The Impact of 3-Dimensional Molecular Models on The Elucidation of Structures of Aliphatic Hydrocarbons

Francis Abban-Acquah & Justice Edusei Ackah
Science Department, Wiawso College of Education, Sefwi Wiawso, Ghana

Received: 27 September 2022; Accepted: 14 October 2022; Published: 13 April 2023

ABSTRACT

Science students of Colleges of Education find it difficult to write structural formulae and give IUPAC names of aliphatic hydrocarbons. This study was, therefore, aimed at finding out the impact of 3-D molecular models on the elucidation of structures of aliphatic hydrocarbons. Purposive sampling was used to select 130 students, 65 each in the control group and the experimental group. A questionnaire and tests were used to collect data. Data collected was analysed using a two-tailed unpaired t-test in inferential statistics. The study revealed that when students are asked to draw structures of aliphatic hydrocarbons, they find it difficult to represent atomic symbols; write chemical formulae; identify all the carbon atoms in linear structures; identify parent chains; number carbon atoms with respect to the functional groups present; and to identify the tetravalent nature of carbon. The mean scores for the control group and the experimental group were 19.28% and 62.15%, respectively, and the test statistics value (-28.63) was less than the critical value (1.99), (*P*=0.000).Therefore, there is a significant difference in students' performance and achievement when lessons are taught by board illustrations and by 3-D molecular models, and the use of the 3-D molecular models had a positive impact on the elucidation of structures of aliphatic hydrocarbons. It is recommended that further research is carried out on the topic using computer-generated structures, especially in schools where the number of computers is suf?cient.

Keywords: Aliphatic, hydrocarbons, tetravalent, molecular models

INTRODUCTION

Molecular models are very useful tools which can be used to demonstrate the structures of aliphatic hydrocarbons as well as the tetravalent nature of carbon. The importance of the research in this area is due to the fact that there is a strong link between the teachers' content knowledge and the pedagogy they use to teach (OECD, Organisation for Economic Co-operation and Development, 2019). Primarily, teachers' knowledge affects the teaching and learning process while the learner's knowledge is influenced by their experiences. It is, therefore, reasonable to relate the learning experiences of the learner to that of the influence of the teacher.According to Wilbraham, Staley, Matta & Waterman (2007),hydrocarbons are compounds containing carbon and hydrogen atoms only whilethe tetravalent nature of carbon is the ability of carbon atoms to form four covalent bonds.Zhou, Martín, Dattila, Xi, López, Pérez-Ramírez & Yeo (2022) further explained that aliphatic compounds are hydrocarbons that contain open carbon chains and include alkanes, alkenes and alkynes.

The performance of students in chemistry is very importantand depends onthe pedagogical content knowledge of teachers as well as the use of appropriate teaching and learning resources (Guerriero, 2017). Many efforts have been made by the Government of Ghana, the Ministry of Education as well as many other stakeholders to address science education issues. However, limited resources in terms of models make the teaching and learning of some topics, like the structures and naming of hydrocarbons, remain a problem(Sarkodie & Adu-Gyamfi, 2015).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VII Issue III March 2023

In spite of all efforts put in place by tutors and administrators, science students of Colleges of Education cannot write structural formulae and give the International Union of Pure and Applied Chemistry (IUPAC) names of aliphatic hydrocarbons. Most of their wrong answers revealed specific misconceptions which need to be corrected. Skelly & Hall (1993) defined a misconception as a mental representation of a concept, which does not conform to scientific theory, principle or the like.

The purpose of this study was to find out the impactof 3-D molecular modelsonthe elucidationof structures of aliphatic hydrocarbons within the science course content of Colleges of Education.

The current study was guided by two research questions: (1) what difficulties do students encounter when asked to draw structures of aliphatic hydrocarbons?; (2) will the use of 3-dimensional molecular models elicit a significant difference in students' performance and achievement in the elucidation of structures of aliphatic hydrocarbons?

Research Hypotheses

Ho: There is no significant difference in students' performance and achievement when lessons are taught by board illustrations and by 3-dimensional molecular models.

H_1: There is a significant difference in students' performance and achievement when lessons are taught by board illustrations and by 3-dimensional molecular models.

