compared to other areas. Diez-Ojeda et al. (2021) also highlighted challenges in integrating the vast body of scientific knowledge in chemistry into classrooms. Thus, it's essential to bring industry closer to education to strengthen the link between science, technology, and society while fostering students' competencies.

Taken together, the results indicate that while students demonstrate awareness of chemistry concepts and applications, their ability to apply chemical knowledge to analyse real-world situations and chemical processes remains limited. These findings highlight the need for instructional approaches that emphasise conceptual understanding, contextual learning, and the application of chemical knowledge to real-life problems rather than reliance on rote memorisation at the secondary school level.

### **Conclusion**

This research conducted a thorough assessment of chemical literacy among undergraduate students with a background in the sciences, aiming to determine whether the Nigerian chemistry curriculum's objective of fostering chemical literacy has been achieved among students who are not majoring in core chemistry-related courses. The findings reveal a significant inadequacy in meeting these educational objectives, as many undergraduates struggled to accurately recall essential chemistry concepts. Furthermore, an even greater number were unable to effectively apply the concepts they could recall to real-life situations. This underscores the pressing need to enhance the curriculum to ensure that all students, regardless of their primary areas of study, develop a robust understanding of chemistry.

### **Recommendations**

It is strongly recommended that chemical literacy, particularly regarding concepts not directly associated with environmental issues, be taught through targeted instruction and learning in specific content areas. Such an approach should be rooted in contextual learning, which allows students to engage in practical situations that promote the application of chemical principles to diverse contexts in the future.

Furthermore, teachers must acknowledge that the goals of the chemistry curriculum extend beyond securing immediate academic success in secondary school. The curriculum is fundamentally designed to foster lifelong learners—individuals equipped with the knowledge and skills necessary to make informed personal decisions and actively participate in their communities. By emphasizing this broader vision, educators can inspire students to recognize the relevance of chemistry in their daily lives and civic responsibilities, ultimately guiding them toward becoming informed and proactive citizens.

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