UNIVERSITY OF EDUCATION, WINNEBA

ENHANCING CHEMISTRY STUDENTS' ABILITY TO CLASSIFY AND NAME ALIPHATIC ORGANIC COMPOUNDS USING MOLECULAR MODELS.

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SEPTEMBER, 2017

DECLARATION

STUDENT'S DECLARATION

I, Isabella Agbesi, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my original work and that it has not been submitted, either in part or whole, for another degree elsewhere.

……………………………… ………………………………

SIGNATURE **DATE**

SUPERVISOR'S DECLARATION

I hereby declare that the preparation of this thesis was supervised in accordance with the guidelines on supervision of thesis as laid down by the University of Education, Winneba.

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PROFESSOR JOHN K EMINAH **DATE**

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DEDICATION

This work is dedicated to my husband Mr. Evaristus Tepprey, my daughter Lorrinda Enam Tepprey and the Agbesi and Hini families, especially my late father Thomas Tonny Agbesi.

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ABSTRACT

This study was designed to enhance EPC Mawuko Girls" SHS 2 Home Economics students" understanding of the classification, naming and writing of the structures of aliphatic organic compounds using molecular models. It was also intended to find out the students" views on the use of molecular models in teaching the structural formulae and naming of aliphatic organic compounds. The study was a case study design using the action research approach. The sample for the study was forty-five (45) second year chemistry students in an intact class using purposive sampling technique. Achievement tests (pre-intervention and post-intervention tests), informal interview and questionnaire were used as data collecting instruments and the intervention tool used were the molecular model kits. The instruments were pilot –tested to establish the reliability coefficient and were validated by the research supervisor in the Department of Science Education, University of Education, Winneba as well as two other experienced chemistry teachers in EPC Mawuko Girls" SHS, Ho. The scores obtained from the achievement tests were analysed using Excel spread sheet and Statistical Package for Social Science (SPSS) version 20 to find out the level of achievement of students after the intervention. Overall findings of the study showed among others that the students had difficulties in classifying, naming and writing of the structural formulae of aliphatic organic compounds. There was significant improvement in the performance of students after the intervention as they performed better in the post-intervention test than the pre-intervention test; the students had an overall positive perception concerning the use of molecular models as an instructional material in the learning of classification, naming and writing of the structural formulae of aliphatic organic compounds. It was recommended among others that interested researchers could conduct research into the relative effectiveness of molecular model kits in the naming of inorganic compounds at the SHS level.

CHAPTER ONE

INTRODUCTION

Overview

This chapter was devoted to the background to the study, statement of the problem, purpose of the study, objectives of the study, research questions and significance of the study. Also found in the chapter was limitations of the study, delimitations of the study and organisation of the study.

Background to the Study

All life on earth is composed of carbon compounds; so is the fuel we burn, our food and the clothes we wear. Therefore to understand the major part of the everyday world we need to be familiar with the chemistry of these compounds. Compounds of carbon and hydrogen provide electricity, heat our homes and serve as the foundation of the petrochemical industry (Atkins & Jones, 2000).

Organic chemistry is the study of the enormously varied range of carbon compounds. It cuts across all levels of Ghanaian educational systems such as basic, pre-tertiary and tertiary. Some graduate students study organic chemistry as an area of specialisation. In 1892, the International Union of Pure and Applied Chemistry (IUPAC) came out with the formal system of naming organic compounds and hence the name, IUPAC nomenclature (Gillette, 2004; Heger, 2003; Solomons & Fryhle, 2008). The IUPAC system of naming organic compounds depends on the functional groups, which is grouping compounds by common structural features (Gillette, 2004).

According to Clark (2000), cited in Worsor (2015), a chemistry student can develop two skills in using the IUPAC nomenclature system to name organic compounds. These involve the ability to draw or write the structural formula of an organic compound from its IUPAC name, and write the IUPAC name of an organic compound from its structural formula (p. 1).

The IUPAC nomenclature is an aspect in chemistry where many students, as well as some teachers find very difficult to understand. Analysis of West African Examinations Council (WAEC) Chemistry Chief Examiner‟s Report from 2005-2015 in Ghana lamented on the weakness of most students in expressing the IUPAC nomenclature of organic compounds. In 2014, most candidates were unable to name C_6H_5Cl as chlorobenzene. In 2005 and 2010, the report pointed out that candidates were not able to write correctly the IUPAC names of the structural formulae of some organic compounds they themselves had written from certain molecular formulae. For example, in 2005, candidates were not able write the correct IUPAC names of $HCOOCH_3$, $CH_3CHOHCH_2OH$ and C_6H_5COOH as methyl methanoate, propan-1, 2-diol and phenylmethanoic acid respectively.

These reports suggested that Ghanaian Senior High School (SHS) chemistry students faced challenges with the IUPAC naming of organic compounds. Hence there is no meaningful learning.

Meaningful learning requires active involvement of students. In other words, while a teacher is the facilitator of the teaching and learning process, without the active participation of students meaningful learning cannot take place (Hinckley, 1991). Basically, a teacher‟s knowledge of content, method used and the teachers experience influence what the students learn and knowledge they acquire (Caldderhead, 1996, Clark & Peterson, 1986). Therefore it takes the innovation of an experienced teacher to search for or improvise materials and adopt pedagogies that will help students to grasp scientific concepts.

In view of this, various interventions have been designed by government, teacher organisations and other stakeholders aimed at improving and upgrading science teachers‟ knowledge and skills in order to address the issue of poor quality science teaching. The Ghana Association of Science Teachers (GAST) in particular focused on promoting teaching and learning of science at the pre-tertiary level through the organization of workshops, updating science content in the curriculum, and also developing teaching and learning resources as well as writing of text books.

In spite of these country-wide interventions, Adu-Gyamfi (2011) found that, SHS students in the Kumasi metropolis in Ashanti Region of Ghana showed weaknesses in using the IUPAC system of nomenclature to name and write the structural formulae of alkanes, alkenes, alkynes, alkanols, alkanoic acids, and alkyl alkanoates.

A good understanding of chemistry requires the ability to operate properly between four levels of understanding, namely the macroscopic, microscopic, symbolic and process levels (Barak & Dori, 2005; Dori & Hameiri, 2003). According to Chandrasegaran, Treagust and Mocerino, (2008), students‟ ability to use macroscopic, microscopic and symbolic representations are essential to understanding chemistry concepts and phenomena. Chemistry students are required to think at the microscopic level and explain changes at the macroscopic level in terms of interactions between individual atoms and molecules (Dori, Barak, & Adir, 2003).

Studies have shown that many students found it difficult to properly connect the different levels of understanding (Chandrasegaran *et al*, 2008; Dori & Barak, 2001; Gabel, 1998). Kaberman and Dori (2008) asserted that most students did not understand the macroscopic and microscopic representations of molecules, as well as the meaning of the symbols and formulae used in chemical equations in their study.

These difficulties coupled with challenges in understanding the spatial orientation of atoms in structures of molecules, obstructed students" ability to solve problems in chemistry (Dori *et al*, 2003; Gabel 1998).These difficulties are true of students in some Ghanaian Senior High School (WAEC, 2005-2014 including EPC Mawuko Girls" SHS where the researcher teaches.

In contemporary science, models play an important role in bridging the gap between abstract and reality and help in explaining the understanding of theories, (Morrison, 1999 2000, 20009); Black, 1962). Research has shown that technologies can provide tools that enable students to rotate objects, manipulate representations of spatial structures, and construct molecular models (Barak, 2007; Barak & Dori, 2005; His, Linn, & Bell, 1997). Bark and Wirbs (2002) admitted that the usefulness of molecular model kits as a help tool in science education could be explained by the assumption that visualization of structural models plays an important role by supporting students, when connecting the different levels of science concept representation. Gilbert, (2005) found that visual aids may help students relate the macroscopic, microscopic and symbolic representation levels of chemical entities to each other. Visual aids could also enhance students" conceptual understanding and spatial ability (Barak &Dori, 2011; Williamson & Abraham, 1995). It can also facilitate the processing of complex data, make the scientific process more dynamic, and provide ways for studying interesting and complex phenomena. For this reason, this study was designed to use molecular models to enhance selected EPC Mawuko Girls" SHS chemistry students" of the structure and names of aliphatic organic compounds.

Statement of the Problem

The IUPAC nomenclature of carbon compounds are studied at the SHS 2 level under section 6 of the chemistry teaching syllabus. It covers such areas as alkanes, alkenes, alkanols, alkanoic acids, and alkanoic Acids derivatives (for example, amides and alkanoates).

Over the years, the chemistry reports of the West African Examination Council Chief Examiners have consistently alluded to students‟ inability to name and write correct structures of organic compounds. Second year Home Economics students of EPC Mawuko Girls‟ SHS, Ho are of no exception because analysis of WASSCE chemistry results in the School indicated that most of the failures were Home Economics students. The inability of the SHS science students to understand the IUPAC system of nomenclature of organic compounds has become a matter of concern to many chemistry teachers in the School.

Having observed this problem, the researcher utilized molecular model kits to address the challenges faced by the second year Home Economics students of EPC Mawuko Girls‟ SHS, Ho in naming and writing the structures of aliphatic organic compounds.

Purpose of the Study

The main purpose of the study was to enhance EPC Mawuko SHS 2 Home Economics students‟ ability to classify, name and write the structures of aliphatic organic compounds using molecular model kits. It was also intended to find out the students‟ views on the use of molecular model kits in teaching the structural formulae and naming of aliphatic organic compounds.

Objectives of the Study

The objectives of the study were to:

1. Determine the difficulties the second year Home Economics students of EPC Mawuko Girls‟ SHS encountered when naming and writing the structures of aliphatic organic compounds;
2. Teach the students the classes, names and the structures of selected aliphatic organic compounds using molecular models;
3. Determine, if any significant difference exist between the mean pre-intervention test score of the students and their mean post-intervention test score; and
4. Find out the students‟ views on the use of molecular model kits in teaching the structural formulae and names of aliphatic organic compounds.

Research Questions

The following research questions were addressed in the study:

1. What difficulties do the second year Home Economic students of EPC Mawuko Girls‟ SHS encounter when classifying, naming and writing the structures of aliphatic organic compounds?
2. What will be the effect of molecular models on the students‟ ability to classify aliphatic organic compounds based on their functional groups?
3. What will be the effect of molecular models on the students‟ ability to write the structures of aliphatic organic compounds?
4. What will be the effect of molecular models on the students‟ ability to name the structures of aliphatic organic compounds?

5. Is there any significant difference between the mean pre-intervention test score of the students and their mean post-intervention test score?
6. What views do the students hold on the use of molecular model kits as instructional materials?

Significance of the Study

The outcome of this research would particularly help the SHS 2 Home Economics students to appreciate and develop better understanding of the concepts involved in the process of classification, naming and writing of the structural formulae of aliphatic organic compounds. This would make them change their misconception of organic chemistry as being an abstract and difficult discipline.

The findings of the research would equally provide Educational authorities, Heads of science department and chemistry teachers with credible information on the use of models and their implication for teaching and learning of chemistry.

The study would further serve as an eye-opener for chemistry teachers to integrate models in the teaching and learning of chemistry, as well as design and use other teaching resources to enhance students‟ understanding of the structural formulas and naming of organic compound.

Delimitations of the Study

The study was restricted mainly to SHS 2 Home Economics students because in addition to time and financial constraints, analysis of WASSCE chemistry results in the school indicated that most of the failures were Home Economics students. Additionally, the study could not cover such areas of organic chemistry as amines, amides, phenols, ketones, aldehydes, etc. but involved alkanes, alkenes, alkynes, alkanols, alkanoic acids and alkanoates up to ten (10) carbon atoms.

Limitations of the Study

Some extraneous variables beyond the control of the researcher might have affected the results of the study such as truancy on the part of students during the intervention stage and these could equally affect their understanding of the concepts taught.

Another limitation of the study was the failure of the respondents to answer all questions and since a test was used as the main instrument, any form of irregularities that have not been identified might have affected the authenticity of the research outcomes.

Organisation of the Study

Aside this introduction chapter, there were four other additional chapters which were organised logically to give more insights into the issues raised in this chapter. This assisted in answering the research questions. However, each chapter started with a brief overview. Chapter two looked at the review of related literature under the following: theoretical frame work (constructivism and its implication for science teaching and learning), concept of teaching and learning of Science, importance of equipment and materials in science teaching and learning, factors that affect student‟s performance in organic chemistry, perceived difficulties of chemistry students, challenges associated with use of models in science teaching and learning, significance of molecular models in teaching and learning organic chemistry, description of molecular models sets, representation of organic compounds, some organic compounds and their functional groups and IUPAC nomenclature of aliphatic organic compounds (alkanes, alkenes, alkynes, alkanol, alkanoic acids and alkanoates.

The chapter two ended-up with some empirical review based on the study and summary of the chapter.

Chapter three addressed the research methodology. It provided information on research design that was adopted for the study, the study area, the population, sample and sampling technique and the instrument that was used for data collection. The validity and reliability of instrument, interventions, procedures for the data collection and the method of analysis of data was also explained in this chapter.

Chapter four dealt with the findings from the study. The presentation and discussion of the research findings from the study were done with respect to the research questions.

Chapter Five, the last chapter described the summary of the research findings and their interpretations with respect to the literature. It described conclusions relating to the findings from the study. The chapter finally looked at recommendations and suggestions for future study

CHAPTER TWO

LITERATURE REVIEW

Overview

This chapter covered the review of the literature related to the study. The entire review focused on the following topics:

- Theoretical framework (constructivism and its implication for science teaching and learning)
- The concept of teaching and learning of science
- Importance of teaching and learning materials in science teaching and learning
- Factors that affect student"s performance in organic chemistry
- Perceived difficulties of chemistry students
- Significance of molecular models in teaching and learning organic chemistry
- Description of molecular models sets
- Challenges associated with the use of models in science teaching and learning,
- Representation of organic compounds
- Some organic compounds and their functional groups
- IUPAC nomenclature of aliphatic organic compounds
- Guidelines for naming alkanes
- Guidelines for naming alkenes
- Guidelines for naming alkynes
- Guidelines for naming alkanol
- Guidelines for naming alkanoic acids
- Guidelines for naming alkanoates
- Empirical review

- Summary of the chapter

Theoretical Framework

Over a period of years, several theories have been developed to explain the teaching and learning process. One such theory that has been adopted to support this research is that of constructivists design. This theoretical framework holds that learning always builds upon knowledge that a student already knows; this prior knowledge is called a schema. Because all learning is filtered through pre-existing schemata, constructivists suggest that learning is more effective when a student is actively engaged in the learning process rather than attempting to receive knowledge passively. Swan (2005) grouped constructivists into three areas of focus- though they all shared common assumptions about the nature of learning and construction of knowledge. These are student‟s knowledge construction in the social environment (social constructivist), mental world (cognitive constructivists), and physical (constructionism).

The Social constructivist theory: Social constructivism is accredited to **Lev Vygotsky.** According to Vygotsky (1978), social learning precedes development. He intimated that every function in the child‟s cultural development appears twice: starting from the social level and later, on the individual level.

According to Vygotsky (1978), students' problem solving skills fall into three categories:

1. skills which the student cannot perform
2. skills which the student may be able to perform
3. skills that the student can perform with help

Vygotsky (1978) pointed out that children were able to perform very well at higher intellectual levels when asked to work in collaborative situations than when asked to work individually. He stated that less skillful individuals were better able to develop a more complex level of understanding and skills through collaboration, when guided by an expert or a more capable peer than they could do independently. He called this „scaffolding‟. Scaffolding therefore allows students to perform tasks that would normally be slightly beyond their ability without that assistance and guidance from the teacher.

Social interaction extends a child‟s zone of proximal development (ZPD), which is the distance between the actual development level as determined by the independent problem solving and the level of potential development as determined through solving under adult guidance or in collaboration with more capable peers. Knowledge construction actually occurs in this zone (Swan, 2005). Vygotsky‟s views concerning the zone of proximal development (ZPD) provide a strong support for the inclusion of cooperative learning strategies in classroom instruction. Kagan (1989) has pointed out that every cooperative learning strategy, when used appropriately, enables learners to move beyond the text memorization of basic facts and learning lower level skills.

According to Woolfolk (2007), Vygotsky assumed that knowledge construction is fostered using cultural tools (such as rulers, pipette, and computers) and psychological tools (such as works of art, signs, symbols, codes, and language). Vygotsky paid much attention to the role of language in thinking and learning. He asserted that language and thought could be closely related (Swan, 2005). Thus all higher order mental processes such as reasoning and problem solving are achieved by psychological tools. One might say that language is a necessity in the construction of knowledge as it is used in expressing ideas and asking questions, and then shows the links between the past and the future.

The Cognitive Constructivist Theory: Jean Piaget's work led to the cognitive constructivist theory. Piaget believed that cognitive development occurred through a sequence of successive qualitative changes in cognitive structures. Piaget called the mental structures schema (Swan, 2005).

Piaget (1983) revealed that children developed knowledge through active participation in their learning and built their own knowledge through experience. Learning occurred not by passive reception of transmitted information, but by active interaction with objects and ideas through an adaptation involving assimilation, accommodation and equilibration. To Piaget (1983), when children assimilate, they perceive new objects and events according to their existing schema and accommodation is a process by which they reprogramme or modify their existing schemata or mental representation of the external world to fit their new experiences for learning to occur. Equilibration maintains the balance between, always taking in new knowledge and always assimilating knowledge with previously gained knowledge. Knowledge is therefore, not a mirror of the world but is created or "constructed" from the individual‟s constant revision and reorganization of cognitive structures in conjunction with experiences (Piaget, 1983). Thus in the view of Piaget, learners are actively involved in the construction of their own knowledge.

Piaget (1983) asserted that knowledge construction is influenced by students‟ genetic make-up and this changes as the students mature hence, different students construct knowledge differently at different stages of development.

The Constructionist Theory: Seymour Papert being a major spokesperson of constructionism, asserted that constructivist learning happens especially well when people are engaged in constructing a product, something external to them like a sand castle machine, book or computer programme. Papert looked at the construction of public knowledge in disciplines like chemistry which opposed the individual student knowledge construction as in the case of constructivists. To constructionists computers are effective tools to bridge the gap between abstract ideas and reality. According to Swan (2005), computer-based constructions are potential aids to students in assimilating and accommodating new knowledge.

Implications of Constructivism for Teaching and Learning of Science

Teaching using the constructivists approach stressed on active involvement of students in constructing their own knowledge based on experience unique to each individual. The traditional teaching method used in science classrooms allowed for memorization of knowledge normally in the form of formulae, laws or theories which are reproduced during examinations. This objective type of teaching and learning reduce the development of skills such as problem solving and reflective thinking. Constructivists" classrooms provide students with opportunity to observe, work, explore, interact, make enquiry and share their expectation with friends (Kumar & Gupta, 2009). It is necessary for science teachers to shift from the traditional method which only transfer knowledge from teachers" heads to the heads of students. Science teachers should therefore be seen as facilitators of knowledge construction and to ensure a well democratic environment. This provides opportunities for students to discuss and share their ideas freely with each other, probing, experimenting and other problem solving activities. Teaching and learning materials have to be used for instruction and group work emphasises by teachers to achieve collaborative learning as suggested by Dogra (2010). He pointed out that, group discussion and brain storming play a vital role in the constructivist classroom. According to him different activities like concept mapping, T-chart can be used to design constructivist classrooms for biology learning.