This study will strengthen students' understanding ofthe structures of aliphatic hydrocarbons to meet the demands at their level of study. The use of3-D molecularmodelmanipulation is of many design principles that emphasise making abstract scientific phenomena more real (Woodward, 2003). Like the molecular structures of aliphatic hydrocarbons, the use of 3-D molecular models provides opportunities for students to visualise the invisible. Visualisations of spatial structures can enable students to rotate objects being studied and, thus, view them from various directions (Barak & Dori, 2005).

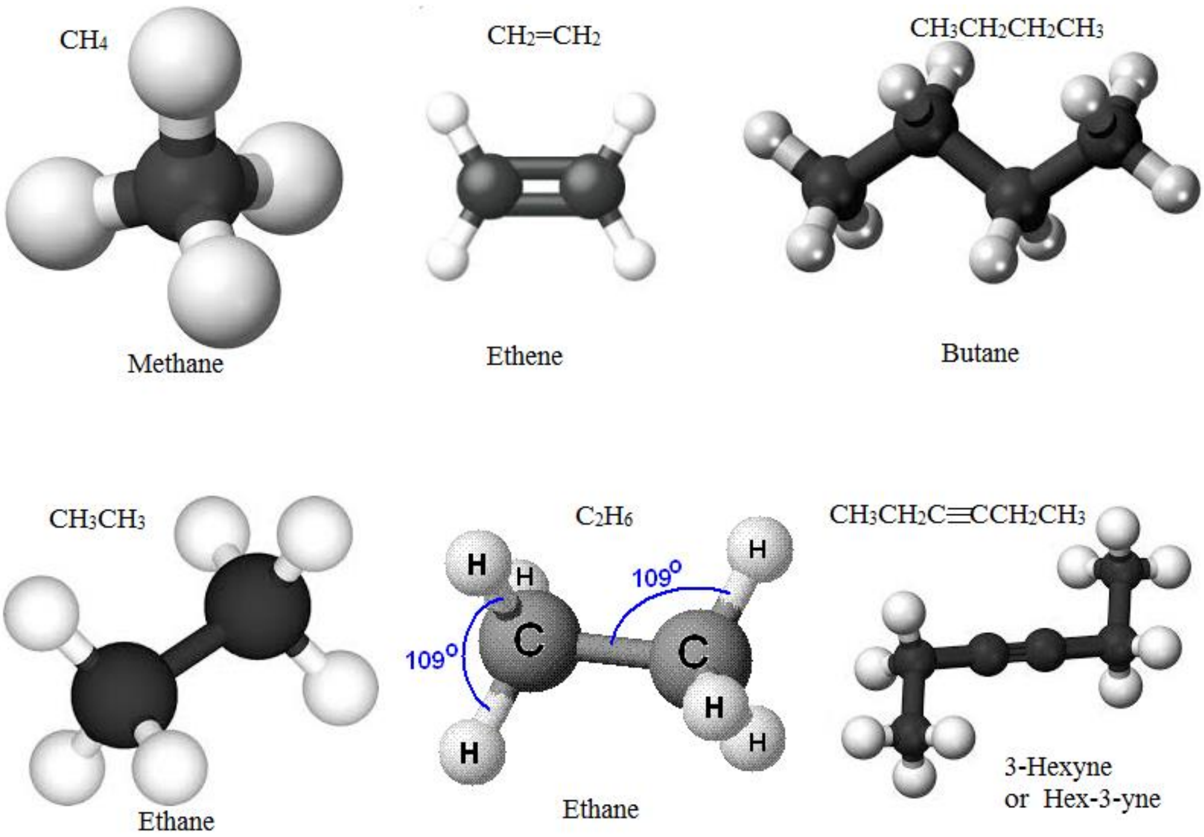


Figure1: 3-dimensional molecular models

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VII Issue III March 2023

THEORETICAL FRAMEWORK OF THE STUDY

The theoretical basis of this research is embedded in the constructivists' theory of learning. Constructivism is an approach to teaching and learning based on the idea that learning is the result of mental construction (Mascolo & Fischer, 2005). Students learn by fitting new information together with their past experiences. Constructivists believe that learning is affected by the context in which an idea is presented as well as by the students' personal beliefs and attitudes.Constructivists' theory deals with learning whichis a process of constructing meaning:it is how people make sense of their experiences (Merriam, Caffarella& Baumgartner, 2007). Some leading developers of the constructivist theory were John Dewey, Lev Vygotsky, and Jean Piaget. Constructivism theory concerns learning basically and not teaching. The emphasis is, therefore, laid on the learning environment and it is learner-centered rather than teacher-centered (Proulx, 2006). The teacher's role is to ask what should be taught and how it could be learned (Proulx, 2006). Henson (2003) cites some of the benefits of learner-centered education put forward by Dewey as including students' increased intellectual curiosity, creativity, drive, and leadership skills.

