



Fostering Positive Attitudes in Organic Chemistry through Digital Tools and Worksheets: A Case Study on Hydrocarbon Nomenclature

Kenneth Afedzi Hayford

Department of Science, Mfantshipim Senior High School, Cape Coast, Ghana

kennethhayford24@gmail.com

Boniface Yaayin

Department of Chemistry Education, University of Education, Winneba, Ghana

byaayin@uew.edu.gh

Enoch Kojo Dorman

Department of Science, Mfantshipim Senior High School, Cape Coast, Ghana

dorman.enochkojo@gmail.com

Mumuni Yakubu

School of Development Studies, University of Cape Coast, Cape Coast, Ghana

mumuyak@gmail.com

Dennis Yeboah Asiamah

Department of Science, Mfantshipim Senior High School, Cape Coast, Ghana

denyeb25@gmail.com

Abstract

This study investigated the impact of ChemDraw software and guided worksheets on senior high school students' attitudes toward drawing and naming hydrocarbons in organic chemistry. Acknowledging the difficulties many students face with hydrocarbon nomenclature, the intervention was designed to enhance conceptual understanding and engagement through the use of digital tools, framed within a constructivist learning approach. A purposive sampling technique was used to select an intact class of 35 chemistry students from a Ghanaian senior high school. A mixed-methods case study design was employed, involving data collection through a researcher-developed attitude scale and semi-structured interviews. Quantitative findings revealed that over 80% of the students reported positive attitudes, indicating increased confidence, ease of use, and improved academic performance. Thematic analysis of interview responses supported these results, emphasizing ChemDraw's interactivity, visual appeal, and relevance to students' learning needs. Although a minority of participants reported initial challenges such as screen fatigue and time demands, the overall response was highly favorable. The findings suggested that integrating ChemDraw with structured support can effectively foster engagement, digital literacy, and conceptual mastery in organic chemistry. The study recommended the wider adoption of such tools and further investigation into tailored support for diverse learners.

Keywords: Hydrocarbon Nomenclature, Digital Tools, Constructivist Learning, Purposive Sampling, Organic Chemistry Education, Student Attitudes.

Reference to this paper should be made as follows:

Hayford, K. A., Yaayin, B., Dorman, E. K., Yakubu, M., & Asiamah, D. Y. (2025). Fostering positive attitudes in organic chemistry through digital tools and worksheets: A case study on hydrocarbon nomenclature. *International Journal of Scientific Research in Education*, 18(2b), 245-256.

INTRODUCTION

Organic chemistry occupies a foundational place in science education, particularly at the Senior High School (SHS) level in Ghana, where it forms a significant component of both integrated and elective chemistry curricula (Ministry of Education [MOE], 2010). The study of organic chemistry equips students with essential skills for understanding molecular structures, functional groups, and the International Union of Pure and Applied Chemistry (IUPAC) system of nomenclature. These competencies are crucial for success in STEM-related fields such as medicine, pharmacy, engineering, agriculture, and environmental science (Chang & Goldsby, 2016; Aryeetey, 2018; Yaayin & Hayford, 2025). However, despite its relevance, organic chemistry is widely perceived as one of the most difficult areas of the science curriculum. Numerous studies and WAEC Chief Examiners' reports have pointed to students' persistent struggles with drawing and naming hydrocarbons fundamental skills in understanding organic compounds (WAEC, 2010; 2018; Adu-Gyamfi et al., 2020; Yaayin et al., 2024).

Students' difficulties with organic chemistry are often linked to the abstract nature of the subject, traditional teacher-centered instructional methods, and the lack of access to innovative and visual teaching tools (Coll & Treagust, 2001; Nicoll, 2001; Adu-Gyamfi & Asaki, 2022). These challenges negatively impact learners' attitudes, reducing their interest and motivation to engage with chemistry topics (Salame et al., 2019; Sibomana et al., 2020). Organic chemistry concepts such as hydrocarbon nomenclature require not only memorization but also conceptual understanding and spatial reasoning, which many students find difficult when taught through conventional chalk-and-talk approaches (Johnstone, 2006; Taber, 2002; Hanson, 2017).

