Journal of Sustainable Educational Technology and Innovation
Volume 2, Issue 1, 14-23.
E-ISSN: 3124-0747
https://ejournal.aps-tpi.org/jseti/index
https://doi.org/10.58723/jseti.v2i1.223

Needs Analysis for the Development of Problem-Posing Multimedia Package for Enhancing Students' Understanding of Organic Chemistry Concepts: A Document Analysis

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Article Info

Article history:

Received: April 21, 2026
Revised: May 24, 2026
Accepted: July 22, 2026

Keywords:

ADDIE Model
Hydrocarbons
Learning Difficulties
Multimedia
Problem-Posing Strategy

Abstract

Background: This systematic needs analysis forms the foundational phase in developing a problem-posing multimedia package to improve senior secondary students' understanding of organic chemistry, specifically hydrocarbons. Grounded in a phenomenological approach, the study captures students' authentic learning challenges to ensure that the intended package addresses the real educational needs of the targeted students.
Aims: The paper aims to identify and analyze prevalent student misconceptions in hydrocarbon concepts, providing diagnostic insights to guide the pedagogical design of the multimedia tool so it directly targets learning gaps.
Methods: A qualitative approach was used with a purposive sample of ten chemistry students. Thematic analysis of students' written documents (tests and exercises) was conducted to identify recurring errors and underlying misconceptions regarding hydrocarbon nomenclature, structure, and properties.
Results: Six major error categories emerged: incorrect compound naming; misidentification of functional groups; poor understanding of isomerism; inappropriate hybridization assignment; erroneous carbon chain numbering; and inaccurate structure drawing. These reflect deeper conceptual gaps, such as difficulty recognizing parent chains, differentiating bonding types, identifying homologous series, and applying IUPAC rules consistently.
Conclusion: The findings confirm that students' difficulties are systematic and conceptual, underscoring the necessity for a tailored instructional intervention. Developing a problem-posing multimedia package designed to explicitly address these identified challenges is essential for enhancing student comprehension and mastery of hydrocarbon concepts.

To cite this article: Ibrahim,T., Sabitu, S &Usman, N, S. (2026). Needs Analysis for the Development of Problem-Posing Multimedia Package for Enhancing Students' Understanding of Organic Chemistry Concepts: A Document Analysis. *Journal of Sustainable Educational Technology and Innovation, 1*(1), 14-23. https://doi.org/10.58723/jseti.v2i1.223

INTRODUCTION

The transition from student to educator presents a profound challenge for pre-service chemistry teachers, who must concurrently master complex subject matter, develop pedagogical skill, and manage classroom dynamics (Wang & Shen, 2021). This challenge is intensified within the Nigerian educational landscape, characterized by systemic constraints such as underfunding, large class sizes evidenced by an average student-teacher ratio of 45:1 UBEC (2022) and a chronic scarcity of instructional resources. These conditions underscore a critical needs analysis for targeted instructional support to bolster teacher preparedness and student outcomes.

A central domain requiring intervention is students' understanding of organic chemistry concepts. This topic is notoriously challenging due to its abstract nature and the cognitive demand of navigating its macroscopic, sub-microscopic, and symbolic representational levels (Johnstone, 1993; Talanquer, 2011). Consequently, learners frequently harbor persistent misconceptions and exhibit recurring errors in fundamental areas such as nomenclature, functional group identification, isomerism, and structural representation (Sabitu et al., 2021). For the pre-service teacher, the repeated confrontation with these ingrained student difficulties can become a source of significant frustration and self-doubt, potentially undermining professional commitment (Wang & Shen, 2021).

To enhance students' understanding, innovative pedagogical strategies are essential. One promising approach is problem-posing, an active-learning paradigm where students generate their own questions or problems based on given scenarios. This strategy promotes deeper cognitive engagement and conceptual mastery (Hendrajaya et al., 2022). However, its effective implementation in complex domains like organic chemistry often requires specialized instructional media. Therefore, the development of a problem-posing multimedia package is proposed. Such a package would integrate visualizations, simulations, and interactive frameworks to scaffold both teaching and learning, addressing the dual deficit of conceptual difficulty and material scarcity (Bodé et al., 2019).