Models in Sciences

The use of models can be seen in the use of billiard ball model of a gas, the Bohr model of the atom, the Gaussian-chain model of a polymer, the double helix model of deoxyribonucleic acid (DNA), agent-based and evolutionary models in the social sciences, and others (Frigg & Hartmann, 2006). Scientists spend a great deal of time building, testing, comparing and revising models, and much literature is dedicated to introducing, applying and interpreting models as valuable tools in modern science. There are several types of models such as idealised models and analogical models.

Idealised models

An idealisation is an intentional simplification of something complicated with the mind of making it more meaningful (Seifert, 2020). Some well-known examples include frictionless planes, point masses, infinite velocities, isolated systems, and markets in perfect equilibrium. Thoughtful arguments over idealisation have focused on two general kinds of idealisations: The Aristotelian and Galilean idealisations (Reiss, 2003). The Aristotelian idealization puts away, all properties of a concrete object that is believed not relevant to the problem at hand. This allows attention to be paid to a limited set of characteristics of interest.

Analogical models

Standard examples of analogical models in science include the billiard ball model of a gas, the computer model of the mind or the liquid drop model of the nucleus. At the most basic level, two or more things are analogous if they share certain relevant similarities (Hesse, 1963). A simple type of analogy is one that is based on shared properties. The earth and the moon are analogous because of the fact that both are large, solid, opaque, spherical bodies, receiving heat and light from the sun, moving along their axes, and gravitating towards other bodies. It is not always that the sameness of properties is a necessary condition for analogical models. An analogy between two objects can also be based on relevant similarities between their properties. In this more liberal sense, there is an analogy between sound and light because echoes are similar to reflections, loudness to brightness, pitch to colour and detectability by the ear to detectability by the eye.

METHODOLOGY OF THE STUDY

Research Design

The design of this study was an experimental research (Johnson, Christensen & Kagermann, 2008). This design involves the manipulation of factors on intact groups while at the same time controlling any other factors or phenomena that may affect the subjects' behaviour by confounding the results. Among the ideas that are included in a design are the strategy: who and what will be studied, and the tools and procedures to be used for collecting and analysing empirical materials (Punch, Creed & Hyde, 2006).

Population and Sample Selection Procedure

The target population consisted of students of Wiawso College of Education and Lamplighter College of Education, both in the Western North Region of Ghana. In all, 130 students, consisting of 100 males and 30 females, were used in the study. Purposive sampling was employed because the participants are likely to be knowledgeable and informative about the phenomenon being investigated (McMillan & Schumacher, 2001).

Research Instruments

The instruments used for the study werequestionnairesandtests. Thequestionnaire items sought to investigate the difficulties students faced when asked to draw or name aliphatic hydrocarbons while thetest items,which were content validated based on the existing course content, sought to investigate the impact of the use of 3-D molecular models in lessons on students' performance in the drawing or naming of aliphatic hydrocarbons.To validate the instruments, the test and questionnaireitems were given to 6 colleague researchers with considerable knowledge in the concept area to review. Their comments were used to redefine the items before they were administered (Joppe, 2000).Golafshani (2003) noted that the consistency at which answered questionnaires or test items or individual scores could remain relatively the same can be determined through the use of the test-retest method at two different times. A reliability test was conducted by determining Cronbach's alpha. Cronbach alpha was then used to calculate the coefficient of reliability, which was found to be 0.825. This was then compared with the tabulated coefficient of reliability which, according to Bryman &Cramer (2004), is acceptable at 0.8. Thus, the internal consistency (reliability) of the instrument was ascertained.