To address these challenges, researchers and educators have increasingly advocated for the integration of digital tools and constructivist learning strategies to enhance student engagement and learning outcomes in chemistry (Gilbert, 2005). Constructivist theory emphasizes learner-centered approaches, active participation, and guided exploration, all of which support deeper conceptual understanding (Honebein 1996; Collini et al., 2024; Triantafyllous, 2024). Among the various digital tools developed for chemistry education, ChemDraw software has emerged as a powerful molecular visualization application that allows students to draw, edit, and identify chemical structures easily. Its intuitive interface and ability to convert chemical names into molecular representations and vice versa make it particularly effective for teaching IUPAC nomenclature (Li et al., 2004).

Furthermore, guided worksheets serve as valuable pedagogical tools that support inquiry-based learning and reinforce concepts through structured tasks. Worksheets can facilitate full student participation, support retention of knowledge, and improve conceptual clarity, especially when used alongside digital tools (Celikler, 2010; Celik et al., 2022; Yaayin & Hayford, 2025). Combining ChemDraw with guided worksheets presents an opportunity to foster positive attitudes in students by making abstract chemical concepts more concrete, interactive, and engaging (Triantafyllou, 2024; Yaayin & Hayford, 2025).

This article presents a case study conducted at Mfantsipim Senior High School in Cape Coast, Ghana, to explore how the use of ChemDraw software, supplemented with guided worksheets, affects students' attitudes toward hydrocarbon drawing and nomenclature. Anchored in the frameworks of constructivist learning theory and the Technology Acceptance Model (TAM) (Davis, 1989), the study investigates how digital interventions can shift students' attitudes from apprehension to enthusiasm in organic chemistry. The insights generated aim to inform teaching practices, curriculum development, and policy decisions in the effort to

modernize and humanize science education. The following research question served as a guide for this investigation:

- What is the effect of ChemDraw software and guided worksheet intervention on students' attitudes towards drawing and naming of hydrocarbons?

LITERATURE REVIEW

To examine students' attitudes toward the use of ChemDraw and guided worksheets, this study draws upon two key theoretical perspectives: The Technology Acceptance Model (TAM) and elements of constructivist learning theory.

Technology Acceptance Model developed by Davis (1989) explains user attitudes toward adopting digital tools, based on two central constructs: perceived usefulness and perceived ease of use. Perceived usefulness refers to the belief that a particular technology enhances performance, while ease of use pertains to how effortless the tool is to operate. In the context of this study, TAM provides a framework for understanding how students perceive and engage with ChemDraw. A positive attitude toward the software is expected when students find it intuitive, accessible, and helpful in learning how to draw and name hydrocarbons. Features such as IUPAC name generation, 2D/3D visualization, and seamless integration with Office tools make ChemDraw a valuable aid in organic chemistry instruction (Eller, 2006; PerkinElmer Inc., 2020). While TAM has been critiqued for overlooking contextual and institutional factors (Ajibade, 2018), it remains a powerful lens for studying adolescent learners, whose technology adoption is heavily influenced by peer perception and usability experience (Spears, 2016; Molleman et al., 2022; Irani et al., 2024).

Although not the central theory of this study, constructivist principles support the pedagogical design of the worksheet intervention. Constructivism emphasizes student-centered, active learning, with tools like ChemDraw serving as cognitive aids that help learners build understanding through visualization and interaction. The use of guided worksheets, based on constructivist principles, provides necessary scaffolding-step-by-step support that helps students master complex tasks such as hydrocarbon nomenclature. Research by Celikler (2010) and Virtayanti and Rohmah (2020) confirmed that well-structured worksheets can reduce misconceptions and improve conceptual clarity in science education.

Student attitude plays a critical role in the successful adoption of technology-enhanced learning. Studies have shown that when learners perceive a digital tool as both helpful and user-friendly, they are more likely to approach it with interest and motivation (Davis et al., 1992; Munir et al., 2024). Munir et al. (2024) reported that SHS students showed generally positive attitudes toward classroom technologies, particularly when used for practice-oriented tasks. Their use of a five-point Likert scale revealed that tools perceived as engaging and supportive led to increased participation and enjoyment in learning.

Similarly, Fabian et al. (2018) found that the integration of mobile technologies in mathematics classrooms significantly improved both student attitudes and academic achievement. These findings, grounded in constructivist pedagogy, emphasize the value of interactive, visual, and hands-on learning environments-characteristics shared by ChemDraw when paired with structured worksheets. However, negative attitudes toward organic chemistry are still common. Boateng (2024) and Salame et al. (2019) identified issues such as low motivation, misconceptions, and poor retention despite conventional teaching strategies. This

suggests a need for tools that can actively engage students and make complex content more accessible and relatable.