This study will employ a document analysis methodology to systematically investigate the existing literature, curriculum documents, and assessment reports. This approach will allow for a comprehensive synthesis of documented learning gaps, prevalent errors, and previously attempted interventions (Bowen, 2009). The analysis will directly inform the design specifications of the multimedia package, ensuring it is grounded in empirical evidence of student needs and contemporary pedagogical theory. Ultimately, this work aims to create a resource that mitigates the identified systemic and cognitive barriers, thereby supporting pre-service teachers in facilitating more meaningful and less stressful learning experiences in organic chemistry.

Organic chemistry is widely acknowledged as one of the most conceptually demanding domains within the science curriculum, characterized by its heavy reliance on abstract, multi-level representations (Salsabila & Aznam, 2024). Students must navigate between symbolic formulae, microscopic particle models, and macroscopic properties a cognitive task many find daunting (Ningrum et al., 2021). This challenge is pronounced in the study of hydrocarbons, the foundational framework of organic chemistry, where persistent misconceptions are well-documented (Almomen & Alotaibi, 2025; Karini et al., 2022).

Research consistently highlights specific conceptual hurdles. Learners commonly struggle with core concepts such as covalent bonding, hybridization, and isomerism, which are essential for progressing to reaction mechanisms . In the Nigerian context, studies by Adeoye et al (2023) & Alexander (2023) corroborate these findings, identifying widespread difficulties with IUPAC nomenclature and structural representation among senior secondary students. These foundational gaps often stem from an over-reliance on rote memorization without deep conceptual understanding, a pedagogical issue noted in regional analyses .

Instructional methodologies significantly influence these learning outcomes. Predominant teaching strategies in many Nigerian secondary schools remain traditional, relying on teacher-centered lectures and static chalkboard diagrams. This approach limits opportunities for students to visualize three-dimensional structures and engage in the dynamic reasoning required in organic chemistry. Consequently, there is a documented disconnect between teaching methods and the spatial-visual demands of the subject.

Emerging pedagogical research underscores the efficacy of more interactive, technology-enhanced learning. Constructivist approaches that incorporate molecular model simulations, problem-based learning, and dynamic visualization tools have shown promise in improving conceptual understanding and correcting misconceptions. Recent local studies affirm this trend; for instance, research by Metcalf et al. (2023) in Southwestern Nigeria demonstrated that students exposed to computer-based molecular modeling showed significantly improved performance in hydrocarbon concepts compared to those taught with conventional methods. Similarly, advocate for contextually relevant multimedia resources to bridge the gap between abstract concepts and students' concrete experiences.

Therefore, the literature substantiates a critical need for instructional innovations in Nigeria that move beyond traditional pedagogy. Developing localized, multimedia learning packages that target identified misconceptions and offer interactive, visual engagement with hydrocarbon structures is not only supported by global research but is also urgently recommended by recent regional studies to enhance meaningful learning in organic chemistry (Nakiboglu, 2003).

Therefore, difficulties in learning hydrocarbons often cascade into broader challenges in organic chemistry. This highlights the need for instructional innovations that target not only conceptual understanding but also student engagement and retention. Recent research emphasizes the importance of integrating multimedia tools to enhance learning (Ahmad et al., 2021; Ahyan et al., 2022). Multimedia-based instruction, especially problem-posing, simulation, and visualization tools that has been shown to improve students' conceptual clarity and retention. Within the ADDIE model of instructional design, needs analysis serves as the cornerstone for developing such tools, ensuring that the instructional product aligns with learners' challenges, curriculum expectations, and teachers' instructional realities (Almomen & Alotaibi, 2025).

The persistent underperformance of students in organic chemistry, particularly in hydrocarbon concepts, is a well-documented concern in Nigerian secondary schools, as consistently reflected in national examination reports. This trend points to a significant disconnect between traditional instructional methods and the cognitive demands of learning a highly abstract and visually intensive subject. While the challenges students face are known anecdotally and through broad performance metrics, a critical gap exists in the granular, evidence-based identification of the specific procedural and conceptual errors that underpin these difficulties (Smith & Jones, 2020).