Data Collection Procedures

The 130 students consisted of two groups, each comprising 65 students made up of 50 males and 15 females. One group (Wiawso College of Education) constituted the experimental group and the other (Lamplighter College of Education) was the control group. In the 1st week, the questionnaire was administered to all the students. The students were briefed on the purpose of the study and guided through the questionnaire items. They were encouraged to provide honest and clear responses. They were then given three days to complete and submit their responses (Charlton& David, 1993). From the 2nd to the 7th week, there was a two-hour lesson per week with the students where the writing of structural formulae and/or the IUPAC naming were integrated into the teaching and learning process. The structures of alkanes**,** alkenes and alkynes were limited to compounds having not more than ten carbon atoms. The control group was taught using board illustrations while 3-D molecular models were used to teach the experimental group. In the 3-D model kits, there were plastic or wooden balls and sticks. The ball representing the carbon atom was black with four bonds and that of the hydrogen atom was white with only one bond. In the 8th week, the test was administered to the two groups concurrently to avoid leakage of questions; and was conducted in line with the laid down regulations of the Institute of Teacher Education and Continuous Professional Development (ITECPD) of the University of Education, Winneba, Ghana. The lesson sequence for the eight weeks is summarised in Table 1.

Table 1: Weekly activities during the study

Week	Activity
1	Questionnaire administration
2-4	Using board illustrations or 3-D molecular models (depending on the group) to assist students to form covalent bonds in aliphatic hydrocarbons. Drawing structures of alkanes, alkenes, and alkynes. Open class discussion of sample students' work.
5-7	IUPAC naming of structures of aliphatic hydrocarbons. Repeated exercises on the IUPAC naming of structures of alkanes, alkenes, and alkynes. Open class discussion of sample students' work.
8	Test administration.

***Adapted from Sarkodie & Adu-Gyamfi (2015)**

Data Analysis

Analysis of data involves the process of editing, cleaning, transforming, and modelling data with the goal of highlighting useful information to make a suggestion, drawconclusions and support decisions. All data were screened to check for errors, missing responses and ensure accuracy. Data was analysed using a two-tailed unpaired t-test in inferential statistics.

Limitations of the Study

According toAnamuah-Mensah, Asabere-Ameyaw & Dennis (2007), a limitation is a condition beyond the control of the researcher that places restrictions on the validity of the study. The results of the research may be influenced by the following:Some of the students were absent from lessons during the treatment stage. They were likely not to understand the concepts taught very well. Other students also kept revising their old notes on the topic hence the study may not be solely responsible for their output in the tests. Also, the study could not detect whether the responses that were given by the students in the questionnaire were true or otherwise. In view of this, the students were encouraged to be as sincere as possible.

RESULTS AND DISCUSSIONS

Research question 1:

What difficulties do students encounter when asked to draw structures of aliphatic hydrocarbons?

Table 2highlightsthe difficulties students encountered when asked to draw structures and give IUPAC names of aliphatic hydrocarbons under 5 subheadings. From the table, 40-46 students (61.34-70.76%) could not write correctly the atomic symbols of hydrogen, chlorine, bromine and carbon in terms of capitalization and lettering (guide in Appendix A). Also, 44 students (67.70%) could not write the chemical formulae of some common compounds. Students' inability to represent atomic symbols and/or write chemical formulae may stem from their lack of grasp of the concept from the basic and/or secondary school levels which may have created some conceptual misconceptions.

According to ?endur (2012), in Turkey, misconceptions about organic chemistry have been found in pre-service teachers, and this factor could negatively influence secondary school students. Omwirhiren & Ubanwa (2016) reiterated that secondary school students' difficulties and misconceptions are most of the time about applying IUPAC rules in naming organic compounds which is at the symbolic level of learning chemical concepts and writing of the structural formulae of hydrocarbons. Sibomana, Karegeya & Sentongo (2021) submitted that the learning of students can be extremely hindered in case their misconceptions about concepts in organic chemistry are not minimized and/or corrected.

Again, from Table 2, 47students (72.30%) could not identify some carbon atoms in some linear structures, 53 students (81.54%) could not select the parent chain or the longest continuous chain in some aliphatic compounds, and 60 students (92.31%) could not number correctly the carbon atoms with respect to the functional group present (guide in Appendix A).The inability of students to identify some carbon atoms in some linear structures, the inability to select parent chains, the lack of or inadequate skills in numbering carbon atoms with respect to the functional group present, and the failure to identify the tetravalent nature of carbon may be as a result ofthe abstract nature of the teaching of such conceptsand/or, largely, the poor teaching method adopted, such as the use of unrelated analogical models.