While several studies have explored general attitudes toward educational technologies, few have examined the combined impact of ChemDraw and guided worksheets in the specific domain of hydrocarbon nomenclature. Moreover, limited research exists on how these tools influence student attitudes in West African senior high schools, particularly within the Ghanaian context.

This study seeks to fill this gap by investigating how SHS students in Cape Coast perceive the use of ChemDraw and guided worksheets in learning to draw and name hydrocarbons. Through the lens of TAM and supported by constructivist principles, this research aims to understand whether such digital interventions foster more positive, motivated, and confident learners in organic chemistry.

Components of the Framework

The conceptual framework underpinning this study is organized around three core components that collectively guide the implementation and evaluation of the ChemDraw and guided worksheet intervention. These components are informed by the theoretical foundations of constructivist learning and the Technology Acceptance Model (TAM), with a specific focus on students' attitudinal responses to the digital tools and instructional strategies employed. In alignment with the study's objectives, the researcher developed a result-oriented and practical conceptual framework to inform the processes of data collection, analysis, and interpretation. The structure of this framework is illustrated in Figure 1.

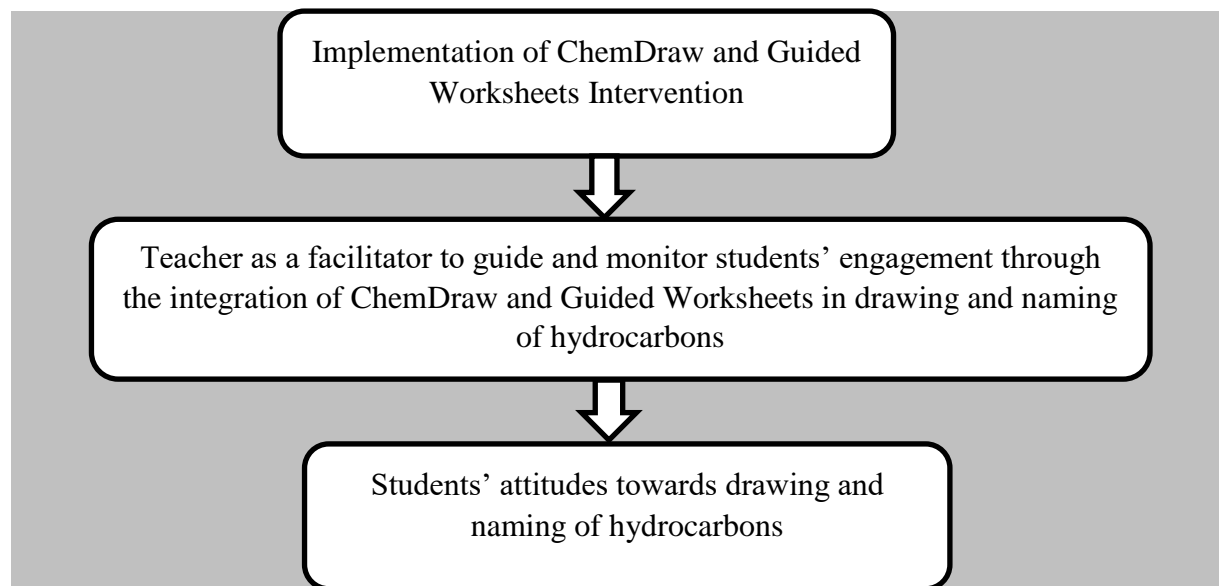


Figure 1: Conceptual Framework. Source: Researchers' Construct (2024)

The first component involves the structured implementation of the ChemDraw software in conjunction with guided worksheets designed according to constructivist pedagogical principles. ChemDraw, a digital chemistry software, provides students with a visual and interactive platform to draw and manipulate hydrocarbon structures, while the guided worksheets offer step-by-step support to reinforce IUPAC naming conventions. The integration of these tools is intended to

bridge the gap between abstract chemical representations and conceptual understanding. This intervention aims to create an engaging and supportive learning environment that facilitates the acquisition of skills required for accurate drawing and naming of hydrocarbons. This phase also aligns with Vygotsky's Zone of Proximal Development (ZPD) and extends to the "Comfort Zone" (Anderson & Gegg-Harrison, 2013), ensuring that the tools are accessible, easy to use, and non-intimidating for students in second-cycle schools.