The Concept of Teaching and Learning of Science

What is teaching?

According to Asokhia (2009) science teaching is the communication of scientific knowledge and skills. For any communication to be effective, three main features must exist: the teacher (information giver), the message (information that is to be passed) and the learner (information receiver). He believed that the use of graphics, (that is, pictures, symbols, realia and illustration) and drawing are means through which this can be achieved. For effective communication the message must be decoded correctly, to avoid distortion. Asokhia agreed with Gardner‟s (2010) assertion which pointed out that a picture was worth a thousand words. This suggested that molecular models as teaching and learning materials can make learning of chemistry interesting and enhance the quality of understanding.

Smith (2007) assumed that teaching was a process of carrying out activities that provide students with experiences that can include learning. It could thus be said that teaching takes place when a teacher organises a series of activities or experiences with the intention of making students to learn new knowledge, and acquire skills and competence in science.

Teaching could also mean that which takes place between two sets of people whereby scientific knowledge are taught or shared. It normally involves teachers helping students to acquire some experience and scientific knowledge through pre-planned activities. This implies that teaching is a process whereby certain conditions are arranged for the student consciously to develop their knowledge and gain experience, based on the lesson objectives.

Tamakloe, Amedahe and Atta (2005) explained teaching as an activity in which a teacher imparts knowledge, skills, attitudes and values to students. The teacher"s role is to guide, counsel and motivate the process. They believed that teaching is not merely lesson delivering or merely dispensing of subject matter but what is needed to make the art complete is the involvement of students fully in the teaching process.

Lowman (1995) believed that not all teaching results in learning. To him, a teacher could anticipate that certain activities would made students to learn the use of the venniercalipers for taking measurements, but could not guarantee that learning actually occurred if, despite the instructional experiences, the learners are not able to perform related tasks effectively. Thus to achieve the goal of teaching both the teacher and the student must agree with each other and participate in the learning process. Mckeachie, (1994) asserted that all teaching techniques could stimulate learning if used appropriately, but emphasised that the student-centred style could lead to better retention, problem solving, application of knowledge, and motivation of learning. Since the success of any teaching and learning depends on a student"s readiness or how well the student is prepared to learn, it implies that students must be motivated to participate in science lesson in order to understand the subject matter through the use of instructional materials like molecular models and apply the student-centred style that provides conducive environment for faster and effective teaching and learning.

What is Learning?

Learning is one of those terms that, regardless of its common usage in everyday life, cannot be easily defined. The majority of authors defined learning as changes in behaviour due to experience. This refers to a change in behaviour, an external change that we can observe, or a relatively permanent change in mental structures due to experience.

Learning according to Santrock (2004) is a relatively permanent influence on behaviour, knowledge and thinking skills which comes by experience. Although not everything we know is learned, he believed that humans possess intuitive capabilities for doing certain things; for instance, humans do not learn to cry, drink or eat as these actions are in-built knowledge that all persons are born with. Learning only increases one"s innate knowledge. Smith and Blake (2005), asserted that learning upsurges knowledge to increase one"s capabilities for effectual action. Learning therefore is an experience gained through modification and as Kundu and Tutoo (2004), indicated learning is considered an active process and not a passive observation. This implies giving students opportunity to acquire direct learning experiences through the manipulation of concrete objects.

Watkin (2012) also pointed out the many different approaches to learning that were evident in the literature and yet none of them was independently able to explain all modes of learning. This was because learning is a reflective activity which enabled the learner to draw upon previous experience to understand and evaluate the present, so as to shape future action and formulate new knowledge.

He highlighted the following key points as the agents of learning:

1. An active process in which the learner relates new experience to existing meaning, and may accommodate and assimilate new ideas;
2. Past, present and future are connected, although a linear connection is not assumed: un-learning and re-learning may be implied; and
3. The process is influenced by the use to which learning is to be put: how the learning informs action in future situations is vital.

Learning is not an automatic process. There are a number of factors that could inhibit the process. Abucay (2009) asserted that a student"s difficulty in learning might be due to different factors including the following: intellectual factors (special intellectual disabilities), learning factors (lack of mastery of what has been taught, limited background of a certain topic or issue and faulty methods of work and study), physical factors (health, visual and physical defects, nutrition and physical development), emotional and social factors (kind of pupil-teacher relationships in the classroom, the social interaction of relationships among pupils, the relationships among members of the school staff, the physical characteristic of a classroom, social readiness, cooperation versus competition and pupils" attitudes towards teachers), mental factors (attitude), environmental factors (classrooms, textbooks, equipment, school supplied and other instructional materials) and teacher"s personality. The teacher"s goal therefore was not only to present only those information learners need but also to facilitate experiences that would help them gain and master the knowledge and skills that they need to know and practice with the help of concrete instructional materials

The Importance of Equipment and Materials in Science Teaching and Learning

Majority of educationists believe that science cannot be learnt in vacuum. For example, Anamuah-Mensah (1995) noted that, the absence of requisite equipment and materials might lead to stunted growth in science education and this might make teachers and students to face great frustrations in the teaching and learning process in the classroom.

Equipment and materials open the students to realism of concepts and aid them to conceptualise and internalise scientific principles. Aina (2013) believed that one major reason for poor performance among students or learners might not be separated from the abstract nature of the courses taught them. Aina was of the view that the absence of teaching and learning materials such as real objects, or pictures made it difficult for learners to understand communicated information. This was because young learners usually lack the ability to assimilate concept abstractly making it imperative to adopt the use of interactive materials

According to Salifu (2006) learning science without the use of equipment and materials could be equated to attempting to drive a car without tyres. This meant that equipment and materials made learning more effective and also facilitated it.

Ayoti and Poipoi (2013) noted that teaching and learning materials attracted the attention of students in what was being taught and thus made it easier for them to understand what they were taught. Teaching and learning materials such as pictures, models, specimens of flowers and the likes attracted the interest of pupils. Also when pupils saw, touched and heard what they were learning about, they paid attention to what was being taught and understood it better. On the whole, the effective use of instructional materials facilitated easy understanding of abstract concepts and promoted effective communication and interaction between the teachers and the students. It also saved time, excited the perceptual thinking of students and made them completely involved in the teaching-learning situation.

Factors that Affect Students Performance in Organic Chemistry

A careful look at Ayikoe"s (2012) research work revealed that the performance of students depended on several factors including school environment, the use of the lecture method, absence of teaching and learning materials and the students" weak chemistry background. This gave an indication that the types of teaching method and instructional materials have some influence on students" performance on classification, writing and naming of organic compounds.

One of the major factors that influenced teaching and learning of concepts in chemistry was the pedagogical content knowledge of the teacher. Geddis (1993) described pedagogical content knowledge as a set of special attributes that helped in the transfer of knowledge to others. It dealt with the most useful forms of representation of ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations which were the ways of presenting and formulating a subject/topic that made it comprehensible to others (Shulman, 1987). Shulman (1987) also suggested that pedagogical content knowledge was the best knowledge base for teaching. The key to distinguishing the knowledge base of teaching laid at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possessed into forms that are pedagogically powerful and yet adaptive to the variations in ability and background that students had. Ausubel (1968) supported this when he asserted that the most important single factor influencing meaningful learning was indeed, what the learner already knows, and as such should be ascertained so as to teach him/her accordingly.

Attitudes of students are very crucial in teaching and learning of concepts in chemistry. Keeves and Morgenstern (1992) noted that attitude of a student affects performance and attitude and achievement were related and that a positive attitude towards science lesson resulted in a good achievement (Anderson, 2006). Most SHS Home Economics students offering chemistry develop some negative attitude towards organic chemistry. This negative attitude manifests in the form of lack of interest, satisfaction and motivation (Gardner &Gauld, 1990).

According to Nisbet and Shucksmith (1986), truancy, lack of motivation, time available for teaching and learning, learning strategies students employed and self-efficacy were notable factors affecting students‟ performance. However, past experiences of the learners and availability of materials (Murphy, 1990), teachers‟ emotional disposition (Tatar, 2005), self-regulations and school climate (Shunk, 2005) and presentation of concepts and topics in an abstract manner (Ornstein, 2006) were also among other factors that affected student performance. However, the researcher in this study was of the view that the use of molecular model kit would limit the effect of these factors and help the second year Home Economics B students of Mawuko Girls SHS overcome the challenges of understanding the structures and names of aliphatic organic compounds.

Perceived Difficulties of Chemistry Students

According to Johnstone (1991), although most chemists thought of chemical reaction using macroscopic, microscopic and the symbolic representations, most chemistry instructions in high schools occur only at the symbolic level and this could be difficult to most students. This was because the microscopic and the symbolic representation of Chemistry were invisible and abstract in nature, and the learning of Chemistry for easy comprehension also depended much more on the use of our senses. Thus, most Chemistry students perceived equations or formulae of chemical substances such as CH_3COOH or CH_4 as a combination of letters and numbers rather than chemical formulae (Wu et al., 2001) cited in Adu-Gyamfi (2011).

The findings of Adu-Gyamfi (2011) revealed that students had difficulty in naming chemical formulae of organic compounds from the IUPAC names as only 25.7% of students scored more than half of the total marks. He attributed this challenge to their inability to:

- identify the correct number of carbon atoms in the parent chain; identify some of the atoms or groups in the structural formula of a compound as substituent groups
- assign the substituent groups to the correct positions in the structure of a compound
- arrange the names of the substituent groups in alphabetical order; identify and use the correct position of a multiple bond; state the correct suffix for a particular multiple bond
- use the correct prefix for two or more identical substituents; identify a functional group in a structural formula of a compound
- assign correct position to a carbon atom to which a functional group was bonded

- state the right suffix for an identified functional group and state the position of a functional group (such as –OH) in the IUPAC name differentiate between a substituent group (such as Br) and functional group (such as –COOH) in a molecule.

Adu-Gyamfi (2011) again noted in his study that Students" performance on writing structural formulae of organic compounds from IUPAC names was very low because only 21.6% of students scored above the half marks. To him, chemistry students" difficulties in writing structural formulae of organic compounds from IUPAC names were due to their inability to: differentiate between condensed; graphical, and molecular formulae of an organic compound and use the correct chemical symbol or a formula for a particular substituent among others

In addition, a study conducted in Ghana attested to students" difficulty in writing chemical formulae of inorganic compounds from the IUPAC names (Baah, 2009). He noted that the difficulty was partly due to the student"s lack of understanding in the Roman numerals that are put in the brackets in the form of „IV" and „V" in Carbon (IV), and tetraoxosulphate (V) respectively.

The structure of chemical substances and chemical bonding is a central concept in chemistry and its understanding is critical to the learning of nearly every topic in chemistry. The topic has been shown to be difficult to both students and teachers. Salta and Tzougraki (2003) reported that both teachers and students including other chemists regarded structure of chemical substances and chemical bonding as complicated concept. However, Peterson and Treagust (1989) and Taber (2001) have found out that students often lack deep conceptual understanding of key concepts connected with structure of chemical substances and chemical bonding.

Significance of Molecular Model Kits in Teaching and Learning Organic Chemistry

In the teaching and learning of many scientific concepts, models play very significant roles. Models are visual aids or pictures that help scientists in highlighting the main ideas and variables in an abstract process or a system. According to Gage and Berliner (1992) the two primary benefits of using models as learning aides were to provide accurate and useful representations of concepts that were needed when solving problems in some particular area and to make the process of understanding in that area easier since it was a visual expression of the topic.

Models are used in explanations of scientific concepts or theories. Models are tools used to find out about the casual relations that hold between certain fact and processes and it was these relations that did the explanatory job (Woodward, 2003). This implies that one could shift the explanatory burden of scientific concepts, theories or laws on to models. Again, models serve as complements of concepts or theories (Leplin, 2002). In support of this, Redhead (1980) stated that a theory might be incompletely specified in the sense that it imposed certain general constraints but remained silent about the details of concrete situations which were provided by a model. Models step in when concepts or theories are too complex to handle. Redhead (1980) observed that, theories might be too complicated to handle or understand. In such a case a simplified model could be employed to allow for a solution or clarification.

A model could be used introduced students to important terms as well as provided an environment for students to explore relevant processes involved in a specific area of learning. According to Justri & Van Driel, (2005) and Hardwicke (1995) one of the most compelling reasons to use models in an introductory science classroom is that scientific practice deals with the construction, validation and application of scientific models, hence science instruction should be designed to engage students in making and using models.

Models were introduced in chemistry teaching as early as 1811 by Dalton (Hardwicke, 1995). Petersen (1970) noted that the „golden age‟ of molecular model started with the production of many commercial molecular model kits based on Stuart‟s space filling models in 1930s where different kinds of molecular models like traditional 3D models, stereo-chemical projections, virtual computer models, were widely used in chemistry education. Petersen stated that, the uses of these models had been proven to be significant in teaching many topics across the curriculum. Ayikoe (2012) revealed that students in an experimental group at St Francis College of Education, Hohoe performed better in the naming of hydrocarbon than those in the control group when they were subjected to the use of computer modules. This was because the mean score for students from the experimental group (M=23.92, SD=4.242) was significantly higher than the means score of students from the controlled group (M=18.48, SD=3.356) with a P-value of 0.000.

The usefulness of molecular models as help tools in science education in general was explained by the assumption that tangible materials like structural models play important roles by supporting students when connecting the different levels of concept representations (Ferk, Vrtacnik, Blejec, & Gril, 2003). The use of concrete models, pictorial representations, animations and simulations have been shown to be beneficial to students‟ understanding of chemical concepts (Tasker & Dalton, 2006). According to Ameko (2015), most students in the Colleges of Education he studied could not identify, name and draw the structures of the first-ten members of the homologues series of alkanes and other aliphatic organic compounds. He therefore conducted a study with 50 students in St Teresa"s College of Education, Hohoe in the Volta Region of Ghana, to remedy the situation using molecular models. The performance of the students was said to have improved significantly since there was a statistical difference between the pre-test (M=24.96) and post-test (M=37.38) result after they have been subjected to a paired t-test.

At higher levels, students are required to do chemical research involving more advanced theories on the structure and names of molecules. When students are used to 3D molecular models which are easily applied to a broad range of topics which deal with especially structure of chemical substances they come to understand the electron density models involve orbital concepts. Hence they are better prepared to succeed because they already have a well-developed 3D picture of an electronic structure to refer to for better research work. Bader (1991) and Politzer and Truhlar (1981) noted that these types of models in use have widespread, precise application in chemical research. From the above, the researcher believed that as students interact physically with the molecular models by building various structures of aliphatic organic compounds the models would help to bridge the gap between abstract and reality.

Description of Molecular Model Kits

The molecular model kits used in the study was named „Molymod Organic". This kit was meant to build a 3D spatial arrangement of organic molecules, crystal structure models and inorganic molecules (Gobert & Buckley, 2000). The sets contained coloured balls representing the various atoms and (fairly) rigid grey short plastic connectors (sticks) represent the various bonds. The atoms used in this work included:

carbon, hydrogen, chlorine, bromine, iodine and oxygen atoms. All the plastics balls had hole(s) moulded into them to accept the connectors and to represent their valency or chemical bond(s) formed at a stable state. Carbon had four holes and so accommodated four connectors all the time to four other species, thus carbon showed tetravalence. Oxygen had two holes only and sodivalence, while the halogens and hydrogen are monovalence because each of them had one hole. Their conventional colours were black for carbon, red for oxygen green for the halogens and white for hydrogen. Atoms such as: nitrogen-blue, phosphorous-purple, sulphur-yellow were in the box but were not used. Double and triple bonds were represented by thin flexible sticks to restrict rotation and support conventional cis/trans stereochemistry (Gobert & Buckley, 2000). The thick in-flexible sticks served as single bonds

Challenges Associated With the Use of Models in Science Teaching and Learning

Much of high school chemistry involved atomic and molecular phenomena that cannot be easily observed and so in order to help students understand these abstract concepts, carefully prepared models were commonly used.

However, models have limitations. Some of the properties such as relative sizes and diameters of the atoms, and the bond length in a typical ball-and-stick models were not exactly shown but the extensive and accepted processes of using models made the model appeared as „facts" to many teachers and students (Boo, 1998). However, these approximations led to an inaccurate understanding of the underlying chemical concepts which were usually not reflected in the models.

One other problem that could arise while using models is that of true representativeness. Redhead (1980) observed that, theories might be too complicated to handle or understood. He asserted that in such a case a simplified model might be employed that could allow for a solution or clarification. However the question of whether a given model of a particular kind was representative enough of the natural phenomenon or the reality it was supposed to represent was of great concern. For example, the bonds in typical ball-and-stick models show a very inaccurate and confusing representation of the true nature of molecular bonds. These models simply show sticks of fixed length to represent all bonds while real bonds varyin shapes and their shapes are determined by the diffuse nature of electrons. Nevertheless no single model provided the total understanding of the structure and function of a molecule and because of this each student‟s understanding was reliant on realizing the weaknesses and strengths of each model (Hardwicke, 1995).

In addition, the success of using models in the writing of the structure and naming of organic compound cannot be exempted from a teacher‟s prior knowledge. However some teachers have a simplified and limited understanding of the use of models and modeling in science (Justi & Driel, 2005).

Another problem that could arise while using models in the classroom is the teacher‟s level of knowledge and understanding about models. This problem creates a powerful reason for teachers to frequently use molecular model kits in teaching the names and structural formulae of organic compounds so that teachers as well as their students could gain the needed knowledge and skills in the use of models. In spite of these problems, the usefulness of molecular models in science teaching and particularly in writing and naming of aliphatic organic compounds cannot be under rated.

Representation of Organic Compounds

There are two major ways to represent organic compounds. These are molecular formula and the structural formula. The molecular formula lists the numbers of each atom as a subscript following the atomic symbol. Thus it indicates the number and type of each atom present in a molecule and does not gives any information concerning the actual arrangement of atoms in the molecule. An example is C_5H_{12} (pentane).

The structural formula may either be represented by Lewis (expanded) structural formula, condensed structural formula or by the Line-angle structure (Gillette, 2004). The expanded structural formula shows all the constituent atoms in a compound and how each is bonded (Gillette, 2004; Valhardt, 1987). Hence the formula must show the bond that can be accommodated by each atom. The expanded structure of pentane can be represented as shown in Figure 1.