Ben-Zvi, Eylon & Silberstein (1986) affirm this assertion by revealing that students, most of the time, are pivoted at learning chemical concepts using everyday observations and this impairs their visualization of basic principles in the concepts. Again, according to Kozma, Chin, Russell& Marx (2000), students' difficulty in learning such concepts is partly due to the fact that students cannot directly perceive molecules and their properties. Students usually have confusion and difficulty in learning organic chemistry because the topic has an extensive new vocabulary and requires three-dimensional thinking (Adu-Gyamfi, Ampiah & Appiah, 2017; Wu, Krajcit& Soloway, 2001). According to Bateman, Booth, Sirochman & Richardson (2002), learners have extreme difficulty converting between the two-dimensional drawings used in textbooks and on boards to represent molecules and their three-dimensional structures. Without this understanding, to continue the course, students pretend they understand the three-dimensional structures, and this hinders their understanding of the advanced concepts.

Table 2: Students' difficulties in drawing structures and naming of aliphatic hydrocarbons

	Students' difficulties	Yes		No		Total	
		N	%	N	%	N	%
Atomic symbols							
1	Hydrogen as h instead of H	42	64.61	23	35.39	65	100
2	Chlorine as cl and CL, instead of Cl	40	61.34	25	38.66	65	100
3	Bromine as b instead of Br	45	69.23	20	30.77	65	100
4	Carbon as small c which in many cases was too small to be considered as C	46	70.76	19	29.24	65	100
Chemical formulae							
5	Incorrect writing of chemical formulae	44	67.70	21	32.30	65	100
6	Inability to remember chemical formulae of common compounds	32	49.23	33	50.77	65	100
Skill in numbering							
7	Inability to identify the functional groups like an alkane, alkene, and alkyne present in the given compound and naming each accordingly	33	50.77	32	49.23	65	100

8	Inability to identify some carbon atoms in linear structures	47	72.30	18	27.70	65	100
9	Inappropriate selection of the parent chain or the longest continuous chain	53	81.54	12	18.46	65	100
10	Inability to number carbon atoms, especially with respect to the functional group present in order to identify the substituents present and its locant	60	92.31	5	7.69	65	100
IUPAC naming							
11	Lack of or inadequate knowledge in separating numerals and letters, for example, 1, 2, 3 as in 1 2 3 trichlorobutane.	16	24.61	49	75.39	65	100
12	The use of wrong prefix like meth-, eth-, prop-, but-, likewise methyl-, ethyl and propyl	19	29.23	46	70.77	65	100
Bonds							
13	Inability to identify the tetravalent nature of carbon	44	67.70	21	32.30	65	100

***Yes = difficulty exists; No = no difficulty exists; N = number of students; % = percentage of students**

Research question 2:

Will the use of 3-dimensional molecular models elicit a significant difference in students' performance and achievement in the elucidation of structures of aliphatic hydrocarbons?

Table 3 submits the results of the two-tailed unpaired t-test ran on students' performance in the tests after lessons were taught. The mean score for the control group was 19.28% and that of the experimental group was 62.15%.This implies that there is a difference in students' performance and achievement, and, evidently, students taught using 3D molecular models performed better than those taught with board illustrations.

Also, the test statistics value, -28.63, was less than the critical value, 1.99(P = 0.000). This means the null hypothesis (H_0) is rejected and the alternate hypothesis (H_1) is accepted. Therefore, there is a significant difference in students' performance and achievement when lessons are taught by board illustrations and by 3-dimensional molecular models.

Holme, Luxford & Brandriet (2015) reported that conceptual understanding may occur when a learner creates the practical and scientific pathways in order to obtain the correct answers as in the case of the use of the 3-D molecular models.

Uce & Ceyhan (2019) submitted that a concept can be observed in two ways, in its abstract nature and/or concrete ones. They stressed that real concepts are enhanced by students' experiences, whereas, abstract concepts are considerably challenging for students to perceive. In this study, the 3-D molecular models presented real concepts which appealed to students' appreciation and understanding and, hence, explain the better performance of students in the experimental group than those in the control group where board illustration was abstract in nature.

Again, in a study by Hanson (2014) where micro kits were introduced to students who had misconceptions about organic chemistry in Ghana, it was found to be a tool which enhanced students' understanding and academic achievement. Students who applied them in practical experiences made conceptual improvements as they overcame their challenges in principles that directed the study of organic chemistry (Hanson, 2017). These findings are mirrored by the results of the test in this study.