The second component of the framework positions the teacher as a facilitator rather than a traditional transmitter of knowledge. Within this role, the teacher is responsible for guiding students through the use of ChemDraw and the accompanying worksheets, providing instructional scaffolding, clarifying complex concepts, and fostering collaborative learning experiences. The teacher also actively monitors students' progress, offers feedback, and adapts instructional strategies to meet varying student needs. This facilitative approach ensures that students receive the necessary support to engage meaningfully with the intervention and build confidence in applying their learning.

The final component focuses on evaluating students' attitudes toward the drawing and naming of hydrocarbons following their engagement with ChemDraw and the guided worksheets. Informed by the Technology Acceptance Model, this component examines students' perceptions of the tools' ease of use and usefulness, as well as their overall motivation, interest, and confidence in learning organic chemistry. Positive attitudinal outcomes are anticipated when students perceive the intervention as accessible, supportive, and relevant to their academic needs. This component is critical to understanding the affective dimension of learning and the potential of digital tools to foster sustained engagement in complex scientific content.

METHODS

This study employed a case study design using a mixed-methods approach to examine the effect of a digital tool (ChemDraw) and a guided worksheet on students' attitudes toward drawing and naming hydrocarbons in organic chemistry. The integration of both quantitative and qualitative data allowed for a comprehensive exploration of changes in student attitudes following the intervention.

The study involved an intact class of 35 senior secondary school chemistry students selected purposively from a public school in Ghana. These students were in their second year and had been introduced to basic concepts in organic chemistry. The selection was based on their accessibility, willingness to participate, and prior exposure to foundational concepts in hydrocarbon nomenclature. Institutional consent was obtained prior to their inclusion in the study. The intervention consisted of two components:

- **ChemDraw Software:** Students were introduced to ChemDraw, a chemical structure drawing software, through a guided hands-on session. They were taught how to use the software to draw and name various hydrocarbon structures, including alkanes, alkenes, alkynes, cycloalkanes, cycloalkenes, and cycloalkynes.
- **Guided Worksheet:** A structured worksheet accompanied the software session. It contained scaffolded tasks ranging from simple to complex hydrocarbon structures. The worksheet guided students through the IUPAC rules for naming organic compounds and required them to apply the rules using both manual and digital drawing methods.

The intervention spanned two weeks, with three sessions per week, each lasting 60 minutes. To evaluate the effect of the intervention on students' attitudes, the following instruments were used:

- **Hydrocarbon Nomenclature Attitude Scale (HNAS):** A researcher-developed, three-point Likert-type questionnaire (Agree, Undecided, Disagree) was used to assess students' attitudes toward the task of naming and drawing hydrocarbons using ChemDraw and the guided worksheet. The items covered interest, confidence, perceived relevance, and engagement.
- **Semi-Structured Interview Guide:** Selected participants (n = 10) were interviewed after the intervention to explore their experiences in depth. The guide focused on perceived ease of use, confidence levels, motivation, and reflections on the integration of digital tools into learning.

Quantitative data from the HNAS were analyzed using descriptive statistics (percentages and mean scores) to identify patterns in students' attitudes post-intervention.

Qualitative data from interviews were analyzed thematically. Transcripts were reviewed for recurring patterns and coded into categories reflecting student perceptions about using ChemDraw and the worksheet in learning hydrocarbon nomenclature.

The head of the participating school reviewed and approved the consent letter prior to the commencement of the study. The purpose, procedures, and ethical considerations of the research were clearly explained to the participants. Informed consent was obtained from all participants before their involvement in the study. Participation was entirely voluntary, and participants were assured of the confidentiality and anonymity of their responses. All collected data were securely stored and used exclusively for academic purposes. To safeguard the internal validity of the study, data collection procedures were conducted objectively and without bias.

RESULTS AND DISCUSSION

The results related to this research question were obtained through both quantitative (questionnaire responses) and qualitative (interview excerpts) data, aimed at exploring students' attitudes following the use of ChemDraw software and guided worksheets in learning how to draw and name hydrocarbons.