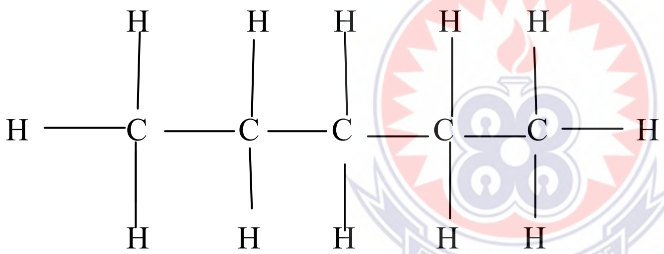


Fig 1: Expanded Structure of Pentane

In representing the condensed structural formula, each carbon atom and the hydrogen bonded directly to it are listed as a molecular formula, followed by a similar molecular formula for the neighbouring carbon atom; branched groups are shown in brackets after the carbon atom to which they are bonded. Thus, the condensed formula is written to account for correct indication of symbols of each element, correct indication of number atoms of each element and correct use of parenthesis where applicable without showing how individual atoms are bonded. Bonds/lines might be used to emphasise how the carbon chains are related (Delay & Delay, 2005). The condensed structural formula does not show the covalent bond(s) but if shown, then it is for the purpose of clarifying a specific portion of the structure (Gillette, 2004).

One can therefore represent the structure of pentane as shown in Figure 2.

$CH_3(CH_2)_3CH_3$.

Fig 2: The Condensed Formula of Pentane

According to Gillette, line-angle structures use lines to show chemical bonds without the carbon and the hydrogen atoms. Thus, in representing the structure, every bond is shown as a line in zigzag manner and every terminal also taken as a methyl ($-CH_3$) group if not specified. Hence the line-angle structure of pentane assumes the form in Figure 3

Fig 3: The Line Angle Structure of Pentane

Some Organic Compounds and Their Functional Groups

Using the IUPAC system of naming organic compounds depend largely on the functional groups, which is a group of bonded atoms which give an organic compound its characteristic chemical properties (Ameyibor & Wiredu, 2001). Gillette (2004) saw it as grouping compounds by shared structural features. The concept of functional groups is central in organic chemistry, both as a means to classify structures and for predicting properties of reactions (Abbey, Ameyibor, Alhassan, Essiah, Fometu & Wiredu, 2001). The understanding the chemistry of the functional groups allows one to understand organic molecules, as well as the large biological molecules that allow life to exist (Caret, Denniston & Topping, 1997).

Table 1 shows some organic compounds and their functional groups that the study focused on.

Table 1: Some Organic Compounds and their Functional Groups.

Compound	Functional Group	Suffix	Example	IUPAC Name
Alkane	C—C	-ane	CH_3CH_3	ethane
Alkene	C=C	-ene	$H_2C{=}CH_2$	ethene
Alkyne	C≡C	-yne	HC≡CH	ethyne
Alkanol	OH	-ol	CH_3CH_2OH	ethanol
Alkanoic Acid	COOH	-oic acid	CH_3COOH	ethanoic acid
Alkanoate	COO	-oate	CH_3COOCH_3	methyl ethanoate

It can be deduced from Table 1 that functional groups serve as a bases for classifying organic compounds into families and naming of organic compounds.

IUPAC Nomenclature of Aliphatic Organic Compounds

One of the major structural groups of organic molecules, the aliphatic compounds are organic compounds that contain carbon and hydrogen joined together in either straight or branched chains, or non-aromatic rings. Woodcock (2014) explained aliphatic compounds as compounds that do not incorporate any aromatic rings in their molecular structure and are also not alicyclic. Aliphatic compounds consist of hydrocarbons (alkanes, alkenes, and alkynes) and their derivatives (substances derived from them by replacing one or more hydrogen atoms by atoms of other elements or groups of atoms) such as alkanols, alkanoic acids etc.

A lot of rules have been drawn up to help us in naming the many organic compounds that exist. The IUPAC nomenclature system is a set of logical rules devised and used by organic chemists to elude problems caused by arbitrary nomenclature. This system has replaced the "trivial" (common) names which have no rational or systematics principles that guide their assignments. In any Chemistry examination, if students know these rules and are given the structural formula of a compound, they can easily write a unique name for every distinct compound. With the IUPAC naming system there are three parts to each organic compound namely:

- The root or base which indicates the number of carbon atoms in the longest continuous carbon chain
- A suffix or ending which shows the functional groups that may be present in the compound or the family to which the organic compound belongs.
- A prefix indicating the number, position, and identity of any substituent atoms or groups of atoms that have replaced any hydrogen atom or atoms that complete the molecular structure (Daley& Daley, 2005; Gillette, 2004 & Woodcock, 2014).

Knowing how to apply and interpret these three essential features of organic compound could enable one to write the chemical name and draw the structural formula of a given compound (Gillette, 2004).

The rational naming system however, shows how the carbon atoms of a given compound are bonded together in unique lattice chains or rings and as well as how to identify and locate any functional groups present in the compound. The number and positions of hydrogen atoms are mostly not indicated when naming organic compounds, rather, it is assumed from the tetravalency of carbon because it is considered as a common element of organic compounds.

Guidelines for Naming Alkanes

Alkanes are saturated hydrocarbons having only single covalent bonds. The names of alkanes form the basis of naming most organic compounds. However, the main difference is the ending of the name, which is dependent on the functional group. Firstly, the functional group of the compound is identified. This will determine the ending of the name (-ane for alkane). The longest carbon chain is worked out to form the root name to which – ane is added. The carbon atoms in the longest chain are numbered such that the most heavily substituted carbon takes the least number. The various substituents (if any) are then identified with their location on the longest chain. The numbers of similar substituent groups are indicated using prefixes (di-, tri-, tetra-and so on) to show the presence of 2, 3,4 etc identical branched groups, or identical double and triple bonds. If the compound bears a halogen as a substituent then it should be named as haloalkanes (Solomons & Fryhle, 2008).The final name is written by arranging the substituents in alphabetical order and with no spaces, with commas between numbers, and with hyphens between numbers and letters. Nevertheless in naming alkanes bearing both a halo and an alkyl substituent group the chains are numbered from the end nearer to the first substituent group but if the two substituents are at equal distance from the end of the chain, then consider the alphabetical order of numbering (Skonieczy, 2006)

Guidelines for Naming Alkenes

Alkenes are unsaturated hydrocarbons containing at least one carbon to carbon double (C=C) as their functional group. In naming alkenes, the root is determined by the longest chain in which the C=C functional group is found. The numbering of the carbon atoms is done from the end that would give the carbon atom on which the double bond begins the least number (Goodwin, 2003).

The locant for the alkene suffix may come before the parent name or be placed immediately before the suffix (Solomons & Fryhle, 2008).

For symmetrical alkenes, the nearest substituent rule is used to determine the end where numbering starts. If more than one double bond is present the compound is named as a diene, triene or equivalent prefix indicating the number of double bonds and each double bond is assigned a locator number. The final name is written out with no spaces, with commas between numbers, and with hyphens between numbers and letters as in alkanes

Guidelines for Naming Alkynes

The naming of alkynes follows similar pattern like the alkenes. Here the root name ends with –yne indicating the presence of C≡C functional group. If double bonds are present, double bonds precede triple bonds in the IUPAC name but the chain is numbered from the end nearest a multiple bond, regardless of its nature. Priority is, however, given to –OH group over the triple bond when numbering the continuous carbon chain (Solomons & Fryhle, 2008). Examples are shown in Figure 4a and 4b

$HC{\equiv}CCH{=}CH_2$	**$HC{\equiv}CCH_2OH$**
Fig 4a: 1-buten-3-yne	**Fig 4b: 2-propyn-1-ol**
(or but-1-ene-3-yne)	**(or prop-2-yn-ol)**

Guidelines for Naming Alkanols

The IUPAC system of naming alkanols is also, based on that of alkanes. The root suffix is –o1 and replaces the final –e of the alkane. In selecting the longest carbon chain, the alkane is numbered beginning with the carbon nearest to the hydroxyl (-OH) group. The substituents are treated just as in cases of alkanes, alkenes and alkynes and the final name written out.

Guidelines for Naming Alkanoic Acids

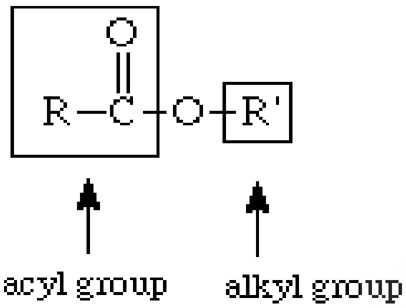
The IUPAC rules allows for two systems of naming depending on how complex the acid molecule is. Alkanoic acids are derived from open chain alkane and named by replacing the –e of corresponding alkane with –oic acid. The carbon bearing the carboxy group is always numbered as carbon one, -C-1.

Alternatively aromatic acids are named referring to the –COOH as carboxylic acid. The carbon atom to which the –COOH group is attached is numbered as carbon one –C-1.Thus, the carbon of the –COOH itself is not numbered.

Guidelines for Naming Alkanoates or Esters

These compounds have two carbon chains separated by oxygen (-O-). They consist of an alkyl (R‟) group from the alkanol that formed them and the acyl (RC=O) portion from the alkanoic acid. Both chains are named separately. The alkyl group is named like a substituent using the "-yl" ending while the acyl portion is named by replacing the "**-**ic acid**"** suffix of the corresponding alkanoic acid with "**-**ate**"**. They are therefore named as alkyl derivatives of carboxylic (alkanoic) acids. Skonieczy (2006) stressed that in naming an alkanoate, there should be no hyphen between the name of the alkyl group and that of the acyl group.

The carbonyl group in the alkanoate family is always at the end of a carbon chain and as such is always the first position. As with the alkanoic acids the locant (1) is omitted on the acyl part of the name in writing out the final name. The general formula of esters can be deduced from the guideline as RCOOR‟ and a functional group as –COO-. Figures 1 and 2 showed the structural representation of the general formula and the functional group of alkanoate.



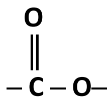


Fig. 6: Alkanoate Functional Group

Fig. 5: General Structural Formula for Alkanoate

Empirical Review

A careful looked at the available literature revealed that some work had been done to mitigate difficulties students faced in classifying, writing and naming of organic compounds. Using computer modules, Ayikoe (2012) conducted a study in St. Francis College of Education Hohoe to investigate the effect of computer modules on students‟ performance in the naming of hydrocarbons. He found out that, the experimental group performed better than the control group.

Ayikoe used three instruments (Opinionnaire, Tests & Questionnaire) which were all pen and paper tests to collect data. Hence students‟ difficulties encountered could only be inferred but not directly determined since the instrument used could not expose the reasons for their wrong answers for remedy. It must be noted that, Ayikoe‟s study was limited to Colleges of Education and covered only hydrocarbons.

Similarly, Ameko (2015) used molecular models to guide fifty (50) students of St Theresa‟s College of Education, Hohoe to improve their performance in identifying functional groups, drawing and naming of aliphatic organic compounds. Unlike Ayikoe, who used Opinionnaire, Tests & Questionnaire as his data collection tools, Ameko used only written tests which he administered to the students.

Two things were notable about Ameko‟s study – the first being the fact that it also concerned a College of Education, while the second point concerned the instrument he used. The exclusive use of tests by Ameko (2015) meant that students‟ thought processes were only inferred from mute evidence. As Hodder (2001) noted, written texts were example of mute evidence which needed interpretation.

Contrasting the two studies mentioned above, Worsor‟s (2015) study concerned a senior highs school and involved ninety-eight (98) chemistry students in Zion SHS in the Volta Region. The study sought to find out the effect of atomic models on the performance of students in the naming of organic compounds. This was limited to only alkane, alkenes and alkynes.

The study dealt extensively with various difficulties chemistry students faced when naming alkanes, alkenes and alkynes using the traditional approach and the use of the model method.

While concluding from his findings that the use of atomic model had significant effects on chemistry students‟ performance, he enumerated a number of difficulties that were being encountered by the students when naming and writing the structures of organic compounds. Notable among the difficulties were locating functional groups and their positions and branching in the main chain. The study however did not mention the students" reasons for such difficulties since the instrument employed could not solicit these reasons. Derrida (1978) stated that only the research subjects know the actual meaning of what they wrote but not those who interpreted it. Also the difficulties science students encountered when solving problems were not just because they lacked the knowledge in that specific field but rather due to the deficiencies in the way they applied the knowledge (Sulvartham & Frazer, 1981). Hence their difficulties could best be determined from them verbally.

Although Ameko (2015) used molecular models to guide students to identify functional group, draw and name aliphatic organic compounds in a College of Education in Ghana, no such study has been conducted with the SHS chemistry students in Ghana. It was for this reason coupled with the inability of chemistry students of E.P.C Mawuko Girls" SHS to classify, name and write structures of such compounds that the researcher undertook this study.

Summary of the Literature Review

The constructivists" theory of teaching and learning mainly concerns teaching and not learning and that learning is more effective when a student is actively engaged in the learning process rather than attempting to receive knowledge passively. The emphasis is therefore laid on the environment and learner-centred rather than teacher-centred instructional approaches. The researcher"s role is to ensure a well democratic environment, facilitate and guide the SHS students in the learning process to name and write the structures of aliphatic organic compounds by constructing their own knowledge using molecular model kits.

In naming aliphatic organic compounds in general, the IUPAC system (which is dependent on the functional group) is used. Alkanes form the basis of naming organic compounds hence must be taught well before proceeding to the other classes or groups. However, in naming and writing the structural and condensed formulae, care must be taken to identify the three parts of the compounds: the root, the suffix and the prefix (Daley& Daley, 2005; Gillette, 2004; Skonieczy, 2006 & Woodcock, 2014).

The purpose of using molecular model kits was to provide three-dimensional images that helped students to see how atoms and molecules are bonded. Most of these models are made of plastic and come in various colours, shapes, and structures to enable formation of different organic molecules. It was found out that the effective use of instructional materials, like molecular model kits facilitated easy understanding of abstract concepts, promoted effective communication, excited the perceptual thinking of students and made them actively involved in the teaching-learning process. Despite some problems in the use of models (Dori, Barak, & Adir, 2003; Coll & Treagust, 2003), the pedagogical content knowledge of the teacher makes models an outstanding resources in learning about the naming and writing the structures of aliphatic organic compounds.

Written texts are mute evidence which could be interpreted differently, hence students" difficulties encountered during the process of classifying, naming and writing of structure of aliphatic organic compounds can best be detected when they are interviewed in addition to the written text.

Of the three studies conducted in Ghana on the use of molecular models on students" performance, the most recent was the one conducted by Worsor (2015). Although the study highlighted difficulties that science student faced when naming and writing structures of organic compounds, there was no indication of the students" reasons for supplying those answers. Worsor (2015) used achievement test to gather data and could not be in position to tell whether the student difficulties were due to the lack of knowledge of IUPAC knowledge or the application of the IUPAC rules. Moreover, the study used atomic model which failed to eliminate the problem of locating the functional group since the atomic models do not have provision for multiple bonds. Worsor"s study was only based on hydrocarbon but not their derivatives such as alkanols, alkanoic acids and among others.

On his part, Ameko (2015), used molecular models to improve the performance of students in naming aliphatic organic compounds which included hydrocarbon. Ameko"s (2015) study was on students of Colleges of Education and not SHS. Like Worsor (2015), Ameko (2015) could not, by using only achievement test, to determine the actual reasons for which his (Ameko"s) students gave wrong answers to the items he used to determine their difficulties. The best he could do was to infer from their wrong answers. This needed interpretation and could thus be wrong or right.

Ayikoe (2012), unlike the two researchers mentioned, used opinionnaire, achievement tests and questionnaire in his study. But his study involved students of Colleges of Education and focused only on hydrocarbons. Ayikoe (2012) did not give any indication of the effect of his modules on students" knowledge of chemistry in such areas as alkanols, alkanoic acids, alkanoates and other derivatives of hydrocarbon as the SHS chemistry syllabus recommended. Additionally, the instruments utilized could not provide verbal evidence of the students" difficulties. The evidence provided was only mute. This challenge was overcome in this study through the use of informal interviews with selected students who had provided wrong answers to the test items.

The absence of any study involving chemistry students" of SHS which focused on the use of molecular model kits to increase their ability in classifying, naming, and writing the structure of aliphatic compounds led the researcher to designed this study.

CHAPTER THREE

METHODOLOGY

Overview

This chapter discussed the methodology that was used in carrying out this study in order to enhance SHS chemistry students" knowledge in classification, naming and writing the structure of aliphatic organic compounds. It also discussed the research design that was adopted for the study, the study area, the population, sample and sampling technique and the instruments that were used for data collection. The validity and reliability of instrument, interventions, procedures for the data collection and the method of analysis of data were also described in this chapter.

Research Design

The research design for this study was a case study design using the action research approach. According to Seidu (2007), research design describes the procedures and methods used to gather data and the choice of design must be appropriate to the subject under investigation.

To Seidu (2007), an action research is a problem solving research devoted to the solution of an immediate problem in a given situation. According to him, an action research fosters on informed decision-making and systematic problem solving among practitioners. The research therefore aimed at finding out chemistry students" difficulties and misconceptions, and how they could be corrected using molecular models.

Given (2008) outlined the relevance of Action Research in the Sage Encyclopedia of Qualitative Research Methods as:

1. Investigating the current situation, in partnership, and planning change
2. Introducing changes: trying out new practices with the aim of improvement
3. Monitoring the impact of changes: collecting a wide range of data. Analyzing and interpreting data to generate actionable knowledge.

Steepless (2014) described the cyclical nature of the action research model and stated that the approach enables researchers and their participants to learn from each other through a cycle of planning, action, observation and reflection. He indicated that the cyclical nature fosters deeper understanding of a given situation starting with conceptualisation and moving through several interventions and evaluation. In the research, pre-intervention, intervention and post intervention activities were used to achieve this mission.

A case study design was used because one intact class was used for an in-depth study which took place in a real - life context. This was explained by Yin (2003), as an in-depth study of a particular research problem rather than a sweeping statistical survey. Cepni (2010) further explained that the greatest strength of case study is that it allows the researcher to concentrate on a specific instance or situation and to identify, the various interactive processes at work. These processes may remain hidden in a large scale survey but may be crucial to the success or failure of the study. The case study research design is also useful for testing whether a specific theory and model actually applies to phenomena in the real world and it was on this basis that the molecular model kit was used to find out if chemistry student"s knowledge can be enhanced in naming and writing structures of aliphatic organic compounds.

A key strength of case study method involves using multiple sources and techniques in the data gathering process. The researcher employed triangulation which is a mixed method approach where both qualitative and quantitative methods of inquiry are used to collect data. Triangulation may be defined as the use of two or more methods of data collection in the study of some aspect of human behaviour (Cohen, Manion & Morrison, 2007). According to Cohen, et al.(2007), the triangular techniques attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint through the use of both quantitative and qualitative data.

Qualitative method is used to understand, in depth, the viewpoint of research participants concerning the difficulties they faced doing a task since qualitative research is more descriptive than predictive (Vanderstoep & Johnston, 2009). Qualitative methods provide a holistic description of the phenomena under study. It could also be used to describe data numerically and answer the specific questions or hypothesis raised. Quantitative method quantifies data and converts it to numerical scores for answering of research questions (Fraenkel & Wallen, 2009).

The Study Area

The study was conducted at the EPC Mawuko Girls‟ SHS, in the Ho Municipality of the Volta Region. The School was a private girls‟ secondary school established by the Evangelical Presbyterian Church in 1983 but was fully absorbed by the Government of Ghana in January 1991 with boarding facilities. The area is a vast growing commercial and residential settlement. Trading and farming are the most pre-dominant economic activities of the area.