Table 3: Results of the two-tailed unpaired t-test

	Control group	Experimental group
Means	19.28	62.15
Observations	64	64
Hypothesized Mean Difference	0	
df	63	
t Stat	-28.63	
P(T<=t) two-tail	0.000*	
t Critical two-tail	1.998	

*P=0.0005

CONCLUSIONS

The difficulties students encounter when asked to draw structures of aliphatic hydrocarbons include their inability to represent atomic symbols, write chemical formulae, identify all the carbon atoms in linear structures, identify parent chains, number carbon atoms with respect to the functional groups present, and to identify the tetravalent nature of carbon.

The mean scores for the control group and the experimental group were 19.28% and 62.15%, respectively, and the two-tailed unpaired t-test ran at a significance level of 0.0005 showed that the test statistics value (-28.63) was less than the critical value (1.99) at P=0.000. Therefore, there is a significant difference in students' performance and achievement when lessons are taught by board illustrations and by 3-dimensional molecular models, and the use of the 3-D molecular models had a positive impact on the elucidation of structures of aliphatic hydrocarbons.

REFERENCES

1. Adu-Gyamfi, K., Ampiah, J. G., & Appiah, J. Y. (2017). Students' difficulties in IUPAC naming of organic compounds. *Journal of Science and Mathematics Education, 6*(2), 77-106.
2. Anamuah-Mensah, J., Asabere-Ameyaw, A., & Dennis, S. (2007). Bridging the gap: Linking school and the world of work in Ghana. *Journal of Career and Technical Education, 23*(1), 133-152.
3. Barak, M., & Dori, Y. J. (2005). Enhancing undergraduate students' chemistry understanding through modelling molecules. School Science Review, 77(278), 59- 64
4. Bateman, R. C., Booth, D., Sirochman, R., & Richardson, J. R. (2002). Teaching and assessing three-dimentional molecular literacy in undergraduate biochemistry. *Journal of Chemical Education, 79*(5).
5. Ben-Zvi, R., Eylon, B., & Silberstein, J. (1986). Is an atom of copper malleable? *Journal of Chemical Education, 63*, 64-66.
6. Bryman, A., & Cramer, D. (2004). *Quantitative data analysis with SPSS 12 and 13: A guide for social scientists*. London: Routledge.
7. Charlton, T., & David, K. (1993). *Managing misbehaviour in schools,* (2nd ed.). London: Routledge.
8. Frigg, R., & Hartmann, S. (2006). Models in Science. Retrieved January 25,2022 from the website: http://plato.Stanford.edu/entries/models-science/#RepModIModPhe
9. Golafshani, N. (2003). Understanding reliability and validity in qualitative research. *The Qualitative Report, 8*(4), 597-607.
10. Guerriero, S. (Ed.). (2017). *Pedagogical knowledge and the changing nature of the teaching profession.* Paris: OECD Publishing.