Data from the Hydrocarbon Naming Attitude Scale (HNAS), particularly items 8-12 and 14-15 in Table 1, revealed that a significant majority of students developed a positive attitude toward drawing and naming hydrocarbons after the intervention.

Table 1: Attitudinal Responses of Students to the Use of ChemDraw and Guided Worksheets in Hydrocarbon Lessons

S/N	Attitude Item on ChemDraw and Worksheet	A (%)	U (%)	D (%)
1.	It was easy for me to learn to use ChemDraw	89	2	9
2.	I feel confident in using ChemDraw to draw hydrocarbons now	80	9	11
3.	The ChemDraw worksheets guided me through the drawing and naming process effectively	71	23	6
4.	I did not encounter technical issues with ChemDraw that slowed my learning process	66	17	17
5.	My understanding of drawing and naming hydrocarbons has improved	86	14	0

	due to using ChemDraw			
6.	I found using ChemDraw comfortable for learning to draw hydrocarbons	77	9	14
7.	Using ChemDraw and the worksheets has enhanced my problem-solving and digital literacy skills	80	0	29
8.	The combination of ChemDraw and worksheets enhanced critical thinking and creativity in learning hydrocarbons	89	11	0
9.	I found the process of drawing hydrocarbons using ChemDraw meaningfully engaging	74	0	26
10.	I did not feel bored while using ChemDraw to learn hydrocarbons	83	17	0
11.	The use of ChemDraw sustains my interest in learning hydrocarbons	80	11	9
12.	The time it took for me to complete tasks using ChemDraw was appropriate for the lesson objectives	69	0	31
13.	Using ChemDraw and the worksheets saves time compared to traditional methods of drawing and naming hydrocarbons	91	9	0
14.	I would recommend ChemDraw and guided worksheets strategy to other students learning hydrocarbons	89	2	9
15.	Overall, using ChemDraw has improved my performance in drawing and naming hydrocarbons	91	0	9

A = Agree, U = Undecided, D = Disagree, Sample size (N) = 35. Source: Field Survey (2024).

To validate the results of the Hydrocarbon Naming and Attitude Scale (HNAS), the researcher triangulated the summarized quantitative responses with data obtained from a structured interview guide. The analysis followed a thematic approach, with themes emerging from participants' narratives either supporting or contradicting the HNAS findings. Participants were grouped based on these emerging themes, ensuring consistency between their survey responses and in-depth interviews. Interviewees were given ample opportunity to express themselves freely and without bias or pressure, ensuring authentic responses regarding their experiences with ChemDraw. Particular attention was paid to how participants interacted with the software using the worksheet instructions, their perceptions of ChemDraw's features, its accessibility, and the extent to which the intervention embodied constructivist principles-especially the framework of the comfort zone of proximal development.

To maintain ethical standards, all participants were anonymized using the pseudonym "Respondent" (e.g., Respondent1 for the first interviewee, Respondent10 for the last). This practice aligns with research ethics regarding confidentiality and anonymity, protecting participants' identities and ensuring they could speak candidly about the intervention. The ethical and analytical approach aligns with Booth (2016), who emphasized the benefits of using pseudonyms for promoting anonymity, brevity, clarity, and understanding in academic writing. Similarly, O'Sullivan and Jefferson (2020) noted that research guided by these principles enhances the logical flow, accessibility, and depth of understanding in the presentation of findings.

Ease of Use, Accessibility and Constraints

Table 1 revealed that participants generally exhibited a positive attitude towards the use of ChemDraw and guided worksheets. On average, 80% of the respondents agreed with each of the 15 items on the Hydrocarbon Naming and Attitude Scale (HNAS), indicating strong approval for the intervention. This high level of agreement highlights how ChemDraw, alongside the

structured worksheet, enhanced students' conceptual understanding of hydrocarbons by making the drawing and naming process simpler and engaging.

For instance, 80% of participants expressed confidence in using ChemDraw to draw hydrocarbons (Item 2), while 66% reported they did not experience technical challenges (Item 4), despite being new to the software. Similarly, an average of 78% across Items 1, 2, 4, 5, and 6 confirmed that ChemDraw helped boost their confidence and understanding in drawing and naming hydrocarbon skeletal structures. Though a minority (22%) found the tool less accessible or initially challenging, the overall sentiment leaned strongly positive.