Population

Castillo, (2009) defined population as a large well-defined collection of individuals or objects who have the common characteristics. The target population referred to the group of individuals to which researchers are interested in generalizing their conclusions whiles the accessible population is the population which is available for the researcher and to which the researchers could apply their conclusions (Castillo, 2009). The target population for the study was all chemistry students of the 2016/2017 academic year in the government assisted Senior High Schools (SHS) in the Ho Municipality of the Volta Region. The researcher selected this region because of her familiarity with the academic environment and challenges of the region and has been teaching in this region for the past seventeen years. However the accessible population for the study consisted of one hundred and eighty one (181) SHS 2 chemistry students in EPC Mawuko Girls‟ SHS, in the Ho Municipality of the Volta Region.

Sample and Sampling Technique

The process of selecting participants from the population is very important. If the sample selected is to represent the target population then the people in it should be similar to the other members of the target population. This will make generalization from the sample to target population reliable. Generalisability refers to the extent to which we can apply the findings of our research to the target population we are interested in (McLeod, 2014). However, researchers who are mostly concerned about evaluating the effectiveness of a particular programme might not worry much about whether the findings are generalisable to people who are not in the programme (Vanderstoep & Johnson, 2009 p. 26).

According to Cohen et al. (2007), in sampling, judgements have to be made about four key factors : the sample size, representativeness and parameters of the sample, access to the sample and the sampling strategy to be used.The correct sample size depends on the purpose of the study and the nature of the population under scrutiny. Generally speaking, the larger the sample the better, as this not only gives greater reliability but also enables more sophisticated statistics to be used. The number of variables researchers set out to control in their analysis and the types of statistical tests that they wish to make must inform their decisions about sample size prior to the actual research undertaken. Furthermore, too large a sample might become unwieldy and too small a sample might be unrepresentative (Cohen et al., 2007).

On representativeness, the researcher will need to consider the extent to which it is important that the sample in fact represents the whole population in question if it is to be a valid sample. The researcher will need to be clear with what it is that is being represented, that isto set the parameter characteristics of the wider population – the sampling frame – clearly and correctly.

Access is a key issue and is an early factor that must be decided in research. Researchers will need to ensure that access is not only permitted but also, in fact, practicable. Access to sensitive areas might be not only difficult but also problematic both legally and administratively. In some sensitive areas access to a sample might be denied by the potential sample participants themselves.

In general, there are two ways to select members for a study: randomly or non - randomly. A random sample**,** sometimes called a probabilistic sample is a sample in which each member of the sampling frame has an equal chance of being selected as a study participant. (Vanderstoep & Johnson, 2009). This meant every member of the wider population has an equal chance of being included in the sample; inclusion or exclusion from the sample is a matter of chance and nothing else (Cohen et al., 2007). A non - random sample is a sample in which each member of the sampling frame does not have an equal chance of being selected as a participant in the study (Vanderstoep

& Johnson 2009). The researcher must decide whether to opt for a probability (also known as a random sample) or a non-probability sample also known as a purposive sample.

The researcher adopted non-probability sampling techniques to select the sample. According to (Vanderstoep & Johnson, 2009), participants in this sampling technique are selected based on characteristics they possess or their availability to participate. The researcher used this technique to select participants because participants under this technique should meet pre - established criteria (Given, 2008).

The sample for the study was forty-five (45) second year chemistry students. The researcher used purposive sampling techniques in which an intact class of Home Economics 2B was selected. 2B class was chosen because of its familiarity and accessibility to the researcher, hence rich information about the class performance and achievement was readily available for the study. Also it was because the analysis of WASSCE chemistry results in the school from 2012 to 2015 showed that most of the failures were Home Economics students.

Research Instruments

In order to answer the various research questions, it became imperative to choose appropriate data collection devices. Zohrabi (2013) identified questionnaires, interviews, classroom observations and tests as some of the procedures for data collection. As a result, the researcher used achievement tests as the main instrument which was supported with informal interview and questionnaire to gather data for this study. Pre-intervention test and interview were used to assess students" prior knowledge and difficulties in the IUPAC system of nomenclature in classifying, naming and writing of structural formulae of aliphatic organic compounds before the implementation of the interventions. The pre- intervention test and post- intervention test were conducted for all students in the selected class and the two results compared. This was used to answer research questions 2 to 4. The questionnaire was used to find out students" views on the use of molecular model kits in teaching the structural formulae and naming of aliphatic organic compounds. The tests could serve as reliable instruments that could help obtain credible information about students" performance and the interview could help in knowing the students" reasons for their wrong answers. However the questionnaire could ensure consistency of presentation of questions to respondent, a greater perception for anonymity for respondents and less time-consuming to administer.

Achievement Tests

The achievement tests consisted of test items based on the SHS chemistry syllabus and compared to standardised questions on the IUPAC system of naming organic compounds set by the WAEC for the West African Secondary School Certificate Examinations (WASSCE).

Test 1 which was made up of four sections (A-D) altogether was administered to the students before the intervention activities as a diagnostic test and same test 1 named as test 2 was administered to them as post-intervention test to determine the effectiveness of the intervention.

The first section, which was A, required that students classify some named compounds as alkane, alkene alkyne, alkanol, alkanoic acid or alkanoate. In section B, the 10 test items required the students to name correctly some given structural formulae of aliphatic organic compounds by IUPAC nomenclature, the 5 test items in section C required the students to provide the structural formulae of the five given

IUPAC names of aliphatic organic compounds and the section D which consisted of the last 5 test items required the students to provide condensed formulae of the five given IUPAC names of aliphatic organic compounds. Each test covered such areas of aliphatic organic compounds as alkanes, alkenes, alkynes, alkanols, alkanoic acids, and alkanoates and was administered for duration of 45 minutes. See Appendix A and B for the pre-intervention test and post-intervention test respectively. Answers of students to questions of both tests were marked using a marking scheme that the researcher prepared. See Appendix C for marking scheme of pre-intervention test and post-intervention test. Each test was scored out of 25 marks.

Interviews

The researcher conducted an informal interview with one student at a time after the pre-intervention test (Appendix D). A week after the test scripts had been scored; the researcher conducted an informal interview with ten (10) selected students who were also involved in the study. The selection was based on their respective scores in the achievement test. This was in the form of oral questionnaire and the needed information was given orally and face-to-face. This enabled the researcher to find out the students" reasons for supplying such answers to the test items.

Questionnaire

Questionnaires are straight forward written questions which require an answer by ticking the appropriate box; an efficient ways of collecting facts (Hannan, 2007). The respondents could also be provided with spaces in which they formulate their own responses. The questionnaire was a researcher designed one to elicit students" perceptions on the use of molecular model kits in teaching the structural formulas and naming of aliphatic organic compounds. Both closed and open-ended questions were used (Appendix E). The twelve (12) closed-ended items with their associated Likert scales were used to find out specific responses. The Likert-type scales were used because the scales are often observed to provide data with relatively high reliability (Gabel & Wolf, 1993). The last two items were meant for the students to express themselves freely to bring out what the closed-ended aspect of the questionnaire could not provide.

Validity of the Main Instrument

Awanta & Asiedu-Addo (2008) explained validity as the extent to which an instrument measures what it is intended to measure and performs as it is designed to perform. In order to validate the research instruments, the researcher consulted the SHS Chemistry syllabus as well as some prescribed Chemistry textbooks and past WAEC questions for SHS students. The purpose was to gain insight into what learners are expected to learn in order to develop the instruments accordingly.

The tests were validated by having two experienced colleague teachers review the items with respect to course objectives stated in the syllabus. After constructing the test items, the researcher consulted her supervisor to cross check them for content and construct validity. This made the researcher to modify, cancel and include some items.

Reliability of the Main Instruments

Reliability of any instrument is very important because, it concerns the degree to which an experiment, test or any measuring procedure yield the same results on repeated trials (Ruland, Bakken & Roislien, 2007). The reliability of the main instrument was determined using Pearson"s test-retest correlation coefficient. This idea was supported by Charles (1995), who indicated that test-retest method at two different times could be used to determine the consistency of which answered questionnaire or test items or individual scores could remain relatively the same (stability of instrument). To determine the coefficient of reliability of the instruments the tests items were pilot tested on twenty one (21) General Science 2B students of same characteristics in the school. The results of the pilot test were used to calculate the reliability coefficient.

Again, Borg, Gall and Gall, (1993) pointed out that if the measurement results are to be used for making a decision about a group or for research purposes, or if an erroneous initial decision can be easily corrected, then the scores with modest reliability coefficients in the range 0.50 to 0.70 might be acceptable. The Pearson reliability coefficient for the pilot tests (test 1 and test 2) using excel 2010 was approximately 0.70 indicating a reliable instrument (Appendix F). However the open-ended items in the questionnaire were used as a means through which the respondents expressed themselves freely on the use of molecular model. These expressions were put into themes for purposes of triangulation which helped to crosscheck the authenticity of the data collected using closed-ended questions as revealed by O'Donoghue and Punch (2003) and also give a balance picture of the situation suggested by Altrichter, Feldman, Posch and Somekh (2008).

Pilot Study

Before the commencement of the main stages of data collection, a pilot study was conducted. This involved every aspect of the research such as instruments, interventions, and data collection -procedures. The result was used for reconstruction of some of the test items and correction of some lapses in the interventions and data collection processes. To avoid contamination, five (5) second year Visual Arts students of same characteristics in the school were used.

Data Collection Procedures

The researcher collected her data in three stages, namely: pre-intervention stage, intervention stage and post-intervention stage.

Pre-Intervention Stage

The pre-intervention stage involved the administration of a pre-intervention test named test 1. The test 1 which lasted for forty-five (45) minutes was administered by the researcher to the forty-five (45) second year Home Economics students of EPC Mawuko Girls‟ SHS, Ho. This was done after a colleague chemistry teacher had taught the students without using the molecular model kit as an instructional material of the topic. The test results were used to determine each student‟s prior knowledge and difficulties that they faced in classifying, naming and writing structures of aliphatic organic compounds before the start of intervention. The laid down rules and regulations of WAEC for conducting examinations were observed during the administration of the test and the entire answered test scripts were collected, marked, recorded and the scores collated for analysis. The researcher conducted an interview with one student at a time after the pre-intervention test to get an insight into the difficulties the student encountered during the pre-intervention test.

Intervention Stage

To enhance students understanding of the concept of classification, naming and writing of structural formulae of aliphatic organic compounds, the researcher at this stage carried out an intervention by using molecular model kits to teach classification, structures and IUPAC names of these aliphatic organic compounds; alkanes, alkenes, alkynes, alkanols, alkanoic acids and alkanoates. The instruction covered up to aliphatic compounds that contained ten carbon atoms. Five (5) weeks of instruction of

80 minutes per week was used. The steps or stages involved are illustrated in Figure 7.

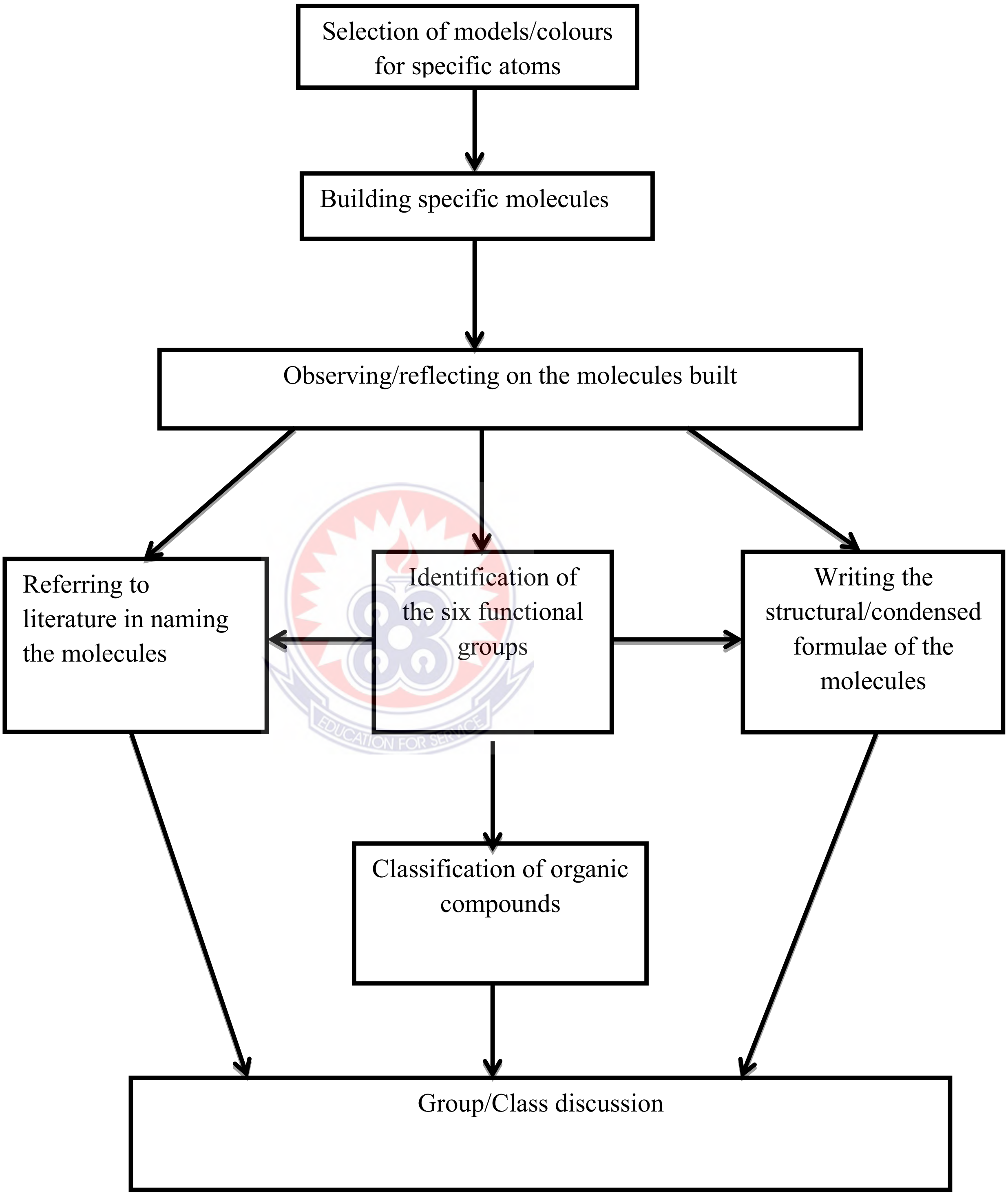


Fig 7: Diagrammatic Representation of the Use of Molecular models During the Intervention

First Week

ALKANES

To make the lesson activity oriented and ensure full participation, the researcher put the students into ten (10) groups of a maximum number of five (5) and each group was given one molecular model kit to use.

The researcher clearly stated the objectives of the lesson and guided the students to identify the models of the various atoms, their respective colours, the number of hole(s) a particular atom has and the type of stick(s) that should be used to represent a particular bond. The various atoms, symbols, colours codes and holes in them are shown in Table 2.

Table 2: Atoms and their Symbols, Colour Codes and Number of Hole(s)

Atom	Symbol	Colour	Number of Hole
Hydrogen	H	White	1
Carbon	C	Black	4
Oxygen	O	Red	2
Nitrogen	N	Blue	3
Chlorine	Cl	Green	1
Bromine	Br	Orange	1

Students were taught that alkanes are hydrocarbons containing carbon(s) and hydrogen(s) only in their structures. The general formulae for alkanes was given as $C_nH_{2n}+_2$, where (n) stands for the number of carbons in the structure or the formula. They were also taught that using the IUPAC system to name and write structural formulae of organic compounds, the functional group (which is an atom or group of atoms largely responsible for the chemical behaviour of organic compounds) of a compound is taking into consideration hence that of alkane is **C-C**

Students were told that the IUPAC system names all compounds by first identifying and naming the basic carbon skeleton of the molecule. Then, using prefixes, suffixes and numerals any groups or substituents which are attached to the skeleton are identified and named. For alkane the suffix is „ane" and the prefix is determined by the longest continuous carbon chain. Students were asked to choose any number of carbon atoms that would form the longest carbon chain which was considered as the parent name of the compound. Students were guided to use the black carbon model to form the skeletal structure. Students were further asked to pick their one, two, three, four or five carbon structures formed and fix the white hydrogen model into the three holes left in each carbon atoms to form methane, ethane, propane, butane and pentane respectively. They were guided by the contents of Table 3.

Table 3: Number of Carbon Atoms with their Corresponding Prefixes and Names

Number of Carbon Atom	Prefix	Alkane
1	Eth	Methane
2	Eth	Ethane
3	Prop	Propane
4	But	Butane
5	Pent	Pentane
6	Hex	Hexane
7	Hept	Heptane
8	Oct	Octane
9	Non	Nonane
10	Dec	Decane

Students were further guided to write the molecular formulae of the five compounds by counting the carbon and hydrogen atoms present in each compound which they wrote as CH_4, C_2H_6, C_3H_8, C_4H_{10} and C_5H_{12}. The researcher explained to students that the presence of substitutes on the main skeleton such as alkyl groups or others such as halogens are indicated as prefixes with numerals immediately in front of the prefix indicating the carbon of attachment. They were told that if two of the same group are present then two numerals are used even if they are the same numerals separated by a comma and „di‟ is added as the prefix. For three of the same group they added „tri‟ and four add „tetra‟. If more than one prefix was present, they were placed in alphabetical order. Hyphens were used to separate numerals from letters and commas to separate numerals from numerals. Tables 4 and 5 showed some alkyl and other substituents and their names respectively.

Table 4 shows the formulae for some alkyl groups and their names.

Table 4: Alkyl- substituents and their Names

Substituent	Name
$-CH_3$	Methyl
$-CH_2CH_3$ or (C_2H_5)	Ethyl
$-CH_2CH_2CH_3$ or (C_3H_7)	Propyl
$-CH_2CH_2CH_2CH_3$ or (C_4H_9)	Butyl

Table 5 shows some selected substituents and their names.

Table 5: List of Some other Substituents and their Names

Substituent	Name
-F	Floro
-Cl	Chloro
-Br	Bromo
-I	Iodo
-OH	Hydroxy
-NO_2	Nitro

Based on the explanations given earlier, the researcher guided the students to name and write aliphatic alkanes with substituents by replacing some of the hydrogen atoms in their main structures with some substituents using Tables 4 and 5.

Lastly, students were asked to name and write some the structures of some aliphatic alkanes bearing in mind the parent root, prefixes and substituents without using the molecular models. For example 3-ethyl-3, 4-dimethylhexane was written as illustrated in Figure 8.