11. Hanson, R. (2014). Using small-scale chemistry equipment for the study of some organic chemistry topics: A case study in an undergraduate class in Ghana. *Journal of Educational Practice, 5*(18).
12. 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).
13. Henson, K. T. (2003). Foundations for learner-centered education: A knowledge base. Education, 124(1), 5-16
14. Hess, R. D. (1963). The latent resources of the child's mind. *Journal of Research in Science Teaching, 1*(1), 20-26.
15. Holme, T. A., Luxford, C. J., & Brandriet, A. (2015). Defining conceptual understanding in general chemistry. *Journal of Chemical Education.* DOI:10.1021/acs.jchemed.5b00218
16. Johnson, M. W., Christensen, C. M., & Kagermann, H. (2008). Reinventing your business model. *Harvard Business Review, 86*(12), 57-68.
17. Joppe, M. (2000). The research processes. Retrieved December 17, 2021 from the website: http://www.ryerson.ca/~mjoppe/rp.htm.
18. Kozma, R., Chin, E., Russell, J., & Marx, N. (2000). The roles of representations and tools in the chemistry laboratory and their implications for chemistry learning. *Journal of the. Learning Sciences, 9*, 105-143.
19. Mascolo, M. F., & Fischer, K. W. (2005). *Constructivist encyclopedia of child development* (pp. 49-63). Cambridge, England: Cambridge University Press.
20. McMillan, J. H., & Schumacher, S. (2001).*Research in education: A conceptual introduction* (5th ed.).New York: Longman.
21. Merriam, S. B., Caffarella, R. S., & Baumgartner, L. M. (2007). Learning in adulthood: A comprehensive guide (3rd ed.). San Francisco, CA: Jossey-Bass.
22. OECD (Organisation for Economic Co-operation and Development) (2019). *The relevance of general pedagogical knowledge for successful teaching: Systematic review and meta-analysis of the international evidence from primary to tertiary education.* OECD Education Working Paper No. 212, JT03456145. Paris: OECD Publishing.
23. Omwirhiren, E. M., & Ubanwa, A. O. (2016). An analysis of misconception in organic chemistry among selected senior secondary school students in Zaria local government area of Kaduna State, Nigeria. *International Journal of Education and Research, 4*(7), 247-266.
24. Proulx, J. (2006). Constructivism: A re-equilibration and clarification of the concepts, and some potential implications for teaching and pedagogy. Radical Pedagogy, 5(1). Retrieved January 25, 2022 from http://radicalpedagogy.icaap.org/content/issue8_l/proulx.html.
25. Punch, R., Creed, P. A., & Hyde, M. B. (2006). Career barriers perceived by hard-of-hearing adolescents: Implications for practice from a mixed-methods study. *Journal of Deaf Studies and Deaf Education*, *11*(2), 224-237.
26. Reiss, J. (2003).Causal inference in the abstract or seven myths about thought experiments, in causality: Metaphysics and Methods Research Project. Technical Report 03/02. LSE.
27. Sarkodie, P. A., & Adu-Gyamfi, K. (2015). Improving students' performance in naming and writing structural formulae of hydrocarbons using the ball-and-stick models. *Bulgarian Journal of Science Education*, *24*(2), 203-219.
28. Seifert, V. A. (2020). The role of idealisations in describing an isolated molecule. *Foundations of Chemistry, 22*(1), 15-29.
29. ?endur, G. (2012). Prospective science teachers' misconceptions in organic chemistry: The role of alkenes. *Journal of Turkish Science Education, 9*(3), 160-185.
30. Sibomana, A., Karegeya, C., & Sentongo, J. (2021). 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. DOI: https://dx.doi.org/10.4314/ajesms.v16i.2.2

31. Skelly, K. M., & Hall, D. (1993).*The development and validation of a categorization of sources of misconceptions in chemistry.* Paper presented at the 3rd international seminar on misconceptions and educational strategies in science and mathematics.Ithaca.
32. Uce, M., & Ceyhan, I. (2019). Misconception in chemistry education and practices to eliminate them: Literature analysis. *Journal of Education and Training Studies*, *7*(3). DOI: 10.11114/jets.v7i3.3990
33. Wilbraham, A. C., Staley, D. D., Matta, M. S., & Waterman, E. L. (2007). *Prentice Hall chemistry*. Boston, Massachusetts: Prentice Hall.
34. Woodward, J. (2003). Making things happen: A theory of causal explanation. New York: Oxford University Press.
35. Wu, H.-K., Krajcit, J. S., & Soloway, E. (2001). Promoting understanding of chemical representations: Students' use of visualization tool in the classroom. *Journal of Research in Science Teaching, 38*(7), 821-842.
36. Zhou, Y., Martín, A. J., Dattila, F., Xi, S., López, N., Pérez-Ramírez, J., & Yeo, B. S. (2022). Long-chain hydrocarbons by CO_2 electroreduction using polarized nickel catalysts. *Nature Catalysis*, *5*(6), 545-554.

APPENDICES

APPENDIX A: Sample Questionnaire Items

1. Write the atomic symbols of the following elements:

- Hydrogen ………………………………………
- Carbon ………………………………………
- Chlorine ………………………………………
- Fluorine ………………………………………
- Iodine ………………………………………
- Nitrogen ………………………………………
- Sulfur ………………………………………
- Bromine ………………………………………

1. Did you face any difficulties identifying some of the atomic symbols?

[ ] Yes [ ] No

1. If Yes, what were some of the difficulties? (You may tick more than 1, if necessary)

[ ] Symbols

[ ] Capitalization

[ ] Lettering

[ ] Do not remember

[ ] Any other, ………………………………………………………………………..……

1. Which element(s) were more difficult to write their symbols?…………………………………

Why?……………………………………………………………………………………………………..