These results were further supported by interview responses. For example, Respondent5 described ChemDraw as “a very special app... interesting and educative,” particularly noting its effectiveness for visual learners. Similarly, Respondent8 stated: “ChemDraw made it easier for me to understand the various rules for drawing and naming organic compounds... I now get it totally,” showing a clear transition from basic to deeper conceptual understanding. Respondent4 shared a more nuanced experience: “It gave me quite a bit of stress when I started but after some time it was better,” suggesting initial difficulties were overcome with familiarity.

Overall, these responses demonstrate that students with foundational digital literacy were better positioned to adapt and benefit from the intervention. Even participants who initially struggled, like Respondent4 and Respondent2, eventually acknowledged the tool's relevance in deepening their conceptual grasp. Others, such as Respondent7 and Respondent3, further emphasized ChemDraw's user-friendly nature, calling it “easy and cool” and “very interesting and easy, also engaging,” respectively. These insights affirm that ChemDraw, when supported by guided worksheets, serves as an effective and engaging technological tool for fostering student understanding of hydrocarbons and enhancing their confidence in applying chemical principles.

Features of ChemDraw and Participants' Attitude Towards it

The findings from both the quantitative and qualitative data highlight that the features of ChemDraw significantly influenced participants' attitudes, motivation, and engagement during the intervention. The software's interactive interface, ease of use, and visual appeal emerged as critical aspects that shaped students' positive experiences. For instance, Respondent9 noted that *“The interface was very attractive and drawing the structures was fun,”* and Respondent7 added, *“The ability to give different colours to different compounds kept me going.”* These comments underscore how ChemDraw's design elements fostered active involvement and made the learning of organic chemistry more enjoyable.

A substantial majority of participants (80%) were motivated by the opportunity to use an innovative tool that aligned well with their lesson objectives. The software, when used alongside the guided worksheet, supported effective manipulation, visualization, and naming of hydrocarbon structures. Respondent8 remarked, *“It's quite engaging since it keeps both your body and mind active,”* while Respondent5 stated, *“I can now draw and name a lot of hydrocarbons without suffering.”* These sentiments reflect a shift in perception, with students viewing organic chemistry as more accessible and less daunting through the use of ChemDraw.

The quantitative data further reinforced this positive trend, with 91% of students agreeing that ChemDraw improved their performance, and 89% affirming the usefulness of the worksheet in facilitating their learning. In item 12 of the attitude scale, 69% of students also agreed that ChemDraw was a time-saver and appropriate for the learning objectives.

However, not all participants found the experience uniformly positive. A minority (20%) expressed challenges, particularly related to screen time and the time-intensive nature of learning. Respondent1 stated, “*Prolonged screen time made it a bit uncomfortable,*” and Respondent4 added, “*It actually requires a lot of time to learn organic chemistry.*” These reflections point to constraints such as cognitive load and individual preferences, which may influence the effectiveness of the tool for some learners.

Despite some limitations, participants’ overall attitude toward ChemDraw remained highly positive. They described the software as engaging, effective, and well-aligned with their academic needs. Many expressed willingness to recommend its use to peers, highlighting its value as a pedagogical tool in organic chemistry instruction. These findings align with the results of Munir et al. (2024), which showed that students generally exhibit positive attitudes toward the integration of technology in classroom instruction and practice. Overall, the study demonstrates that ChemDraw’s features when combined with structured guidance can meaningfully enhance students’ attitudes, active participation, and conceptual understanding in complex chemistry topics.

CONCLUSION

The study found that integrating ChemDraw software with guided worksheets significantly improved students’ attitudes, engagement, and performance in drawing and naming hydrocarbons. Most students reported that the tool was easy to use, visually engaging, and helpful in enhancing their understanding of organic chemistry concepts, despite a few initial challenges such as screen fatigue and learning curves. Overall, the intervention boosted students’ confidence, interest, and digital literacy, validating its effectiveness as a pedagogical tool. These findings support the integration of technology and structured support in chemistry education, suggesting that such approaches can make complex topics more accessible and enjoyable. Future research could explore ways to adapt these interventions to diverse learning needs and reduce potential barriers to sustained engagement.

CONFLICT OF INTEREST

There is no conflict of interest regarding this study.