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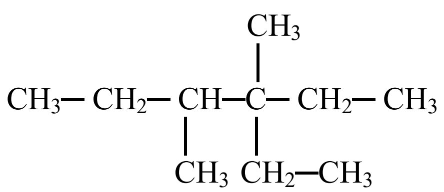

Fig 8: Structure of 3-ethyl-3,4-dimethylhexane

Second Week

Alkenes and Alkynes

In order to guide students to identify alkene and alkyne compounds, the researcher explained to them that alkenes and alkynes are the other two types of hydrocarbons with the general formulae of C_nH_{2n} and C_nH_{2n-2} respectively. Students were led to identify the functional group of alkenes as C ═ C bond and for alkynes as C ≡ C bond. They were guided to understand that from alkanes to alkenes, the number of hydrogen atoms decreased by two (2) and from alkenes to alkynes also by other two (2) as such there would be a double bond in alkenes and a triple bonds in alkynes to cater for the two (2) hydrogen atoms and the four (4) hydrogen atoms respectively since two electrons are represented by a single bond.

Students were guided to build the structures for the first five molecules of both aliphatic alkene and alkyne using the model kits in their groups. They were asked to follow the procedures used in building the alkanes. Students were asked to name some alkene and alkyne compounds but were however taught that, for alkenes and alkynes if the number of carbon atoms was more than two (2) then the position of the double and triple bonds must be identified as a number in naming the molecule. The students were led to indicate dashes (─) between figures and alphabets when naming alkenes and alkynes. For example, the molecules ($CH_3CHCHCH_2CH_2CH_2CH_3$) and ($CH_3CCCH_2CH_2CH_2CH_3$) were called 2 ─ heptene or hept–2– ene and 2 ─ heptyne or hept–2– yne respectively. The researcher explained to the students that the double bond and the triple bond were between the second and the third carbon atoms in each case, hence the least number which was two (2), must be used

Third Week

Alkanols (Alcohol)

In this lesson, the researcher explained to students that alkanols have a general formula of (C_nH_{2n+1} OH), where (n) is the number of carbon atom(s) in the molecule and (-OH) the hydroxyl group is their functional group.

The researcher explained to students that the prefix in alkanols is obtained by removing the “e““‘ending of their corresponding alkanes and the sufix “-ol” is added to obtain the parent name. To achieve this, students were guided to remove one hydrogen atom from built up alkanes such as CH_4, C_2H_6 and C_6H_{14} and replace them with (-OH) to obtain CH_3OH, C_2H_5OH and $C_6H_{13}OH$ respectively. Students were guided on how to name their built up alkanols by using the prefix of their corresponding alkanes by removing the last letter (e) and replacing them with (ol), hence the names methanol, ethanol and hexanol were given to CH_3OH, C_2H_5OH and $C_6H_{13}OH$ respectively by the students.

Students were also led to name and build alkanols with substituents just as it was done in naming the alkane. For example the compound in Figure 9 was named as 2-bromo-3-methyl-2-butanol or 2-bromo-3-methylbutan-2-ol.

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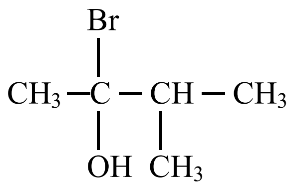

Fig 9: Structure of 2-bromo-3-methyl-2-butanol or 2-bromo-3-methylbutan-2-ol.

Students were guided to name and build polyhydric alkanols. They were taught that for these alkanols, the corresponding alkanes are named, the positions of the –OH group indicated, and diol, triol, tetraol, added for two, three, four, –OH group present. For example, the compound in Figure 9 was named as 2-methylpropan-1, 2-diol

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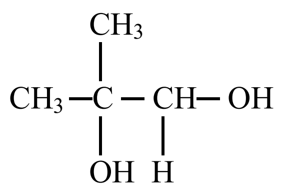

Fig 10: structure of 2-methylpropan-1, 2-diol

The researcher led students in discussions based on their findings.

Fourth Week

Alkanoic Acids (Carboxylic acids)

The researcher in her lesson explained to students that carboxylic acids or alkanoic acids have the general formula, $C_nH_{2n+1}COOH$ or R-COOH and the functional group for alkanoic acids is (COOH) carboxyl group. R= C_nH_{2n+1} or alkyl group. The carboxyl group (-COOH), consists of a carbon atom bonded by a double bond to an oxygen atom and by a single bond to a hydroxyl group (-OH).

Students were taught that the parent name is obtained from the prefix by removing the “e‘‘‘‘ ending of their corresponding alkanes and the suffix “oic acid” added. The students were guided by the researcher to build structures of compounds such as pentanoic acid, octanoic acid etc after they were informed that alkanoic acids are formed when the last hydrogen atom at the end of an alkane is removed and replaced with COOH. They were guided in naming some substituents just as in alkanes and alkanols. They were also told to use dioic, trioic, tetraoic, after indicating their position when more than one –COOH group are present. For example students were able to build 2-ethyl-1, 3-propanedioic acid as shown in Figure 11.

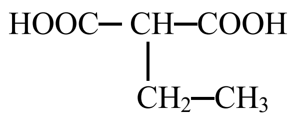

Fig 11: Structure of 2-ethyl-1, 3-propanedioic acid

Students finally named and wrote structures of some aliphatic alkanoic acids using their molecular model kits and this proceeded with class discussion.

Fifth Week

Alkanoates

For students to identify, name and write the structures of alkanoates effectively, they were guided that these compounds have the general formula $C_nH_{2n+1}COOC_nH_{2n+1}$ or $RCOOR^1$, where R and R^1 are alkyl groups. The researcher explained that alkanoate functional group is —COO— and this consists of a carbon atom bonded by a double bond to an oxygen atom and singly bonded to another oxygen atom which has a single bond with an alkyl group.

Students were equally taught that alkanoates are formed from the reaction between an alkanol and an alkanoic acid where the hydrogen atom in the acid‟s functional group (COOH) has been replaced by an alkyl group from an alkanol. The researcher led students to use the molecular model kits to build the alkanoates such as $CH_3CH_2COOCH_2CH_3$), $CH_3COOCH_2CH_3$) and $C_5H_{11}OOCCH_3$).

The students were guided that in naming alkanoates, the parent name has prefix obtained by naming the alkyl group from the alkanols that formed it, and adding the corresponding alkane name from the alkanoic acid portion without the “e” but rather with the functional suffix "-oate". Students were asked to name their built up structure above and they indicated them as Ethylpropanoate, Ethylethanoate and Pentylethanoate respectively.

Students were guided to use their model kits to do more practice with substituents after the researcher explained that they are named following the usual rules either for the alkyl portion or the alkanoic portion. Examples are given in Figure 12a and 12b.

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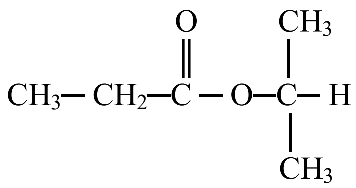


Fig 12a: 2-methylethylpropanoate

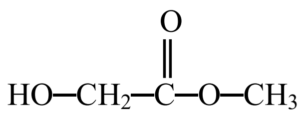


Fig 12b: methyl-2-hydroxyethanoate

Students were guided to classify some compounds enumerated by the researcher in to the classes of aliphatic organic compounds studied based on their functional groups. This proceeded with class discussion.

Post-intervention Stage

At this stage, the post-intervention test named Test 2 of comparable standards as the pre-intervention test (Test 1), was administered to the students under study. Procedures and conditions for the test 1 were repeated during the post-intervention test. This was done to compare students" performance and find out if there was any improvement in classification, naming and writing of the structures of aliphatic organic compounds after caring out the intervention activities using the molecular models.

A questionnaire was also administered to the students to find out their views on the use of molecular model kits as instructional materials in teaching the IUPAC system of naming and writing of aliphatic organic compounds.

Data Analysis Procedures

Descriptive statistics in the form of simple percentages, frequency counts, means and standard deviation were used to answer the research questions on the performance and difficulties of Chemistry students in classification, naming and writing the structural formulae of the aliphatic organic compounds. However, sample wrong answers of the selected students that were interviewed were presented and discussed to ascertain the difficulties the students encountered.

Analysis of students‟ responses to the various questions in the Test 1 and Test 2 was based on the following:

- Students‟ difficulties
- Classification based on functional groups
- Writing of IUPAC names
- Writing of formulae

There was an overall analysis of the test 1 and the test 2 using paired t-test with alpha value of (α = 0.05) to determine if there was any significance improvement in the performance of the students after the intervention strategies.

Statistical Package for Social Science (SPSS) version 20 was used to analyse students‟ responses to the questionnaire on a five point Likert type scale which helped to determine the mean value. Inferences drawn from the statistical analysis results were used to answer research question 6.

CHAPTER FOUR

RESULTS AND DISCUSSION

Overview

The purpose of this study was to enhance SHS 2 Home Economics students"ability in the classification, naming and writing of the structures of aliphatic organic compounds using molecular models. In this chapter, findings from the study were presented and discussed in relation to the six research questions. The discussions of these research questions were based on analysis of data obtained from achievement tests (both pre-intervention test and post-intervention test), informal interview and questionnaire.

1. What difficulties do the second year Home Economic students of EPC Mawuko Girls" SHS encounter when classifying, naming and writing the structures of aliphatic organic compounds?
2. What will be the effect of molecular models on the students" ability to classify aliphatic organic compounds based on their functional groups?
3. What will be the effect of molecular models on the students" ability to write the structures of aliphatic organic compounds?
4. What will be the effect of molecular models on the students" ability to name the structures of aliphatic organic compounds?
5. Is there any significant difference between the mean pre-intervention test score of the students and their mean post-intervention test score?
6. What views do the students hold on the use of molecular model kits as instructional materials?

Presentation of Results by Research Questions

Research Question One: What difficulties do the second year Home Economic students of EPC Mawuko Girls' SHS encounter when classifying, naming and writing the structures of aliphatic organic compounds?

This research question was meant to find out difficulties students encountered when classifying, naming and writing the structures of aliphatic organic compounds before the intervention. To show this, the researcher categorised the test items into:

a. Classification of aliphatic organic compounds (A)
b. Naming of aliphatic organic compounds (B)
c. Writing the structural formulae of the aliphatic organic compounds (C and D)

Students" performance however was presented for each of the 25 test items in figure 13 and it was observed that there were differences in the difficulty level of the items scores. Items of which less than 50.0% of the students provided the correct answers were considered difficult. Analysis of figure 13 showed that many of the students provided wrong answers for the test items in all the categories. Tables 6, 7, 8a and 8b contain wrong answers provided by the selected students who were interviewed in all the three categories stated above. The discussion of these wrong answers brought out clearly the difficulties that students faced.

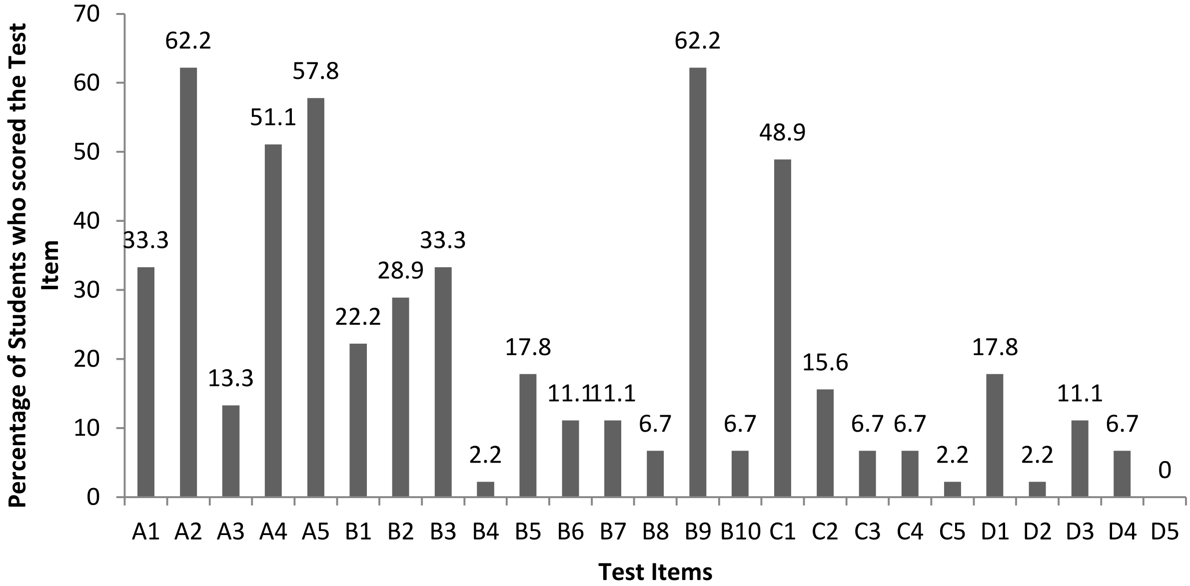


Figure 13: Bar Chart Showing Students' Performance in the Pre-intervention Test (Test 1).

Table 6: Wrong Classes Provided for Category A compounds by Some Students

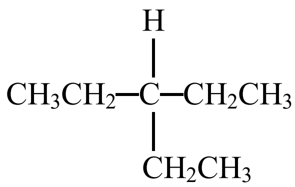
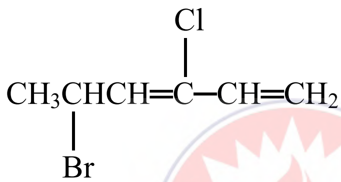
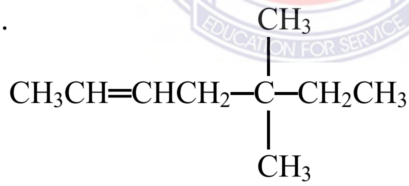
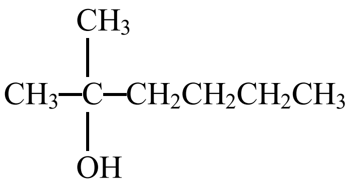
Compound/Item	Wrong Class	Number of Student (N)	Percentage
$CH_3CH_2CHOHCH_3$	Alkanoic acid	1	20
A1	Alkanoate	2	40
$CH_3CH_2COOCH_3$ (A3)	Alkanoic acid	5	100
CH_3CH_2COOH	Alkanol	3	60
A5	Alkanoate	1	20

N = 5

Students' Difficulties:

- Inability to identify functional groups in a given structure of organic compound.

Table 7: Wrong Names Provided for the Compounds in Category B by Some Students

Item number	Test Item	Wrong answers
1	$CH_3C(CH_3)_2CH_3$	a. Pentane b. 2-methylpropane c. 2,3-diethyl-2-butene
2		a. 2-ethyl-2-methylpentane b. 2-ethylpentane c. Heptane d. pentane
3	$CH_3CH{=}CHCH_3$	a. Propyl b. But-1-yne
4		a. 2-bromo,4-chlorohexene b. 3-chloro-5-bromohexene c. 2-bromo3-chlorohexene d. 2-bromo-4-chlorohexene
5	$CH_3(CH2)_7C{\equiv}CH$	a. Nonyl b. 1-methyloctane c. 1-but-yne
6	. 	a. 5-methyl-5methyl2-heptene b. 5-methyl-octene
7		a. 2-methyl,2-hydrohex-ene b. Hexanol c. 2-methylanoate hexane
8	$HOCH_2(CH_2)_4OH$	a. 1-ethanol b. Pentanol c. 1,4-pentanol
9	CH_3COOH	a. Methanoic acid b. Ethanoic c. Methanol
10	. $CH_3CH_2COOCH_3$	a. 3-butanoic b. Hexanoic c. Butanoic acid d. Buthanol

Students' difficulties:

- Inability to identify the number of carbon atoms in the longest continuous chain.
- Inability to identify some of the atoms or groups of atoms in the structural formula of a compound as substituents.
- Challenges in assigning correct positions of the constituents on the carbon atoms that bore the substituents.
- Inability to keep to the alphabetical order of naming substituents
- Difficulty of identifying, naming (suffix) and locating the positions of functional groups correctly.
- Inability to use prefix such as di, tri, tetra, for two, three, four or identical functional groups and substituents.
- Difficulty of separating numerals from numerals and numerals from words using commas and hyphens respectively.

Table 8a: Wrong Structural Formulae Provided for the Named Compounds in Category C by Some Students

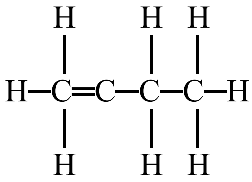
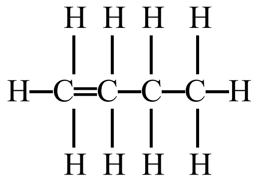
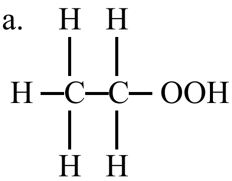
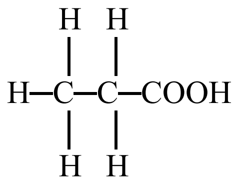
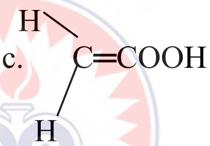
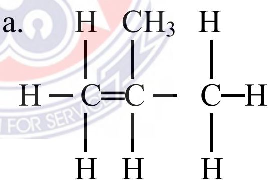
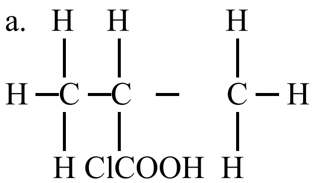
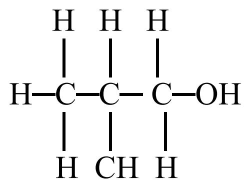
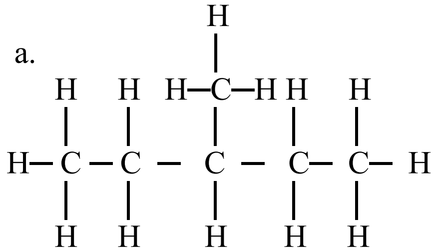
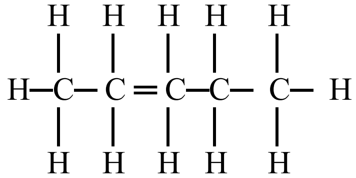
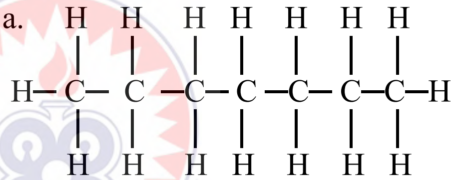
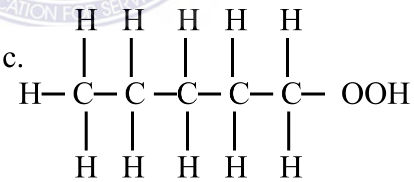
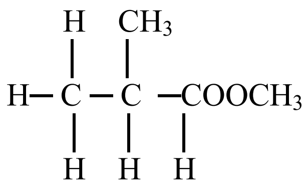
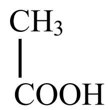
Item number	Compound	Structural formula (expanded)
C1	2-methylheptane	$CH_3C(CH_3)CH_2CH_2CH_2CH_2CH_3$
C2	But-1-yne	 b. 
C3	Ethanoic acid	a.  b.  c. 
C4	2-methylpropan-1-ol	a.  b. $CH_3C(CH_3)COH$
C5	Propyl-2-chloroethanoate	a.  b. 