Current teaching practices, which often rely on chalkboard illustrations and rote memorization, fail to provide the dynamic visualizations and interactive engagement necessary for students to construct accurate mental models of molecular structures and reactions. This pedagogical gap is exacerbated by a notable lack of context-specific, technology-enhanced learning resources designed to address the unique challenges of the Nigerian curriculum and classroom environment. Therefore, a systematic and diagnostic needs analysis is not merely beneficial but essential. By meticulously analyzing students' own written work, this study moves beyond general assumptions to pinpoint the exact nature of their misconceptions from fundamental errors in naming and drawing to complex misunderstandings of isomerism and hybridization. The findings from this investigation will provide an indispensable empirical foundation. They will serve to justify and strategically guide the subsequent development of a problem-posing multimedia package, ensuring that such an intervention is not developed in a vacuum but is precisely targeted to remediate the most critical and recurring learning obstacles faced by students (Akpokiere et al., 2020; Aliyu et al., 2020).

Given the documented challenges in teaching and learning organic chemistry, this study was conducted to perform a systematic needs analysis. The purpose was to identify and categorize the specific errors and misconceptions senior secondary school students in Nigeria exhibit when learning about hydrocarbons. The findings from this inquiry are intended to provide a foundational, evidence-based rationale for the subsequent development of a problem-posing multimedia package tailored to address these identified difficulties. To achieve this purpose, the study was guided by the following research question: What are the specific errors and misconceptions students demonstrate in understanding hydrocarbon concepts, as revealed through the analysis of their written responses?

METHOD

Research Design

This study adopted a qualitative research design, utilizing a document analysis approach. This method is consistent with a phenomenological orientation, which seeks to understand the essence of a phenomenon from the perspective of those who have experienced it (Creswell & Clark, 2017). In this context, the "phenomenon" is the learning difficulty in organic chemistry, and the students' written scripts provide the "lived experience" data.

Participant

The participants for this study were ten (10) Senior Secondary School II (SSII) chemistry students randomly selected from public schools within Katsina State, Nigeria.

Population and the methods of sampling, Instrumentation (sample of questions, scoring method, and psychometric properties (validity and reliability)

This needs analysis targeted Senior Secondary School Two (SS2) chemistry students in Nigerian public schools. A purposive sample of ten students, representing a range of academic performance, was selected to provide in-depth, diagnostic insights into learning obstacles. Data was gathered via an open-ended diagnostic assessment, featuring questions on nomenclature, isomerism, and structural representation, designed to reveal procedural and conceptual errors. Content validity was secured through expert review by chemistry educators, and analytical reliability was ensured through a consensus-based thematic coding process between two researchers. This approach prioritized detailed evidence of student reasoning to directly inform the development of a targeted instructional intervention (Aris et al., 2024).

Instrument

An instrument titled "Organic Chemistry Essay Question," comprising ten essay questions on hydrocarbon concepts, was administered to the students to generate the data. Their written responses (manuscripts) constituted the primary data for the document analysis.

Procedures and if relevant, the time frame

Thematic analysis, following the framework, was employed to analyze the students' manuscripts. The process involved familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. This rigorous process ensured that the identified errors and misconceptions were deeply rooted in the students' actual responses.

Analysis plan (describe statistical tests and the comparisons made; ordinary statistical methods should be used without comment; advanced or unusual methods may require a literature citation): **Scope and/or limitations of the methodology you used:** Thematic Analysis was used. Where direct words of the respondent, the quotes were grouped into codes and related codes were also grouped into themes.

RESULTS AND DISCUSSION

Results

This section presents the findings of the sub-study conducted during the need analysis phase, which identified common mistakes made by students through written manuscripts to justify the need for the development of the package. This is consistent with (Creswell & Clark, 2017), who asserted that phenomenological research entails obtaining the purest, unspoiled data and interpretations from actual participants or persons directly affected by the phenomena. In this study Students are the most significant stakeholders. As a result, the documents of Ten (10) Senior Secondary Schools chemistry students were examined in order to detect common mistakes students' commit with regard to hydrocarbons. Ten (10) essay questions of organic chemistry were presented to the students with the intention to answer one research question as follows: Six common mistakes were detected through the analysis of the students' manuscripts, including wrong naming of Hydrocarbons, wrong identification of functional group, poor knowledge of isomerism phenomenon, wrong hybridization, numbering of carbon and wrong drawing of organic compound structures, as depicted in Figure 1.