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VII Issue III March 2023

2. Identify the chemical formulae of the following common compounds:

- Water ………………………………………
- Methane ………………………………………
- Ethane ………………………………………
- Chloroform ………………………………………
- Ammonia ………………………………………
- Carbon monoxide ………………………………………
- Carbon dioxide ………………………………………

1. Did you face any difficulties identifying some of the chemical formulae?

[ ] Yes [ ] No

1. If Yes, what were some of the difficulties? (You may tick more than 1, if necessary)

[ ] Symbols

[ ] Capitalization

[ ] Lettering

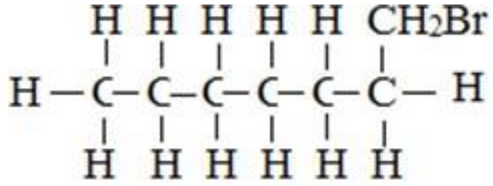
[ ] Do not remember

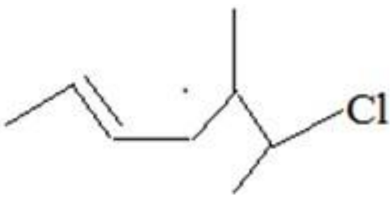
[ ] Any other, …………………………………………………………………………..

1. Which compound(s) were more difficult to write their formulae?…………………………….

Why?……..

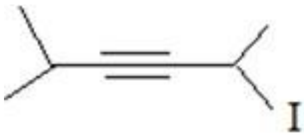
3. Count the number of carbonatoms in the parent chain of each of the following structures and state the IUPAC name for each.





≠Carbon: ……… ………

IUPAC Name: …………………………………. ………………………………….



$CH_3C(CH_3)_2C_2H_5$

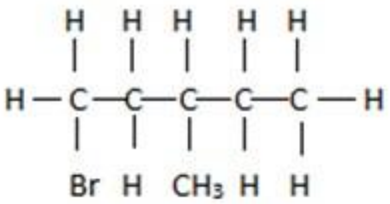
≠Carbon: ……… ………

IUPAC Name: …………………………………. ………………………………….

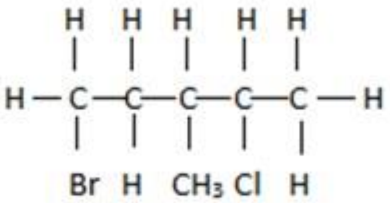
APPENDIX B: Sample Test Items

1. What is the structural formula for 1-bromo-4-chloro-3-methylpentane?
2.

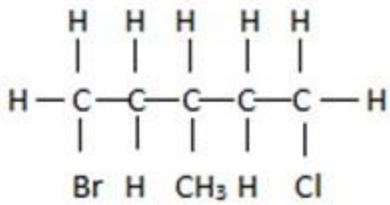
A.



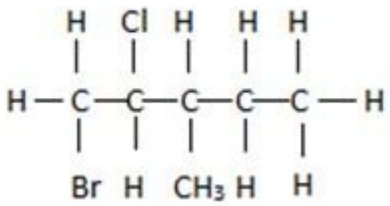
B.



C.



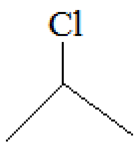
D.



The IUPAC name for the hydrocarbon $(CH_3)_2C{=}CHCH_3$is:

a. 2-methyl-2-ene
b. 2-methylbut-2-ene
c. 2-methylpent-1-ene
d. 2-methylpent-2-ene

Identify the structure shown below:



ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VII Issue III March 2023

a. 2-chloropropene
b. 1-bromo-4-chlorobut-2-yne
c. 2,3-dimethylpent-2-ene
d. 2-bromo-3-methylpentane

Draw the structural formulae of the compounds below:

a. 3-methylbut-1-ene
b. 2, 2-dichlorohexane
c. 1-bromo-propyne
d. 3-fluoro-2-methylpentane

What is the IUPAC name for the hydrocarbon $(CH_3)_3CCHICH_2CH_3$

a. 3-iodo-2-methylhexane
b. 3-iodoheptane
c. 3-iodo-2,2-dimethylpent-1-ene
d. 3-iodo-2,2-dimethylpentane