Table 8b: Wrong Structural Formulae Provided for the Named Compounds in Category D by Some Students

Item number	Compound	Structural formula (expanded)
D1	Hexane	a.  b. C_6H_{14}
D2	Pent-2-ene	a.  b. C_5H_{12} c. $CH_3CHCH_2CH_2CH_3$ d. $CH_3CH{=}CH_3$
D3	Heptan-2-ol	a.  b. $C_7H_{19}OH$
D4	Pentanoic acid	a. $CH_3(CH_2)_2COOCH_3$ b. C_5H_2OOH c. 
D5	Methyl methanoate	a.  b.  c. CH_3CH_3OOH

Students' difficulties:

- Difficulty of differentiating between expanded structural, condensed structural, and molecular formulae of a compound.

- Inability to indicate correct functional groups or attach the functional group to the correct carbon atom in the longest continuous chain.
- Some students failed to indicate covalent bonds, number of atoms of each element and the chemical formulae of named substituents correctly.

Research Question Two: What will be the effect of molecular models on the students' ability to classify aliphatic organic compounds based on their functional groups?

This research question sought to find out the effect of molecular models on the students" ability to classify aliphatic organic compounds based on their functional groups. Table 9 contains the number and percentage of students who responded to the test items.

Table 9: Percentage Representations of the Students' Responses on Classification of Aliphatic Organic Compounds Based on Identification of Functional Groups

		Pre-Intervention Test (100%)			**Post-Intervention Test (100%)**		
S/N	Item	Correct Response n (%)	Wrong Response n (%)	No Response n (%)	Correct Response n (%)	Wrong Response n (%)	No Response n (%)
1	$CH_3CH_2CHOHCH_3$	15 (33.3)	30 (66.7)	0(0)	44 (97.0)	1 (2.2)	0(0)
2	$CH_3CH_2CH_2CH_3$	28 (62.2)	17 (37.8)	0(0)	45 (100)	0(0)	0(0)
3	$CH_3CH_2COOCH_3$	6 (13.3)	39 (86.7)	0(0)	38 (84.4)	7 (15.6)	0(0)
4	$CH_2{=}CH_2$	23 (51.1)	22 (48.9)	0(0)	42 (95.3)	3 (6.7)	0(0)
5	CH_3CH_2COOH	26 (57.8)	19 (42.2)	0(0)	43 (95.6)	2 (4.4)	0(0)

In all the five items shown in Table 9, the number of students who answered each item correctly was consistently lower in the pre-intervention test than in the post-intervention test. While 15 students 33.3% answered item one in the pre-intervention test correctly, in the post-intervention test, 44 (97.0%) students answered the same item correctly. Again, 28(62.2%), 6(13.3%), 23(51.1%) and 26(57.8%) were recorded in the pre-intervention test as against 45(100%), 38(84.4), 42(95.3) and 43(95.6%) in the post intervention test.

Moreover the data from Table 10 showed that the mean score for the pre-intervention test was 2.18 and the mean score for the post- intervention test was 4.69. The mean difference of the two test scores was 2.51. It was clear that the mean score for the post-intervention test was greater than the mean score for the pre-intervention test. That meant students were able to classify aliphatic organic compounds easily using the functional groups after the intervention. See Appendix G for the raw scores.

Table 10: Summary Statistics of Pre-intervention Test and Post-intervention Test Scores with respect to the Use of Functional Groups in Classification of Aliphatic Organic Compounds

Pre-Intervention Test	**Scores**	**Post-Intervention Test**	**Scores**
Mean	2.18	Mean	4.69
Standard deviation	1.37	Standard deviation	0.51
Range	5	Range	2
Minimum	0	Minimum	3
Maximum	5	Maximum	5

Research Question Three: What will be the effect of molecular models on the students' ability to write the structures of aliphatic organic compounds?

Research question three was meant to determine the effect of molecular models on the students" ability to write the structures of aliphatic organic compounds. Table 11 contains data on students" responses to items on structures of aliphatic organic compounds after they were taught using the molecular model kits strategy.

Table 11: Percentage Representations of the Students' Responses on Writing of Aliphatic Organic Compounds based on the Use of Molecular Models

		Pre- Intervention Test (100%)			**Post-Intervention Test (100%)**		
SN	Item	Correct Response n (%)	Wrong Response n (%)	No Response n (%)	Correct Response n (%)	Wrong Response n (%)	No Response n (%)
1	2-methylheptane	22 (48.9)	17 (37.9)	6 (13.3)	39 (86.7)	6 (13.3)	0(0)
2	but-1-yne	7 (15.6)	28 (62.2)	10 (22.2)	33 (73.3)	12 (26.7)	0(0)
3	Ethanoic acid	3 (6.7)	32 (71.1)	10 (22.2)	27 (60)	17 (37.8)	1 (2.2)
4	2-methylpropan-1-ol	3 (6.7)	30 (66.7)	12 (26.7)	29 (64.4)	16 (35.6)	0(0)
5	Propyl-2-chloroethanoate	1 (2.2)	24 (53.3)	20 (44.4)	26 (57.8)	19 (42.2)	0(0)
6	Hexane	8 (17.8)	30 (66.7)	7 (15.6)	37 (82.2)	8 (17.8)	0(0)
7	Pent-2-ene	1 (2.2)	32 (71.1)	12 (26.7)	25 (55.6)	20 (44.4)	0(0)
8	Heptan-2-ol	5 (11.1)	20 (44.4)	20 (44.4)	32 (71.1)	13 (28.9)	0(0)
9	Pentanoic acid	3 (6.7)	24 (53.3)	18 (40.0)	29 (64.4)	16 (35.6)	0(0)
10	Methyl methanoate	0(0)	20 (44.4)	25 (55.6)	29 (64.4)	15 (33.3)	1 (2.2)

From table 11, most of the students either did not answer the pre-intervention test items or answered them wrongly. The last item (item 10) recorded 44.4% wrong responses and 55.6% no responses. This meant no student had this item correct. However, for the same item 64.4% of the students had it correct and only 1 student (2.2%) refrained from answering it in the post-intervention test. The number of students who answered the items correctly in the pre-intervention test was below 50% in each case. However, the number of students who answered the items correctly in the post-intervention test was above 50% in each case.

Table 12 also showed that the mean score for the pre-test (2.29) was higher than the mean score for the post-test (7.24) and the mean difference of the two test scores was 6.95. The analysis revealed that students" understanding of the structures of aliphatic organic compounds improved since most of the students performed well in the post-intervention test compared to the pre-intervention test. See Appendix H for the raw scores.

Table12: Summary Statistics of Pre-intervention Test and Post-intervention Test Scores with Respect to the Use of Molecular Models to Write the Structure of Aliphatic Organic Compounds

Pre-Intervention Test	Scores	Post-Intervention Test	Scores
Mean	2.29	Mean	7.24
Standard deviation	1.47	Standard deviation	1.40
Range	5	Range	5
Minimum	1	Minimum	5
Maximum	6	Maximum	10

Research Question Four: What will be the effect of molecular models on the students' ability to name the structures of aliphatic organic compounds?

This research question was meant to find out the effect of molecular models on the students" ability to name the structures of aliphatic organic compounds. Table 13 contains data on students" responses to items on naming of aliphatic organic compounds after they were taught using the molecular model kits strategy. To make the results simplified, the correct names of the various structures were used to represent the structural formulae of the compounds.

Table 13: Percentage Representations of the Students' Responses on Naming of Aliphatic Organic Compounds based on the Use of Molecular Models

		Pre- Intervention Test (100%)			**Post-Intervention Test (100%)**		
SN	Item	Correct Response n (%)	Wrong Response n (%)	No Response n (%)	Correct Response n (%)	Wrong Response n (%)	No Response n (%)
1	2,2-dimethylpropane	10 (22.2)	28 (62.2)	7 (15.6)	38 (84.4)	7 (15.6)	0(0)
2	3-ethylpentane	13 (28.9)	25 (55.6)	7 (15.6)	36 (80.0)	8 (17.8)	1 (2.2)
3	2-butene	15 (33.3)	22 (48.9)	8 (17.8)	43 (95.6)	2 (4.4)	0(0)
4	5-bromo-3-chlorohex-1,3-diene	1 (2.2)	40 (88.9)	4 (8.9)	23 (51.1)	22 (48.9)	0(0)
5	1-decyne	8 (17.8)	16 (35.6)	21 (46.7)	36 (80.0)	9 (20.0)	0(0)
6	5,5-dimethyl-2-heptyne	5 (11.1)	20 (44.4)	20 (44.4)	36 (80.0)	6 (13.3)	3 (6.7)
7	2-methyl-2-hexanol	5 (11.1)	26 (57.8)	14 (31.1)	41 (91.1)	3 (6.7)	1 (2.2)
8	1,5-pentandiol	3 (6.7)	13 (28.9)	29 (64.4)	27 (60.0)	16 (35.6)	2 (4.4)
9	Ethanoic acid	28 (62.2)	11 (24.4)	6 (13.3)	36 (80)	9 (20)	0(0)
10	Methylpropanoate	3 (6.7)	27 (60.0)	15 (33.3)	26 (57.8)	19 (42.2)	0(0)

From Table 13, it could be seen that the number of students who did not answer each of the items reduced in each case from the pre- intervention test to the post-intervention test. For the first five items in the pre-intervention test, 7 (15.6%), 7 (15.6%), 8 (17.8%), 4 (8.9%), 21 (46.7%) students did not answer the items while 0(0%), 1 (2.2%), 0(0%), 0(0%), 0(0%) students in the post-intervention test did not answer the items. Again, the number of students who answered each item correctly was consistently lower in the pre-intervention test than in the post-intervention test. While 10 students (22.2%) answered item one in the pre-intervention test correctly, 38 students (84.4%) answered the same item correctly in the post-intervention test. Again, the number of students who answered the items correctly in the post-test was more than 50% in each case. However, with the exception of one item (Ethanoic acid) which recorded 62.2%, the rest of the items recorded percentages below 50 in the pre-intervention test. The data in Table 14 revealed that students‟ understanding of the concept had improved with mean score for post-intervention test (M = 6.49) as against the mean score for pre-intervention test (M = 1.20), the mean difference was (5.29).

Table 14: Summary Statistics of Pre-intervention Test and Post-intervention test Scores with Respect to the Use of Molecular Models to Name Aliphatic Organic Compounds

Pre-Intervention Test	**Scores**	**Post-Intervention Test**	**Scores**
Mean	1.20	Mean	6.49
Standard deviation	1.09	Standard deviation	1.34
Range	4	Range	6
Minimum	0	Minimum	4
Maximum	4	Maximum	10

The mean score for the post-intervention test is greater than the mean score for the pre-intervention test (M-Post-intervention test > M – Pre-intervention test). This shows an improvement in students" understanding of the concept after the intervention. See Appendix I for the raw scores.

Research Question Five: Is there any significant difference between the mean pre-intervention test score of the students and their mean post-intervention test score?

In order to determine whether there was a significant difference between the performance of students" in the pre-intervention test and in the post-intervention test after teaching them with the molecular models, the students" overall pre-intervention test score and their overall post-intervention test score were analysed using a paired t-test with confidence level of 0.05. The results are shown in Table 15.

Table 15: Summary Statistics and Paired T-test results of Students Overall Scores in Pre-intervention Test and Post-intervention Test

Item	Mean	Mean Dif	SD	N	T	DF	Sig(2-tailed)
Pre-intervention test scores	5.60		2.965	45			
		12.778			-19.956	44	0.000*
Post-intervention test scores	18.38		2.480	45			

*** = Significant (P<0.05)**

According to the analysis, the mean score for post-intervention test (18.38) was greater than the mean score for pre-intervention test (5.60); the mean difference was

(12.778); M – Post-intervention test > M – Pre-intervention test. It was deduced from Table 15 ($p=0.000$) that the mean difference between the mean pre-intervention test score and the mean post-intervention test score was statistically significant since p-value was lesser than 0.05 ($p < 0.05$). The students performed better in the post-intervention test than the pre-intervention test. This means that the intervention adopted yielded a positive result by enhancing the students" ability to classify, write and name the structures of aliphatic organic compounds. See Appendix J for the overall scores.

Research Question Six: What views do the students hold on the use of molecular models as instructional materials?

This question sought to determine the views the students held about the use of molecular model kits as instructional materials. Table 16 contains the mean score of students who agreed or disagreed with the assertions made in the questionnaire. See page 79 for Table 16 on page 78.

Table 16: Students' Views about the Use of Molecular Models in Teaching Aliphatic Compounds

SN	Item	SA n (%)	A n (%)	U n (%)	D n (%)	SD n (%)	Mean	STD
1	The use of molecular model kits in teaching the names of aliphatic organic compounds motivates learners.	38 (84.4)	7 (15.6)				1.16	.367
2	The use of molecular model kits in teaching and learning of the structural formula of aliphatic organic compound makes the lesson more interesting.	35 (77.8)	10 (22.2)				1.22	.420
3	The molecular model kits help me to improve upon the understanding of the naming of structures of aliphatic organic compounds.	31 (68.9)	14 (31.1)				1.31	.468
4	The use of molecular model kits in teaching the structural formula of aliphatic organic compound was self-explanatory.	26 (57.8)	16 (35.6)	3 (6.7)			1.47	.626
5	It was difficult using molecular model kits for teaching and learning of the structures of aliphatic organic compounds.	1 (2.2)	6 (13.3)	2 (4.4)	5 (11.1)	31 (68.9)	4.31	1.184
6	It was boring using molecular model kits for the teaching and learning of the names of aliphatic organic compounds.	2 (4.4)	5 (11.1)	12 (26.7)	12 (26.7)	24 (53.3)	4.13	1.198
7	Using molecular model kits in teaching the structures of aliphatic organic compounds makes the lesson abstracts.		2 (4.4)	2 (4.4)	16 (35.6)	25 (55.6)	4.13	1.I98
8	The molecular model kits facilitate individual or group learning.	28 (62.2)	12 (26.7)	3 (6.7)	1 (2.2)	1 (2.2)	1.56	.893
9	The molecular model kits can be used with little or no help.	19 (42.2)	20 (44.4)	2 (4.4)	2 (4.4)	2 (4.4)	1.84	1.021
10	The use of molecular model kits during the teaching and learning of the structures of aliphatic organic compounds makes me participate actively in the lesson.	29 (64.4)	16 (35.6)				1.36	.484
11	At anytime and anywhere, the molecular model kits can be used.	14 (31.1)	20 (44.4)	6 (13.3)	3 (6.7)	2 (4.4)	2.09	1.062
12	It is friendly using molecular model kits in teaching and learning the names of aliphatic organic compounds.	30 (66.7)	13 (28.9)	2 (4.4)			1.38	.576

Mean scores below 3 meant strongly agreed or agreed and mean scores above 3 meant disagreed or strongly disagreed. A mean score of 3 means undecided. It could be seen from Table 16 that majority of the students strongly agreed or agreed that the use of molecular model kits in teaching the names of aliphatic organic compounds motivated them (M=1.16) and made the lesson more interesting (M=1.22). The molecular models helped students to improve upon the understanding of the naming of structures of aliphatic organic compounds (M=1.31), facilitated individual or group learning (M=1.56) and could be used with little or no help (M=1.84). The use of molecular models during the teaching and learning of the structures of aliphatic organic compounds made students participated actively in the lesson (M=1.36) and it is user friendly (M=1.38).

The students however disagreed that it was difficult using molecular models for learning of the structures of aliphatic organic compounds (4.31), made the lesson abstract (4.13) and boring (4.13).

Students were also given open ended items to show their perception on the use of the molecular model kits in teaching the names and writing the structures of aliphatic organic compounds. This was meant to allow for free expression about their perception. They were made to respond to the items as „YES", UNCERTAIN and „NO" with reasons. Their reasons were grouped under five (5) main themes. The researcher deemed the grouping necessary because the researcher realised that similar ideas had been expressed in different language forms by individual respondent.

Table 17 shows the summary of open-ended response from the students. From Table 17, 43 students (95.6%) appreciated the use of molecular models in teaching the names and writing the structures of aliphatic organic compounds.

Table 17: Summary of Open-ended Response from Students

Responses	Frequency	Percentage
Yes	43	95.6
No	-	-
Uncertain	2	4.4
total	45	100

Also, 2 students (4.4%) from Table 17 were indecisive with a reason that they were not regular during the intervention stage (Appendix K, sample 5). However, there was no objection to the use of the molecular model kits as instructional material. There was therefore a positive indication from the respondents on the use of molecular model kits as a good instructional material.

Table 18: Summary of Students' Reasons for their Choice to the Open ended Question

Reason	Frequency (n)	Percentage
real and interesting	5	11.1
easy and understanding	25	55.6
motivate and interesting	5	11.1
participate actively	8	17.8
not regular in class	2	4.4
Total	**45**	**100.0**

From Table 18, this group of respondents believed that the use of the molecular model kits made the lessons real and interesting (n=5, 11.1%), easy and understanding (n=25. 55.6%), interesting and motivated (n=5, 11.1%) and finally made them active participants (Appendix K, samples 1, 2, 3 and 4 respectively)

Discussion of Results

The data collected from the achievement tests (pre and post-intervention tests), informal interview and questionnaire were discussed in line with the six research questions.

Difficulties students encountered when classifying, naming and writing the structures of aliphatic organic compounds by IUPAC nomenclature and reasons for the difficulties

The difficulties faced by the students who took part in the study were presented in terms of the three categories noted earlier (A, B and C & D). Each category included alkanes, alkenes, alkynes, alkanols, alkanoic acids and alkanoates.

Students‟ difficulties in the classification of aliphatic organic compounds based on functional group were measured with test items A1 to A5. From Figure 13, the findings showed that majority of the students did not find it difficult to provide correct classes to items A2 (alkane), A4 (alkene) and A5 (alkanoic acids).This was because the percentage scores for these items were above 50%. However, item A1 was difficult (33.3%) and A3 recorded the least percentage of 13.3%. Again of the selected students who were interviewed, all of them classified item A3 (alkyl alkanoate) as alkanoic acid representing 100% and three students classified item A5 as alkanols (Table 6). The results revealed that the students could not differentiate between these three classes (alkanols, alkanoic acids and alkyl alkanoate) of aliphatic organic compound. This could be due to the relatively long time and attention given to the teaching of IUPAC nomenclature of hydrocarbons as compared to the other areas of organic compounds and the inability of the students to identify the various functional groups on which organic compounds are classified. This finding agreed with those made by Worsor, (2015) and Adu-Gyemfi, (2011) that locating the functional groups and their positions was one major problem faced by SHS students in the naming of organic compounds by the IUPAC principle.

Test items B1 to B10 were used to identify students" difficulties in naming aliphatic organic compounds. The findings from this study showed that many of the students named item B9 (CH_3COOH) correctly with a percentage of 62.2%. This might be due to the frequent use of the acid in the laboratory especially during the preparation of buffer solution. However, many of the students found it difficult to name the rest of the test items. For example, only 2.2% of them were able to name item B5 correctly as 5-bromo-3-chloro-1, 3- diene. Analysis of the wrong answers given by the selected students who were interviewed revealed their difficulties.