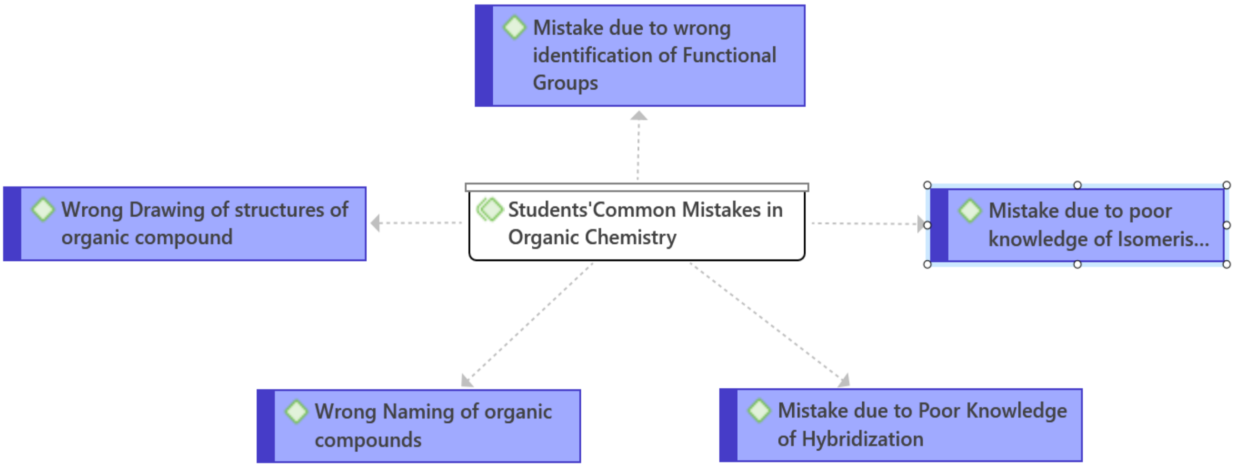

Figure 1. Students' Common Mistakes

Wrong Naming of Organic Compounds

Giving accurate name of hydrocarbons has been observed in students' manuscripts. This usually occurs because of students' misconceptions; they cannot be able to correctly differentiate between parent chain and branched chain in a structure. For example, Student 002 wrongly named the structure of 2, 2-dimethylpentane (see Figure 2). The student just named it as hydrochloric acid. This may be due to the poor knowledge of parent chain, branched chain and seniority in carbon atoms with respect to attached substituents. Also, student 005 couldn't identify parent chain and branched chain.