REFERENCES

- Adu-Gyamfi, K. & Asaki, I. A. (2022). Teachers’ conceptual difficulties in teaching senior high school organic chemistry. *Contemporary Mathematics and Science Education*, 3(2), ep22019. <https://doi.org/10.30935/conmaths/12382>
- Adu-Gyamfi, K., Ampiah, J. G., & Agyei, D. D. (2020). Participatory teaching and learning approach. A framework for teaching redox reactions at the high school level. *International Journal of Education and Practice*, 8(1), 106-120. <https://doi.org/10.18488/journal.61.2020.81.106.120>
- Ajibade, P. (2018). Technology acceptance model limitations and criticisms: exploring the practical applications and use in technology-related studies, mixed-method, and qualitative researches. *Library Philosophy and Practice (e-journal)*, 8(3), 54-63.

- Anderson, N., & Gegg-Harrison, T. (2013). Learning computer science in the ‘comfort zone of proximal development’. In *Proceedings of the 44th ACM Technical Symposium on Computer Science Education (SIGCSE '13)* (pp. 495–500). ACM. <https://doi.org/10.1145/2445196.2445344>.
- Aryeetey, C. (2018). *Using molecular models to enhance the ability of students in drawing and naming structural formulae of cyclic hydrocarbons* (Unpublished MPhil thesis). University of Education, Winneba. <http://41.74.91.244:8080/handle/123456789/1262>.
- Boateng, S. (2024). Assessing conceptual difficulties experienced by pre-service chemistry teachers in organic chemistry. *Eurasia Journal of Mathematics Science and Technology Education*, 20(2), em2398. <https://doi.org/10.29333/ejmste/14156>
- Booth, A. (2016). Searching for qualitative research for inclusion in systematic reviews: a structured methodological review. *Systematic Reviews*, 5(1). <https://doi.org/10.1186/s13643-016-0249-x>.
- Celik, E., Baki, G. O., & Isik, A. (2022). The effect of cluster teaching with worksheets on students’ academic achievement in distance education. *Turkish Online Journal of Distance Education*, 23(3), 137-152. <https://doi.org/10.17718/tojde.1137255>.
- Çelikler, D. (2010). The effect of worksheets developed for the subject of chemical compounds on student achievement and permanent learning. *The International Journal of Research in Teacher Education*, 1(1), 42-51.
- Chang, R., & Goldsby, K. A. (2016). *Chemistry*. McGraw-Hill Education.
- Coll, R. K., & Treagust, D. F. (2001). Learners’ mental models of chemical bonding. *Research in Science Education*, 3(1), 357-382.
- Collini, M. A., Miguel, K., Weber, R., & Atkinson, M. B. (2024). Investigating changes in students’ attitudes towards organic chemistry: a longitudinal study. *Chemistry Education Research and Practice*, 25(3), 613-624.
- Davis, F. (1989) Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 13, 319-340.
- Davis, F., Bagozzi, R. & Warshaw, P. (1992). Extrinsic and intrinsic motivation to use computers in the workplace. *Journal of Applied Social Psychology*, 22, 1111-1132.
- Eller, G. A. (2006). Improving the Quality of Published Chemical Names with Nomenclature Software. *Molecules*, 11(11), 915–928. <https://doi.org/10.3390/11110915>.
- Fabian, K., Topping, K. J., & Barron, I. G. (2018). Using mobile technologies for mathematics: Effects on students attitude and achievement. *Journal of Educational Technology Research and Development*, 66(5), 1119-1139.
- Gilbert, P., & Irons, C. (2005). Focused therapies and compassionate mind training for shame and self-attacking, using cognitive, behavioral, emotional, and imagery interventions. In P. Gilbert (Ed.), *Compassion: Conceptualizations, research, and use in psychotherapy* (275–337). Routledge. <https://doi.org/10.4324/9780203003459-15>
- Hanson, R. (2017). Enhancing students ‘performance in organic chemistry through context based learning and micro activities: A case study. *European Journal of Research and reflection in Educational Sciences*, 5(6), 7 – 20.
- Honebein, P. C. (1996). Seven goals for the design of constructivist learning environments. *Constructivist learning environments: Case studies in instructional design*, 11(12), 11.