One major difficulty identified from the result was the identification of the number of carbon atoms present in the longest continuous chains. This was because item B1was named as pentane instead of 2,2-dimethylpropane since the student counted all the carbon atoms of the group in the bracket ($(CH_3)_2$) within the structure of the molecule as part of the parent chain. Again, item B2 was named by a student as heptane instead of 3-ethylpentane because she failed to identify one of the ethyl groups that were bonded to the third carbon atom as a substituent and counted the two carbon atoms in addition to the parent structure. A student who named item B5 as 1-methyloctane in place of Dec-1-yne or 1-decyne when interviewed said she considered the methyl group attached to $(CH_2)_7$ as a substituent hence she did not count the carbon atom as part of the parent structure.

Findings from Table 7 (page 67) also showed that the students faced some difficulties in identifying, naming and locating the substituents on parent structures of aliphatic organic compounds. For example, the structure in items B1 and B2 were respectively named wrongly as pentane and heptane instead of 2, 2-dimethylpropane and 3-ethylpentane. This implies that the students did not identify the two methyl groups located on the second carbon atom in B1 and the ethyl group on the third carbon atom as a substituent in B2. However, one student ignored the presence of ethyl substituent on B2 and named the item as pentane hence, the problem of substituent identification. Item B2 was again named by one other student as 2-ethylpentane. This was an indication of wrong position of the ethyl substituent because the substituent was on the third (3) carbon atom and not the second (2) one.

The results of the study also indicated that the students had difficulty in naming compounds with two or more substituents. Taking item B6 as an example, the student who named it as 5-methyl-5methyl 2-pentene instead of 5, 5-dimethyl-2-heptene did not identify the two methyl groups as identical substituents hence she failed to use the prefix „di"to indicate that the methyl groups were two in number. The item B4 with its wrong answers revealed that the students had difficulty of which constituent should be named first, thus they could not name them alphabetically. The student who named it as wrong answer b should have named the –Br substituent before the –Cl. Also, the students were not able to identify the position of –Br as 5th position as in wrong answers a, c and d. This could be due to the fact that, the counting of the carbon atoms in the longest continuous chain was done in such a way to assign the possible position to the substituents which is not acceptable in the IUPAC naming of alkene (double bond). The students had failed to consider the position of the double bond before numbering the carbon atoms from left.

The study also confirmed that the students had difficulty of identifying, naming (suffix) and locating positions of functional groups correctly. Sample answers of item B10 showed that the students could not identify the compound as belonging to the alkanoate functional group since three of the sample wrong answers showed it as alkanoic acid because of the presence of the –COO and the fourth answer indicated it as an alkanols which is a total misconception due to inadequate ideas on functional groups. Considering items B4 and B8 answers, three of the students that were interviewed named them as –ene and –ol instead of diene and diol respectively. Their reason was that they were used to one multiple bonds (double bond) and one hydroxyl group in organic compounds which were suffixes of alkene (–ene) and alkanols (–ol) respectively. Again, wrong answers a and c of item B9 (Page 67) showed that those students did not consider the carbon atom bearing the O and OH groups as carbon atom one as they have taken it as parts of the carboxylic functional group. Consequently, they failed to count it. This was due to inadequate knowledge on the IUPAC rules on naming of alkanoic acids. One student who named the B9 as butanoic acid gave a reason that in numbering the carbon atoms, the functional groups are not counted. However, the student who named it as ethanoic omitted the suffix acid as she forgot to write it.

From Table 7, test item B4 revealed a student‟s inability to use hyphen to separate words from numerals. The student had failed to put hyphen between the word bromo and the numeral 4 in sample wrong answer a rather she used comma which is used for separating numeral from numeral.

The difficulties students encountered when writing both the expanded and the condensed structural formulae of aliphatic organic compounds were measured with item C1 to C5 and items D1 to D5. The findings revealed that majority of the students found it difficult to write the structural formulae of the named compounds as the highest score item (C1) recorded only 48.9% of the total participants of the study and none of the students was able to write the condensed formula of item D5.

The study proved that the students had difficulty in differentiating between expanded structural, condensed structural, and molecular formulae of aliphatic organic compounds. The wrong answers a of C1 and b of C4 were seen as practical evidences where students wrote the condensed formulae of the items in place of their expanded structural formulae. Again, answers a and b of D1, a and b of D3 and c and d of D4 (Page 70) represented the expanded structural and molecular formulae respectively of the named compounds. Here the students failed to write the condensed formulae of the compounds as required by the question.

From Table 8a, the findings showed the students" inability to indicate covalent bonds correctly. For example, the first carbon atoms in the wrong answers a and b of item C2 and the carbon atom 1 and atom 2 of wrong answer a of item C4 had extra one bond making each carbon atom a pentavalent atom. Again, the second carbon atom of wrong answer a of item C2 lacked one bond and one other atom making the carbon atom a trivalent atom. Also, the sample wrong answer c and d of item D2 (Table 8b) had their carbon atoms three and one respectively as pentavalent atoms. This clearly suggested that the students had inadequate understanding of the concepts of valency and the octet rule in bonding atoms.

From Table 8a, the structural formula of ethanoic acid were written wrongly in three ways in which the students failed to indicate the covalent bonds in the –COOH functional group as in the marking scheme. However, the analysis of answer a showed that the student thought that indicating a bond between the carbon and the OOH (C-OOH) made the compound as an acid. Thus, the student did not know the expanded structural formula of the alkanoic acids functional group.

The findings of Table 8a showed that the students had difficulty in showing correct functional groups or attaching the functional groups to the correct carbon atoms in the parent chain. This was seen in sample wrong answer a and b of item C2 where students indicated double bond(an alkene functional group) for triple bond(an alkyne functional group) as demanded by the question. Again, a student who introduced a double bond into the structure of C3 (ethanoic acid) when interviewed claimed that the carbon atom bearing the two hydrogen atoms in the answer needed two other bonds to attain its tetravalency, hence she did that. Also, the structure of the C4 was that of Alkanol but a student used double bond in place of hydroxyl group. Similar situations were seen in sample wrong answers a and b of C5 where –COOH and OH functional groups were used instead of RCOOR for alkyl alkanoate.

The answer b of C3 did not show correct number of carbon atom to be in the parent chain. Thus instead of two of the carbon atoms for an eth root, the student used three carbon atoms with the reason that the COOH is a functional group hence its carbon atom should not be counted. She therefore failed to show the right number of carbon atoms in the longest continuous chain.

The types of difficulties identified in some of the students‟ answers and the discussion clearly confirmed that they had problems in learning the rules governing the IUPAC nomenclature of organic compounds. It was also because the teaching of the functional groups, names and writing the structures of aliphatic organic compound were usually done in abstract, which generated many misconceptions in the students.

The findings gave credence to Peterson & Treagust‟s (1989) finding as well as Taber‟s (2001) finding that students often lack deep conceptual understanding of key concept connected with structure and chemical bonding. The findings further confirmed the reports of WAEC Chemistry Chief Examiners (2005-2015) in Ghana that most students showed weakness in IUPAC nomenclature of organic compounds.

Classification of aliphatic organic compounds based on functional groups identification

Findings made with respect to research question two revealed that students were able to identify functional groups and use this knowledge to classify aliphatic organic compounds. This was evident in the mean performance of the students in the post-intervention test scores compared to the mean performance of the students in the pre-intervention test. Thus, the mean score (2.18) of the pre-intervention test was less than the mean score (4.69) of the post-intervention test. This finding was similar to that reported by Ameko (2015) that the students he studied had good knowledge about functional groups as a guide for naming and drawing some aliphatic organic compounds after the intervention with the molecular models. Ameko (2015) indicated that the understanding of functional groups enabled his students to identify, draw and name some aliphatic organic compounds and this made them to develop interest and improved upon their understanding of the nomenclature of organic compounds.

The findings from the current study revealed that students‟ improved performance was due to the teaching strategy used. This was consistent with the assertion made by Ayoti and Poipoi (2013) that teaching and learning materials attracted the attention of students in what was taught and thus made it easier for them to understand what they were taught. This finding strongly confirmed the assertion that the concept of functional groups is central in organic chemistry, both as a means to classify structures and for predicting properties of reactions (Abbey, Ameyibor, Alhassan, Essiah, Fometu & Wiredu, 2001).

Skelly and Hall (1993) noted that if the learners prior conceptions needed to process a new information was incomplete, knowledge gaps would result in confusion, inaccurate reasoning and eventually in the formation of misconception. This current study had identified this confusion among the students in their attempt to classify the test items into alkanols, alkanoic acid and the alkyl alkanoates. However, the use of the molecular model at the intervention stage helped the students to eliminate the said confusion. Thus, the number of students who answered item A3 correctly had increased from 6 (13.3%) to 39 (86.7%). This performance supported Ameko"s (2015) statement that the use of well-organized molecular models in the teaching of abstract concept in organic chemistry can make learning effective and teaching very easy with marvellous output of work. This was perhaps the reason for the remarkable improvement in the students" mean scores of the post intervention test.

The effect of molecular models on the students' ability to write the structures of aliphatic organic compounds

The analysis of results from the study revealed that there was an improvement in the pre-intervention test score from a mean score of 2.29 and standard deviation of 1.49 for the pre-intervention test to a mean score of 7.24 and standard deviation of 1.4 for the post-intervention test having a mean difference of 4.95. The performance of the students after the intervention indicated that the intervention process was very successful. This might have resulted from the exposure of the students to the use of the molecular model kits as instructional materials. These kits were tangible and therefore helped to reduce the level of abstraction and brought some concreteness into the building of the structures of aliphatic organic compounds. These models allowed the students to visualise and conceptualise the spatial arrangement of the atoms and also the symbolic form of the structure representation (Barak & Dori, 2011).Thus, the molecular models helped to organise the student‟s conceptual structure in a particular direction to help in better understanding. This was in consonance with the assumption that tangible materials like structural models played important roles by supporting students when connecting the different levels of concept representations (Ferk, Vrtacnik, Blejec, & Gril, 2003) and supported by a study conducted by Coll, France, and Taylor (2005) which indicated that models provided useful representations of objects or actual situations that brought out the concepts that were learnt.

This study revealed that the use of the molecular models could serve as a better method of teaching the structure of organic compounds. This seemed to be supported by Ameko (2015) who reported a statistical significant difference between the use of molecular models 3D and the use of textbooks 2D and agreed with Teichert and Stacy‟s (2002) assertion that many studies conducted clearly revealed that the traditional approach to teaching structure and chemical bonding was problematic and generated many misconceptions among students.

The effect of molecular models on the students' ability to name the structures of aliphatic organic compounds

The research sought to find out the effect of molecular models on the students‟ ability to name the structures of aliphatic organic compounds. Evidence from the research showed that the use of the molecular model kits helped the students to understand the concept of naming aliphatic organic compounds. This supported Gage and Berliner‟s (1992) statement that the two primary benefits of using models as learning aids are to provide accurate and useful representations of concepts that are needed when solving problems in some particular area and to make the process of understanding in that area easier, since it is a visual expression of the topic.

The outcome of this study strongly confirmed that of Aina (2013) who was of the view that the absence of teaching and learning materials such as real objects, or pictures made it difficult for learners to understand and interpret communicated information but went contrary to Kozma and Russel (1997) assertion that the use of models, diagrams and equation had little or no impact on students" learning and their understanding of chemical concepts involving invisible entities. Thus, the use of molecular model kits had a meaningful effect on the students" ability to name structures of aliphatic organic compounds.

Difference in students, performance in the overall pre-intervention test score and overall post-intervention test score

The overall analysis of the students" results using the paired t-test with a confidence level of 0.05 indicated that students" understanding of the classification, naming and writing of structures of aliphatic organic compounds improved since there was statistical significant difference of the total post-intervention mean score over the total pre-intervention mean score. This indicated the effectiveness of the molecular model kits as useful aids designed to enhance students" ability in classifying, naming and writing the structural formulae of aliphatic organic compounds. The finding was in line with the assertion that the use of concrete models, pictorial representations, animations and stimulations was beneficial to students" understanding of chemical concepts (Tasker & Dalton, 2006).

However, the number of students who gave wrong responses to the various items in the post-intervention test implies that further work needs to be done. The students‟ performance could be influenced by many factors. Ayikoe‟s (2012) research work revealed that the performance of students depended on several factors including school environments, absence of teaching and learning materials and the students‟ weak chemistry background. Their wrong answers could be attributed to the inherent limitation posed by the model. Again, because no single model provides a total understanding of the structure and function of a molecule, each students understanding was reliant on realising the limitations and strengths of each teaching model (Hardwicke, 1995).

Students' views on the use of molecular models as instructional materials

The findings from the study revealed that the students had very good perceptions concerning the use of molecular models as instructional materials in teaching and learning of the names and structures of aliphatic organic compounds.

According to the students, they were motivated with the use of molecular models in learning the names and structures of aliphatic organic compounds because the models made the structure real and this made them developed interest and improved upon their understanding of the concept. The finding supported the views of Yarden and Yarden (2010) who argued that when teaching and learning materials such as molecular model kits are well organised in the classroom, they could have substantial positive effect on students‟ understanding of concept since they are potential aids that motivate and increase students‟ interest in the topic they never liked. According to Gardner (2010), "a picture is worth a thousand words". This suggested that molecular models as teaching and learning materials can make learning of chemistry interesting and enhance the quality of understanding.

It could be said that the students were comfortable with the use of the molecular model kits since they confirmed that it was user friendly, not boring and made them participate actively in the lesson. This agreed with the findings of Kundu and Tutoo (2004) that learning is considered an active process and not a passive observation, and that teaching aids could reduce boredom in students (Onasanya, 2004) thereby making the teaching and learning process to be much more interesting and enjoyable (Sieber & Hatcher, 2012). This finding also supported the contemporary belief in science education that learners need to be active learners rather than passive recipients of scientific concepts to be learnt meaningfully (Kwang, 2002). This implies giving learners‟ opportunity to acquire direct learning experiences through the manipulation of concrete objects.

The use of molecular models in the study was in line with the idea of constructivism as it motivated and sustained students‟ interest during practical work. This enabled them to acquire skills and first-hand information. The building and naming of aliphatic organic compounds engaged the students actively in experience-based learning, a key to the construction of new meaning (Merriam, Caffarella & Baumgartner, 2007).

On a whole the students had positive perceptions concerning the use of molecular models as instructional materials in teaching and learning of the names and structures of aliphatic organic compounds.

CHAPTER FIVE

SUMMARY, CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Overview

This chapter presented a summary of the findings made from the analysis of data, and the conclusion that could be draw based on the analysis made. It further outlined some recommendations and suggestions for further research studies.

Summary of Major Findings

The summary was done considering each of the research questions. The researcher identified a number of difficulties that second year Home Economics students of EPC Mawuko Girls" SHS faced when classifying, naming and writing the structures of aliphatic organic compounds. These difficulties affected their performance in the pre-intervention scores

Difficulties students encountered when classifying, naming and writing the structures of aliphatic organic compounds by IUPAC nomenclature and reasons for the difficulties

A. Classification of aliphatic organic compounds based on functional groups

1. Identification of functional groups in a given structure of a compound.

B. Naming of aliphatic organic compounds

1. Identification of the number of carbon atoms in the longest continuous chain.
2. Identification of some of the atoms or groups of atoms in the structural formula of a compound as substituents.

3. Assigning correct positions of the constituents on the carbon atoms that bore the substituents.
4. Keeping to the alphabetical order of naming of substituents.
5. Difficulty of identifying, naming (suffix) and locating the position of functional groups correctly.
6. The use of prefix such as di, tri, tetra, etc for two, three, four or etc identical functional groups and substituents.
7. Separation of numerals from numerals and numerals from words using commas and hyphens respectively.

C. Writing the structural formulae of the aliphatic organic compounds

1. Differentiating between structural, condensed, and molecular formulae of a compound.
2. Indicating the correct functional groups or attaching the functional group to the correct carbon atom in the longest continuous chain.
3. Indicating bonds, number of atoms of each element and the chemical formulae of named substituent correctly.

Classification of aliphatic organic compounds based on functional groups identification

The findings of the pre-intervention mean score and the post-intervention mean score showed that the post-intervention mean score was greater than the pre-intervention mean score. The mean scores were 2.18 for pre-intervention test and4.69 for post-intervention test. The result revealed a mean difference of 2.51 indicating a higher performance of students in the post-intervention test over the pre-intervention test. This meant, most students were able to identify the functional groups and used the knowledge to classify aliphatic organic compounds after the intervention process.

The effect of molecular models on the students' ability to write the structures of aliphatic organic compounds

The study revealed that there was an improvement in the pre-intervention test score from a mean score of 2.29 for the pre-intervention test to a mean score of 7.24 for the post-intervention test having a mean difference of 4.95. The students performed far better in writing of the Structures of Aliphatic Organic Compounds in the post-intervention test than in the pre-intervention test.

The effect of molecular models on the students' ability to name the structures of aliphatic organic compounds

The students" knowledge in naming of the aliphatic organic compounds using the IUPAC naming system had improved as a result of the use of the molecular model kits for teaching and learning at the intervention stage. This was because the post-intervention mean score of 6.49 was greater than the pre-intervention mean score of 1.2.

Difference in students' performance in the overall pre-intervention test score and overall post-intervention test score

The paired t-test analysis of the students overall pre and post-intervention scores revealed that their ability to classify, name and write the structures of aliphatic organic compounds had improved significantly due to the use of the molecular model kits. However, a look at the percentage of students who gave wrong responses to the various items in the post-intervention test suggested the use of other teaching aids along the molecular models.

Students' views on the use of molecular model kits as instructional materials

Students" perceptions were found to be positively related to their performance. From the study, the students showed high appreciation towards the use of molecular models in teaching and learning of classification, naming and writing of the structure of aliphatic organic compounds. Their appreciation motivated them to participate actively which in turn helped them improve upon their knowledge about the concept of classification, naming and writing of the structure of aliphatic organic compounds.

Conclusion

The study sought to enhance SHS 2 Home Economics students" understanding in classification, naming and writing of the structures of aliphatic organic compounds using molecular models and also intended to find out students" views on the use of molecular models in teaching the structural formulae and naming of aliphatic organic compounds.

The study revealed that senior high school chemistry students used in this study had not developed an appropriate conceptual understanding of the structure of aliphatic organic compounds and therefore encountered a lot of difficulties on the classification based on functional groups, IUPAC naming and writing of the structural formulae of the compounds. The findings lent credence to Peterson & Treagust (1989) and Taber"s (2001) statement that students often lack deep conceptual understanding of key concept connected with structure and chemical bonding.

The use of molecular models in teaching the concept of classification, naming and writing of the structure of aliphatic organic compounds in this research showed a marked improvement in the students" performance and therefore, was very effective.

The paired t-test analysis on the overall pre and post-intervention scores was significantly different as proved by the findings.