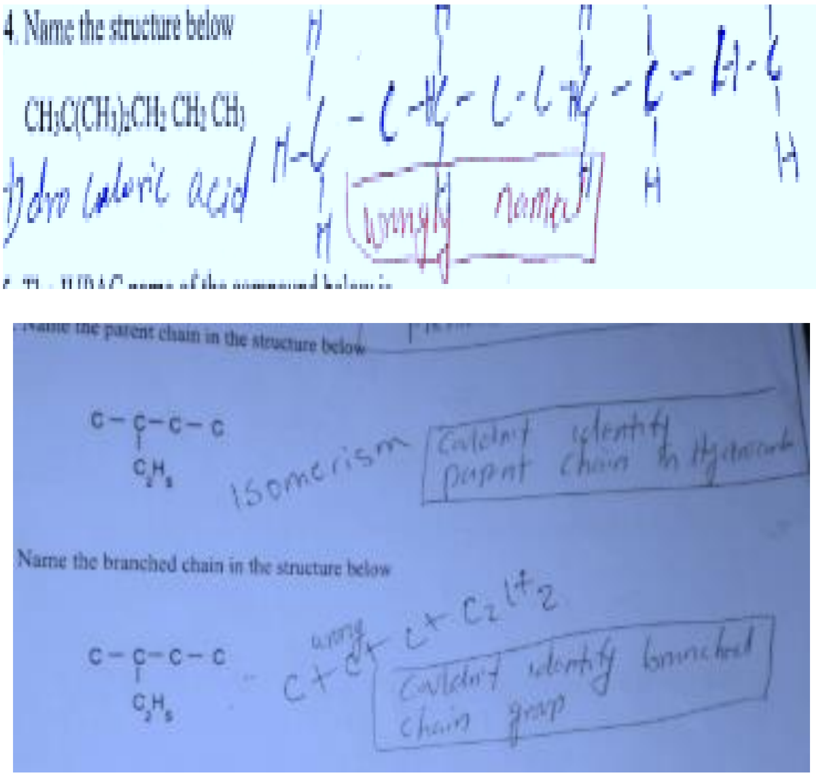

Figure 2. Wrong Naming

Wrong Identification of Functional Group

Similarly, not correctly identifying the hydrocarbon functional groups has been identified as a common mistake made by students in identifying hydrocarbon functional groups. From the analysis of the students' manuscripts, most students could not differentiate between single bond, double bond and triple bond functional groups. This mistake is because of students' poor knowledge of homologous series. This was evident in the Student 002 that he was incorrect for not accurately identifying the three hydrocarbon functional groups which he only wrote "2 carbon" (see Figure 3). It is worthy of note that poor identification of functional groups could lead to so many misconceptions in the field of Organic Chemistry.

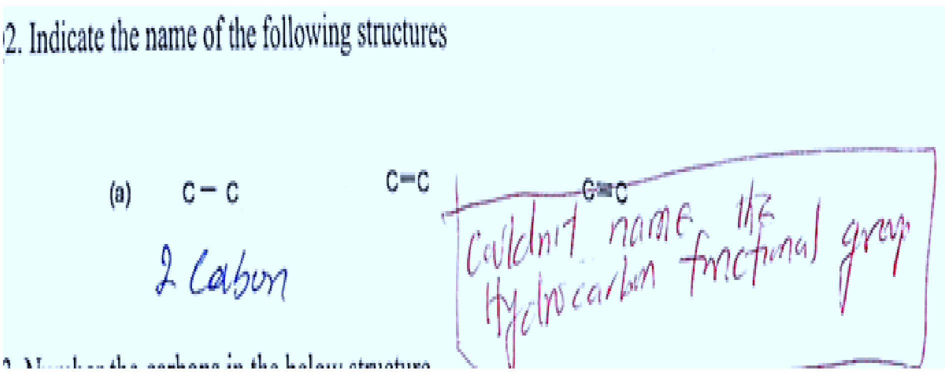

Figure 3. Wrong Identification of Functional Group

Poor Knowledge of the Isomerism Phenomenon

Another common mistake made by students is the inability to clearly demonstrate good knowledge of isomerism. This was identified in the manuscripts of Student 005 and Student 008 in Figure 4.0, who could not identify the isomerism phenomenon based on the given structures and also could not be able to state the types of isomerism based on structures.