- Irani, F., Muotka, J., Lyyra, P., Parviainen, T., & Monto, S. (2024). Social influence in adolescence: Behavioral and neural responses to peer and expert opinion. *Social Neuroscience*, 19(1), 25–36. <https://doi.org/10.1080/17470919.2024.2323745>
- Johnstone, A. H. (2006). Chemical education research in Glasgow in perspective. *Chemistry Education Research and Practice*, 7(2), 49–63. <https://doi.org/10.1039/b5rp90021b>
- Li, Z., Wan, H., Shi, Y., & Ouyang, P. (2004). Personal Experience with Four Kinds of Chemical Structure Drawing Software: Review on ChemDraw, ChemWindow, ISIS/Draw, and ChemSketch. *Journal of Chemical Information and Computer Sciences*, 44(5), 1886–1890. <https://doi.org/10.1021/ci049794h>
- Ministry of Education [MOE]. (2010). *Teaching syllabus for chemistry: Senior high school 1-3*. Curriculum Research and Development Division, Ministry of Education, Accra, Ghana.
- Molleman, L., Ciranka, S., & Van Den Bos, W. (2022). Social influence in adolescence as a double-edged sword. *Proceedings of the Royal Society B Biological Sciences*, 289(1977). <https://doi.org/10.1098/rspb.2022.0045>
- Munir, H., Khan, E. A., & Shafqat, H. S. (2024). Mapping attitude of students towards applying technology in learning. *Journal of Law Social Studies*, 6(1), 40 – 53.
- Nicoll, K. (2001). Radiocarbon chronologies for prehistoric human occupation and hydroclimatic change in Egypt and northern Sudan. *Geoarchaeology*, 16(1), 47 – 64.
- O’Sullivan, T. A., & Jefferson, C. G. (2020). A review of Strategies for enhancing clarity and reader accessibility of qualitative research results. *American Journal of Pharmaceutical Education*, 84(1), 7124. <https://doi.org/10.5688/a1jpe7124>
- PerkinElmer Inc. (2020). *ChemDraw software*. Retrieved February 20, 2024, from <https://content.perkinelmer.com/lab-products-and-services/resources/software>
- Salame, I. I., Patel, S., & Suleman, S. (2019). Examining some of the students’ challenges in learning organic chemistry. *IJCER (International Journal of Chemistry Education Research)*, 6-14. <https://doi.org/10.20885/ijcer.vol3.iss1.art2>.
- Sibomana, A., Karegeya, C., & Sentongo, J. (2020). Students’ conceptual understanding of organic chemistry and classroom implications in the Rwandan perspectives: A literature review. *African Journal of Educational Studies in Mathematics and Sciences*, 16(2), 13-32. <https://doi.org/10.4314/ajesms.v16i.2.2>
- Spear, L. P. (2016). Consequences of adolescent use of alcohol and other drugs: Studies using rodent models. *Neuroscience & Biobehavioral Reviews*, 70, 228-243. <https://doi.org/10.1016/j.neubiorev.2016.07.026>
- Taber, K. S. (2002). *Chemical misconceptions-prevention, diagnosis, and cure: Theoretical background*. London: The Royal Society of Chemistry.
- Triantafyllou, S. A. (2024). A short paper about fundamental pedagogical concepts of constructivism theory in relation to TPACK framework. In *proceedings of the International Conference on Advanced Research in Teaching and Education*, 1(1), 1-7.
- Virtayanti, I. A., & Rohmah, R. S. (2020). Effectiveness of structured worksheet use to reduce student misconceptions in Stoichiometry. *Journal of Tadris Kimiya*, 5(2), 195-203.
- West African Examinations Council (WAEC). (2010). *Chief Examiner’s Report for on the West African Senior School Certificate Examination 2010*. Accra: West African Examination Council.
- West African Examinations Council (WAEC). (2018). *Chief Examiner’s Report for on the West African Senior School Certificate Examination 2018*. Accra: West African Examination Council.

- Yaayin, B., & Hayford, K. A. (2025). Promoting Students' Conceptual Understanding in Drawing and Naming of Hydrocarbons using ChemDraw Software with Guided Worksheets. *European Journal of Education and Pedagogy*, 6(3), 1-6. <https://doi.org/10.24018/ejedu.2025.6.3.956>.
- Yaayin, B., Archie, P., & Dorsah, P. (2024). Utilising context-based learning to promote students' conceptual understanding and performance in organic chemistry. *European Journal of Research and Reflection in Educational Sciences*, 12(6), 28-44.