Lastly, the research findings revealed that the students had an overall positive perception concerning the use of molecular models as instructional material in the learning of the classification, naming and writing of the structural formulae of aliphatic organic compounds. It further indicated features of the molecular models that made it effective and suitable for teaching the concept. It was user friendly, facilitated individual and group learning and could be used with little or no help. These motivated them to participate actively during the intervention stage of the research.

Recommendations

Based on the findings of this study, the researcher made the following recommendations as essential issues for consideration:

1. As the students had difficulties in classification based on functional groups, IUPAC naming and writing of the structural formulae of aliphatic organic compounds, chemistry teachers need to develop more effective and innovative teaching methods to help students quit rote learning in favour of meaningful leaning. To ensure meaningful learning therefore, one needs to help students to become involved actively in constructing their knowledge by interacting extensively with material from their environment and organizing it in a way that could help them apply the needed information correctly and easily in the new situation.
2. All science teachers should be encouraged to use real life examples and analogies in teaching abstract concepts such as structure of aliphatic organic

compounds. Molecular models could help chemistry teachers to improve students‟ interests and attitude towards learning and help the student to conceptualise the classes, structures and the names of the aliphatic organic compounds.

3. Ministry of Education, in collaboration with Ghana Education Service and other related bodies in education should regularly and periodically organise workshops and in-service training for chemistry and integrated science teachers at the SHS level across the country on the use of modern models available in the teaching of the classes, structure and naming of aliphatic organic compounds including the mode of instruction. This would undoubtedly upgrade the teachers‟ knowledge and ensure effective means of teaching organic chemistry.

Suggestions for Future Research

- This research identified chemistry students‟ difficulties in classifying, naming and writing of the structures of aliphatic organic compounds and used molecular models to improve their performance. It also sought the perception of students in using the models as instructional material in the teaching and learning process. However, the study did not consider the Chemistry teachers‟ knowledge level and perception on the use of molecular models. It was therefore suggested that a future research is conducted to look into these issues.
- A similar study should be conducted with larger samples of male and female students in mixed SHS to find out differential performance in classifying, naming and writing of aliphatic organic compounds using molecular models. That the use of larger samples could give a wider view on the use of the

models in teaching and learning of the classes, names and structures of the compounds.

- Interested researchers could conduct research into the relative effectiveness of molecular models in the naming of inorganic compounds at the SHS level.

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APPENDIX A

ACHIEVEMENT TEST ON NAMING AND WRITING THE STRUCTURES OF ALIPHATIC ORGANIC COMPOUNDS ....TEST 1

Date... **TIME: 45Mins.**

Name of School: ....

This test is designed to find out your understanding of IUPAC nomenclature of aliphatic organic compounds. Please provide the responses in the spaces provided. Your identity is not required, and therefore you are to respond to the items to the best of your ability.

SECTION A

Classify the following compounds as alkane, alkene alkyne, alkanol, alkanoic acid or alkanoate.

i). $CH_3CH_2CHOHCH$...

ii). $CH_3CH_2CH_2CH_3$...

iii). $CH_3CH_2COOCH_3$..

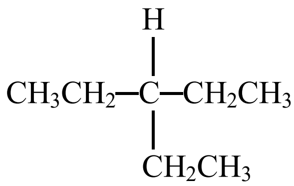
iv). $CH_{2=}CH_2$...

v). CH_3CH_2COOH..

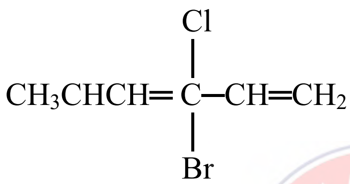
SECTION B

Give the correct IUPAC names of the following organic compounds:

1. $CH_3C(CH_3)_2CH_3$..

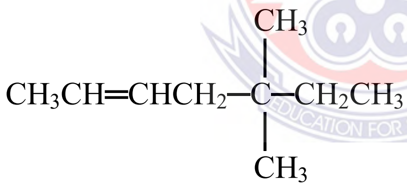
2.  ....

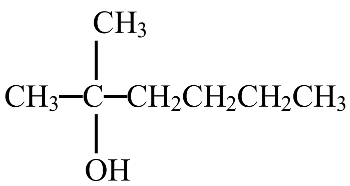
3. $CH_3CH{=}CHCH_3$ ....

4.  ....

5. $CH_3(CH_2)_7C{\equiv}CH$ ....

.

6.  ....

7  ....

8. $HOCH_2(CH_2)_4OH$ ....

9. CH_3COOH..

10. $CH_3CH_2COOCH_3$..

SECTION C

Write the expanded structural formulae of the following organic compounds:

2-methylheptane
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………………………………………………………….................

ii). But-1-yne
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
iii). Ethanoic acid

....
....
....

iv). 2-methylpropan-1-ol
....
....
....
v). Propyl-2- chloroethanoate

SECTION D

Write the condensed formulae for the following compounds:

1. Hexane
....
....
....
....

2. Pent-2 -ene
……………………………………………………………………………………..................
....
....
....
3. Heptan-2-ol
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

4. Pentanoic acid
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
5. Methyl methanoate
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

APPENDIX B

TEST 2 (POST-INTERVENTION TEST)

Date…………………………………………… TIME: 45Mins.

Name of School: ……………………………………………………….

ANSWER ALL QUESTIONS

SECTION A

Classify the following compounds as alkane, alkene alkyne, alkanol, alkanoic acid or alkanoate.

i). $CH_3CH_2CHOHCH$..

ii). $CH_3CH_2CH_2CH_3$…………………………………………………………………

iii). $CH_3CH_2COOCH_3$………………………………………………………………

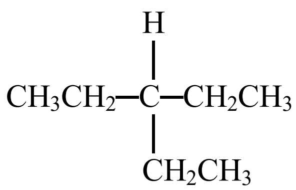
iv). $CH_2{=}CH_2$..

v). CH_3CH_2COOH…………………………………………………....................

SECTION B

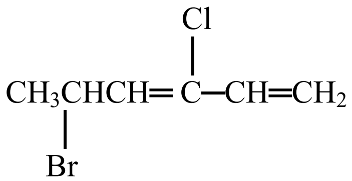
Give the correct IUPAC names of the following organic compounds:

1. $CH_3C(CH_3)_2CH_3$..

2. 

…………………………………………………………

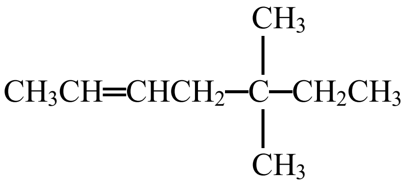
3. $CH_3CH{=}CHCH_3$ …………………………………………………………..

4. 

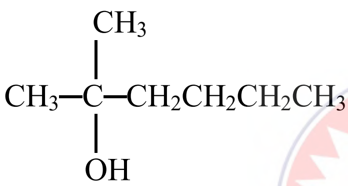
………………………………………………

5. $CH_3(CH_2)_7C{\equiv}CH$ …………………………………………………………..

.

6. 

……………………………………

7 

………………………………………………..

8. $HOCH_2(CH2)_4OH$ ………………………………………………………

9. CH_3COOH……………………………………………………………

10. $CH_3CH_2COOCH_3$……………………………………………………

SECTION C

Write the expanded structural formulae of the following organic compounds:

2-methylheptane

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………..................

ii). But-1-yne

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

iii). Ethanoic acid

……
……
………

iv). 2-methylpropan-1-ol

……
……
……

v). Propyl-2- chloroethanoate

SECTION D

Write the condensed formulae for the following compounds:

1. Hexane

……
……
……
……

2. Pent-2 -ene

……
……
……
……

3. Heptan-2-ol

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

4. Pentanoic acid

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

5. Methyl methanoate

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

APPENDIX C

MARKING SCHEME FOR BOTH PRE-INTERVENTION TEST AND POST INTERVENTION TEST ON CLASSIFICATION, NAMING AND WRITING OF THE STRUCTURES OF ALIPHATIC ORGANIC COMPOUNDS

SECTION A (1mark each)

Classify the following compounds as alkane, alkene alkyne, alkanol, alkanoic acid or alkanoate.

i). $CH_3CH_2CHOHCH_3$……………………………………………Alkanol

ii). $CH_3CH_2CH_2CH_3$………………………………………………Alkane

iii). $CH_3CH_2COOCH_3$……………………………………………Alkanoate

iv). $CH_2{=}CH_2$……………………………………………………Alkene

v). CH_3CH_2COOH…………………………………………… Alkanoic acid

SECTION B (1 mark each)

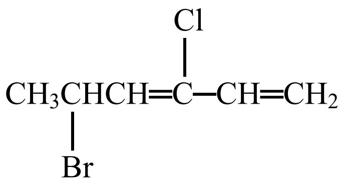
Give the correct IUPAC names of the following organic compounds:

$CH_3C(CH_3)_2CH_3$ 2,2-dimethylpropane

2. $CH_3CH_2{-}C(H)(CH_2CH_3){-}CH_2CH_3$ ……………………… 3-ethylpentane

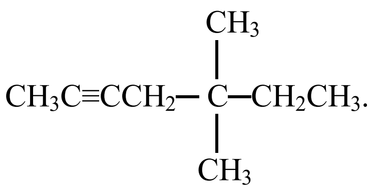
```
              H
              |
2.   CH3CH2—C—CH2CH3
              |
              CH2CH3
```

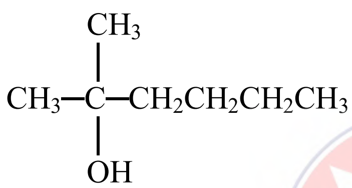
3 $CH_3CH{=}CHCH_3$…………………………….. But-2-ene or 2-butene

4.  ………… 5-bromo-3-chloropent-1, 3-diene

5. $CH_3\,(CH_2)_7C{\equiv}CH$………………………Decyne or Dec-1-yne

.

6.  ....5, 5-dimethylhept-2-yne or 5,5-dimethyl- 2-heptyne

7  …….2-methyl-2-hexanol or 2-methylhexan-2-ol

8. $HOCH_2(CH_2)_4OH$…………………Pentan-1,5-diol or 1,5-pentanediol

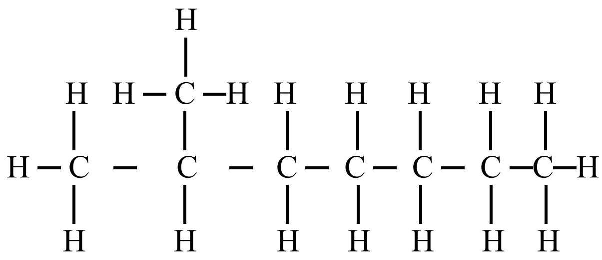
9. CH_3COOH……………………………………..Ethanoic acid

10 $CH_3CH_2COOCH_3$……………………………..Methylpropanoate

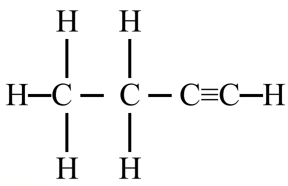
SECTION C (1 mark each)

Write the structural formulae of the following organic compounds:

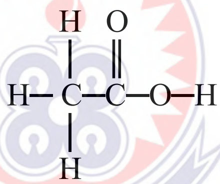
i). 2-methylheptane



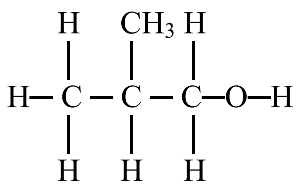
iv). But-l-yne ………………… …………



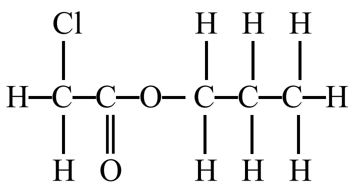
iii). Ethanoic acid………………



iv). 2-methylpropan-1-ol…………………



v). Propyl-2- chloroethanoate……………



SECTION D (1 mark each)

Write the condensed formula for the following compounds:

1. Hexane…………………………………………………………..$CH_3(CH_2)_4CH_3$

2. Pent-2 –ene…………………………………………………$CH_3CHCHCH_2CH_3$

3. Heptan-2-ol……………………………………………....$CH_3(CH_2)_4CH(OH)CH_3$

4. Pentanoic acid…………………………………………........$CH_3(CH_2)_3COOH$

5. Methyl methanoate……………………………………………$HCOOCH_3$

APPENDIX D

INTERVIEW GUIDE FOR STUDENTS

Explain how you arrived at the classes you gave to the compounds.

Explain how you arrived at the IUPAC names you gave to the compounds.

Explain how you arrived at the expanded structural formulae of the named compounds

Explain how you arrived at your condensed formulae of the named compounds

APPENDIX E

QUESTIONNAIRE

INSTITUTION: E.P.C. Mawuko Girls‟ Senior High School

Please this questionnaire is intended to seek for your views on the use of molecular model kits as instructional materials for teaching and learning of the names and writing of the structures of aliphatic organic compounds. The responses from this questionnaire are for academic use only. Hence your responses will be kept completely confidential.

Class:………………. Age:……………..

Please rate how strongly you agree or disagree with each of the following statements by placing a check (√) mark in the appropriate box.

STRONGLY AGREE = S.A AGREE = A UNDECIDED = U DISAGREE = D

STRONGLY DISAGREE = S.D

The use of molecular model kits in teaching the names of aliphatic organic compounds motivates learners.

S.A	A	U	D	S.D
☐	☐	☐	☐	☐

The use of molecular model kits in teaching and learning of the structural formula of aliphatic organic compounds makes the lesson more interesting.

S.A	A	U	D	S.D
☐	☐	☐	☐	☐

The molecular model kits help me to improve upon the understanding of the naming of the structures of aliphatic organic compounds.

S.A	A	U	D	S.D
☐	☐	☐	☐	☐

The use of molecular model kits in teaching the structural formula of aliphatic organic compound was self-explanatory.

S.A ☐ A ☐ U ☐ D ☐ S.D ☐

It was difficult using molecular model kits teaching and learning of the structures of aliphatic organic compounds.

S.A ☐ A ☐ U ☐ D ☐ S.D ☐

It was boring using molecular model kits for teaching and learning of the names of aliphatic organic compounds.

S.A ☐ A ☐ U ☐ D ☐ S.D ☐

Using molecular model kits in teaching the structures of aliphatic organic compounds makes the lesson abstracts.

S.A ☐ A ☐ U ☐ D ☐ S.D ☐

The molecular model kits facilitate individual or group learning.

S.A ☐ A ☐ U ☐ D ☐ S.D ☐

The molecular model kits can be used with little or no help.

S.A ☐ A ☐ U ☐ D ☐ S.D ☐

The use of molecular models during the teaching and learning of the names and writing of the structures of aliphatic organic compounds makes me participate actively in the lesson.

S.A A U D S.D

☐ ☐ ☐ ☐ ☐

At anytime and anywhere the molecular model kits can be used.

S.A A U D S.D

☐ ☐ ☐ ☐ ☐

It is friendly using molecular models in teaching and learning the names of aliphatic organic.

S.A A U D S.D

☐ ☐ ☐ ☐ ☐

Do you appreciate the use of molecular model kits in the teaching and learning of the names and writing of the structures of aliphatic organic compounds?

YES UNCERTAIN NO

☐ ☐ ☐

Give a brief reason for your response to question 13 above.

APPENDIX F

RELIABILITY COEFFICIENT

Test 1	Test 2
9	10
8	12
7	9
7	15
6	12
7	13
11	15
10	15
7	12
15	15
9	14
12	15
9	11
13	15
8	13
5	9
9	15

	Test1	Test 2
Test 1	1	
Test 2	0.70	1

APPENDIX G

Raw Scores for Test 1 and Test 2 on Classification based on Functional Group (Total mark = 5)

Test1	Test 2
2	4
2	5
0	5
4	4
2	4
0	4
4	5
1	5
0	5
3	5
4	5
4	5
1	5
2	5
3	5
1	5
3	5
4	5
2	5
3	5
0	5
1	5
1	5
1	5
3	4
0	5
3	5
4	5
2	5
2	4
1	5
1	4
2	4
1	5
3	4

APPENDIX H

Raw Scores for Test 1 and Test 2 on writing of Structural Formulae of Aliphatic Organic Compounds (Total mark = 10)

TEST 1	TEST 2
1	4
0	5
0	5
1	5
2	5
1	5
1	6
1	5
1	6
0	6
2	6
4	5
0	9
1	7
1	7
2	7
3	7
2	6
1	7
0	7
0	8
2	9
0	8
0	10
0	9
1	7
1	9
2	7
2	7
2	6
0	6
2	6
0	6
1	6
3	6
1	6

APPENDIX I

Raw Scores for Test 1 and Test 2 on Naming of Aliphatic Organic Compounds (Total mark = 10)

TEST 1	TEST 2
2	6
3	6
1	5
6	6
3	5
2	6
2	5
2	9
1	8
4	8
1	7
3	7
1	9
1	7
1	6
1	8
6	7
5	8
2	8
2	9
2	8
1	10
1	8
2	10
2	8
1	9
1	6
1	10
2	6
2	7
5	7
2	7
1	7
1	5

APPENDIX J

Total Raw Scores for Test 1 and Test 2 on Classification, Naming and writing of the Structures of Aliphatic Organic Compounds (Total mark = 25)

TEST 1	**TEST 2**
5	14
5	16
1	15
11	15
7	14
3	15
7	16
4	19
2	19
7	19
7	18
11	17
0	23
4	18
5	17
4	20
12	19
11	19
5	20
5	21
2	21
4	24
2	21
3	25
5	21
2	21
5	20
7	22
6	18
6	17
6	18
5	17
3	17
3	16
10	17
4	18

APPENDIX K

SAMPLES OF STUDENTS" RESPONSES TO OPEN ENDED QUESTIONNAIRE ITEMS

Sample One

13. Do you appreciate the use of molecular models in the teaching and learning of the names and writing of the structures of aliphatic organic compounds?

YES ✓ UNCERTAIN NO

14. Give a brief reason for your response to question 13 above.

it makes the lesson real and interesting, I was actually happy when we were using it.

Sample Two

13. Do you appreciate the use of molecular models in the teaching and learning of the names and writing of the structures of aliphatic organic compounds?

YES ✓ UNCERTAIN NO

14. Give a brief reason for your response to question 13 above.

It makes ~~learning~~ learning easier. And makes ~~us~~ me understand easier.

Sample Three

13. Do you appreciate the use of molecular models in the teaching and learning of the names and writing of the structures of aliphatic organic compounds?

YES ☑ UNCERTAIN ☐ NO ☐

14. Give a brief reason for your response to question 13 above.

I appreciate the use of molecular models because it makes lessons more interesting and motivates learners to know more about the models.

Sample Four

13. Do you appreciate the use of molecular models in the teaching and learning of the names and writing of the structures of aliphatic organic compounds?

YES ☑ UNCERTAIN ☐ NO ☐

14. Give a brief reason for your response to question 13 above.

It makes me participate actively in the lesson.
It also helps us to understand the lesson.

Sample Five

13. Do you appreciate the use of molecular models in the teaching and learning of the names and writing of the structures of aliphatic organic compounds?

YES	UNCERTAIN	NO
☐	☑	☐

14. Give a brief reason for your response to question 13 above.

I was sick for sometime so I was not always in class