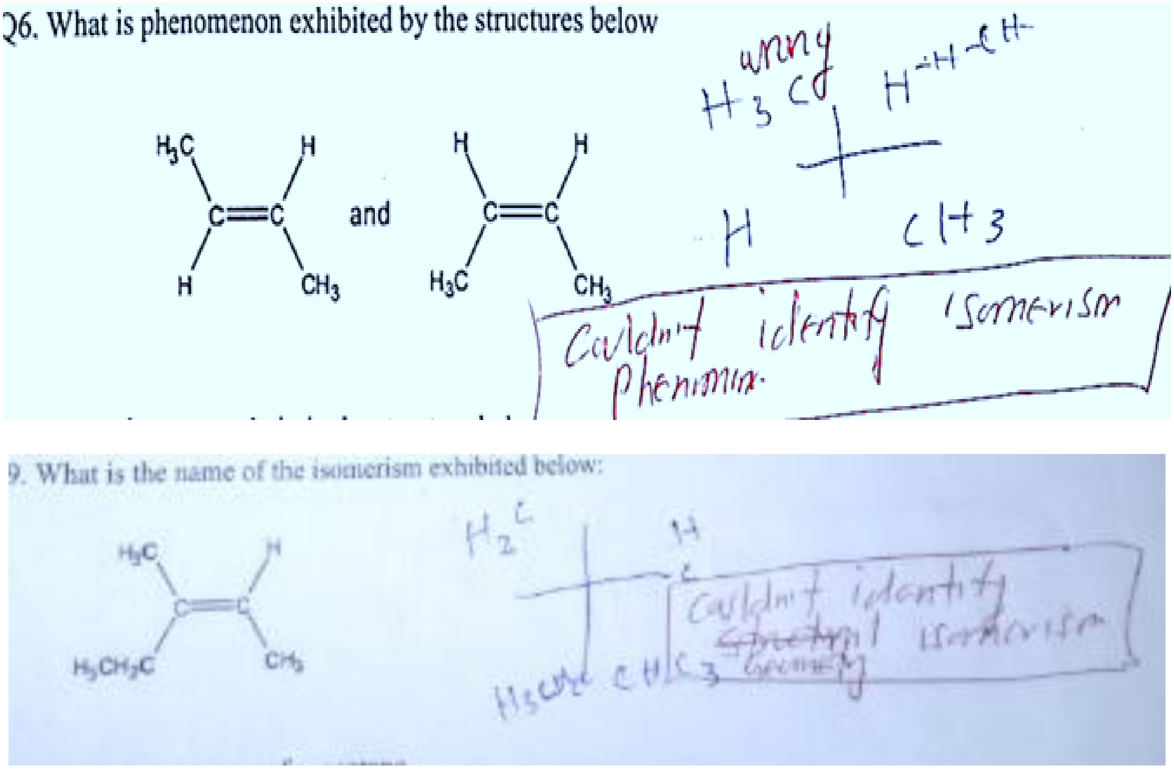

Figure 4. Wrong Identification of Isomerism

Wrong Hybridization

It is a rule that the overall no sub-orbital can take more than two orbitals. However, some failed to adhere to that, usually due to students' poor background of filling electrons into their respective orbitals and also poor background in electronic configuration. In the example shown in Figure 5.0, student 008 portray a poor knowledge on the number of electrons in carbon atom, poor knowledge of orbitals electron accommodation and hybridization of orbitals. This indicates that students could not be able to differentiate between ground state electronic configuration and excited state configuration.

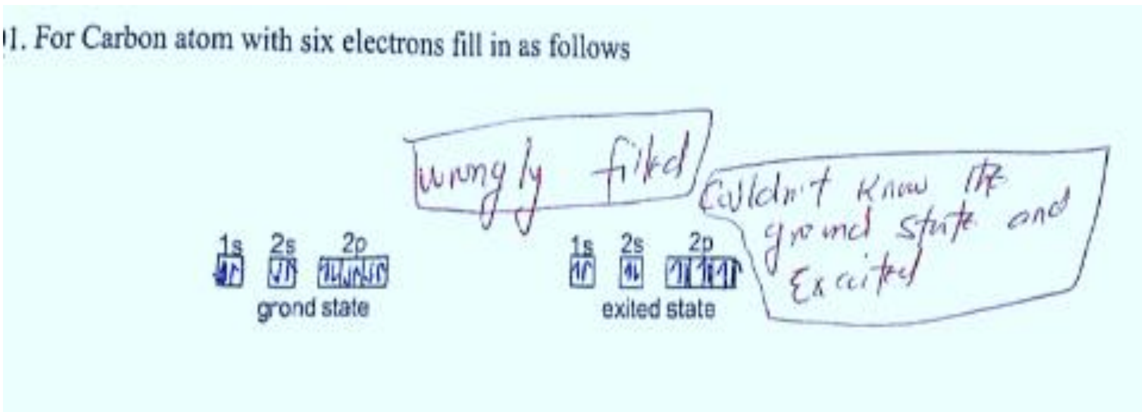

Figure 5. Wrong Hybridization

Numbering of Carbon

Furthermore, it is a rule that numbering of carbon atoms in an organic structure must adhere to seniority/aciditity of carbon atoms which depends on the substituents. However, some failed to adhere to that, usually due to students' poor background of acidity of carbon based on attached substituent and not adequately knowing from where to start the numbering. In the example shown in Fig. 6.0, student 001 and student 009 portray a poor knowledge on how to give numbers to carbon atoms in a hydrocarbon structure.

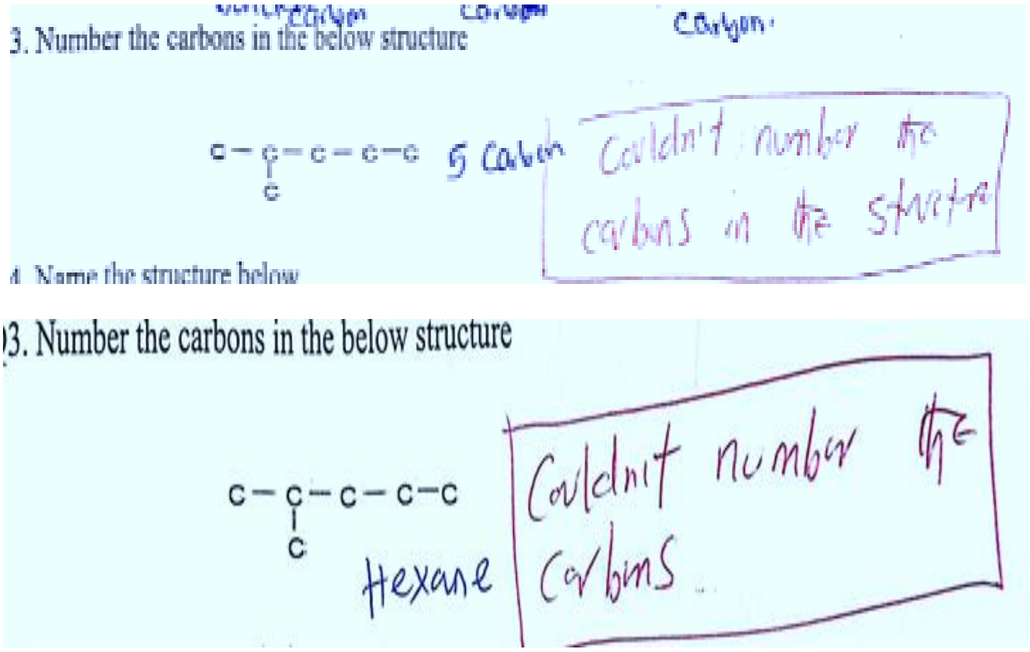

Figure 6. Poor Numbering of Carbon atoms

Wrong Drawing of Organic Compound Structures

Another common mistakes made by students is the inability to clearly draw structures of organic compounds. This was identified in the manuscripts of Student 003, Student 005 and Student 008 in Figure 7.0, whom could not clearly draw simple structure of n-pentane.

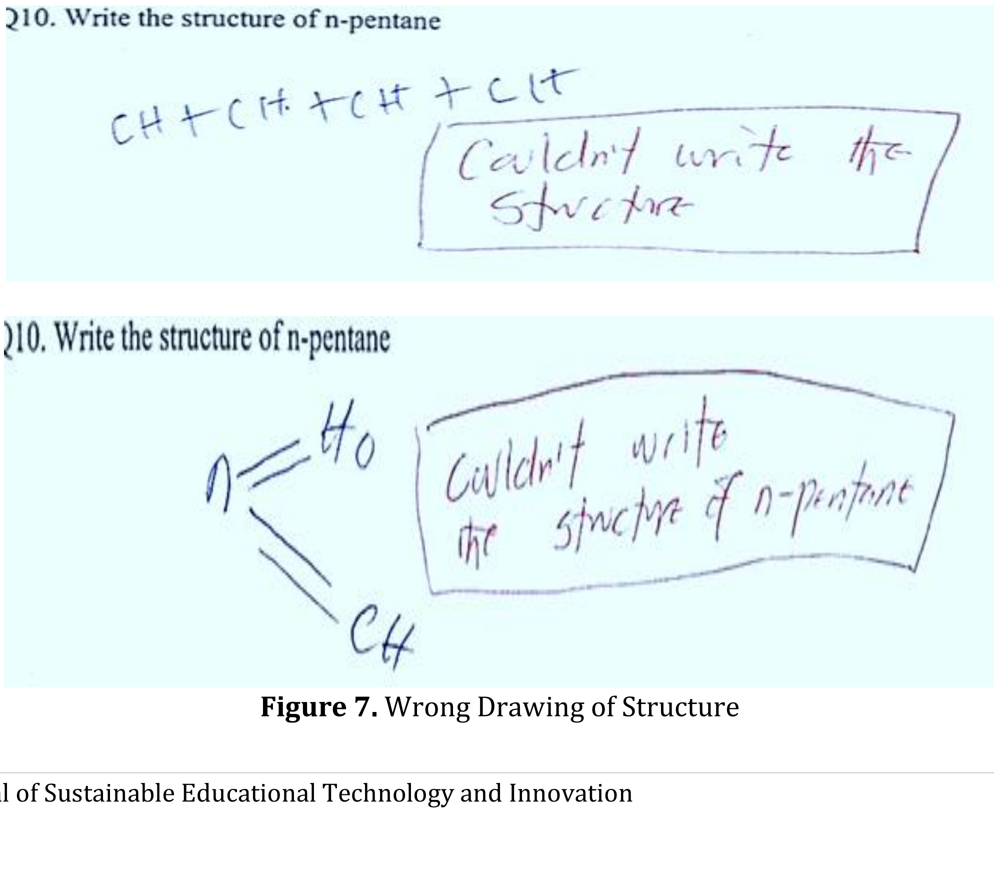

Figure 7. Wrong Drawing of Structure

Discussion

The outcome of the document analysis indicates a layered structure of student difficulties. Foundational misconceptions in atomic theory and electronic configuration appear to evolve into more complex errors in nomenclature, isomerism, and molecular representation. This progression aligns with international research findings on the hierarchical nature of learning in chemistry (Johnstone, 2006; Salsabila & Aznam, 2024). The persistent errors in naming, identifying functional groups, and drawing structures underscore a reliance on rote memorization rather than conceptual understanding. The findings strongly justify the development of a targeted instructional intervention. A problem-posing multimedia package that incorporates dynamic visualization, interactive molecular models, and scaffolded problem-solving activities could directly address these identified gaps. By allowing students to manipulate structures, receive immediate feedback, and engage in posing their own problems, such a package can help bridge the gap between abstract symbolic representations and concrete understanding, thereby promoting deeper conceptual learning (Wang & Shen, 2021).

Implications

The findings highlight a clear need to move beyond traditional lecture-based instruction in organic chemistry. They provide educators with a specific diagnostic framework for identifying common student errors and justify the development of an interactive, problem-posing multimedia tool designed to target these precise conceptual gaps through visualization and practice.

Research Contribution

This study contributes a detailed, context-specific taxonomy of hydrocarbon misconceptions among Nigerian secondary students, bridging global science education research with local classroom realities. It also offers a replicable model for conducting a design-focused needs analysis to inform the development of tailored educational interventions.

Limitations

The study's qualitative design and small sample limit the generalizability of its findings. Relying solely on written documents may not capture all underlying reasoning processes, and as a needs analysis, it does not evaluate the efficacy of the proposed multimedia solution, which requires future testing.

Suggestions

Based on the findings of this study, the following suggestions were made:

1. A problem-posing multimedia package should be developed using the ADDIE instructional design model, with a specific focus on visualizing molecular structures, demonstrating isomerism, and providing interactive practice for nomenclature and hybridization.
2. Chemistry teachers should be trained on how to effectively integrate this multimedia package and other technology-based tools into their instructional practices to create a more engaging and effective learning environment.
3. Curriculum planners and educational policymakers should advocate for and support the incorporation of technology-enhanced learning resources into the national chemistry syllabus.
4. Future research should focus on the development of the proposed package and a subsequent empirical study to evaluate its effectiveness on improving students' conceptual understanding and academic performance in organic chemistry

CONCLUSION

The needs analysis has revealed substantial and specific gaps in Nigerian students' understanding of fundamental hydrocarbon concepts. The recurring errors in nomenclature, functional group identification, isomerism, hybridization, carbon numbering, and structural drawing highlight a critical need for innovative, interactive teaching tools that move beyond traditional lecture methods.

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support of the Tertiary Education Trust Fund through the Management of the Federal University Dutsin-Ma and the support of the participating schools and students in Katsina State, without whom this study would not have been possible.

AUTHOR CONTRIBUTION STATEMENT

TI conceived and designed the study, developed the methodology, and conducted the formal analysis of the interview data. AS contributed to the study's conceptualization, provided critical context and validation regarding chemistry education challenges, and assisted with data curation. NAU contributed to the investigation process, literature review, and preparation of the original draft. All authors participated in reviewing and editing the final manuscript.

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