UNIVERSITY OF EDUCATION, WINNEBA

USING MOLECULAR MODELS TO ENHANCE THE ABILITY OF STUDENTS IN DRAWING AND NAMING STRUCTURAL FORMULAE OF CYCLIC HYDROCARBONS

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A THESIS IN THE DEPARTMENT OF SCIENCE EDUCATION, FACULTY OF SCIENCE EDUCATION SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, UNIVERSITY OF EDUCATION, WINNEBA, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY (SCIENCE EDUCATION) DEGREE

2018

DECLARATION

Student's Declaration

I, ARYEETEY CLAUDIA declare that this research work, with the exception of quotations and references contained in published works, which have been duly acknowledged is entirely my own original work and it has not been submitted either in part or whole elsewhere.

Signature…………………………………… Date:………………………

Supervisor's Declaration

I hereby declare that the preparation and presentation of this research work was supervised by me in accordance with the guidelines for supervision of research work laid down by the University of Education, Winneba.

Supervisor's Name:………………………………………………………..

Signature:…………………………… Date:…………………………………….

AKNOWLEDGEMENTS

I give all the glory and adoration to the Almighty God for bringing me this far and for continuing to protect and guide me in all my endeavours.

My sincere gratitude goes to my dear husband Mr. Samuel Quayson who stood by me through thick and thin helped me both in cash and kind.

I am also highly grateful and indebted to my supervisor Prof. (Mrs.) Ruby Hanson, the Dean, Faculty of Science Education, University of Education, Winneba who spent her precious time out of her busy schedules to supervise this work and make corrections and suggestions, as well as all lecturers and staff of the Department of Chemistry Education, especially Kwarteng Twumasi Ankrah, UEW.

DEDICATION

I dedicate this piece of work to my children Papa Amponsah Quayson, Nii Ayitey Quayson, Maame Araba Quayson and to my parents, Mr. & Mrs J. N. Aryeetey.

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ABSTRACT

This study sought to find out undergraduate first year chemistry students' ability to draw and name the structural formula of cyclic hydrocarbons using the molecular models. The study adopted a case study design which used action research approach. A sample size of 103 respondents participated in the study. Purposive sampling technique was used to select the respondents. The instruments used for data collection were exercises, tests and questionnaires. This was supplemented with observation. The study revealed that first year chemistry education students had not developed appropriate conceptual understanding in drawing and naming organic structures of monocyclic, spiro and bicyclic compounds. A number of their difficulties were revealed in the pre-test with mean 8.88 and the standard deviation 4.05. In the study, students understanding in drawing and naming of organic structures of monocyclic, spiro and bicyclic compounds was improved through the use of organic molecular models. The post-test with mean 17.47 and standard deviation 3.67 results indicated that students performed better after the intervention was implemented. This suggests that the molecular model is an effective tool for teaching nomenclature of organic compounds. This explains why there was a statistical significant difference between the pre-intervention test and post-intervention test results of students. Based on the findings of the study some recommendations were made. Suggestions were made for further studies to be conducted using computer animations instead of the molecular models.

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CHAPTER ONE

INTRODUCTION

Overview

This chapter presents the background to the study, statement of the problem and purpose of the study. The structure of the chapter also includes the objectives, research questions, the significance of the study, delimitations, limitations, definition of terms and organisation of the entire research.

Background to the Study

Education plays a very important and central role in the Ghana's transformation strategy. The transition to a modern and state-of-the-art educational system is happening at all academic levels. Understanding chemistry concepts and its applications play remarkable roles in improving way of life.

Chemistry is one of the most important branches of science; it enables learners to understand what happens around them. However, most of the components of matter are not visible to students, so it proves to be a difficult subject for them. This is because students have to do abstract thinking to perceive what the teacher is explaining. Chemistry subject commonly have abstract concepts, which are central to further learning in both chemistry and other sciences (Taber, 2002). In organic chemistry most of the concepts appears to be abstract and this is the main cause of students' difficulties in learning the subject (Taber, 2002).

According to Samara (2016), organic chemistry occupies a central place in chemistry. Although there are several concepts about which students have difficulty, organic chemistry is considered to be one of the most difficult aspects of the chemistry subject. This is because it demands mastery of a large number of related concepts, and its essential role in developing an understanding in other areas of chemistry such as types of bonding, reactions, conformation and isomerism, as well as derivatives of organic compounds. Invariably, when concepts become difficult for students they tend to shy away from questions set on these concepts during any examination, leading to poor performance. This problem has been found to be prevalent in the teaching and learning of organic chemistry (Halford, 2016).

Organic compounds contain only the elements carbon and hydrogen, and are called hydrocarbons. Even though they are composed of only two types of atoms, there is a wide variety of hydrocarbons because they may consist of varying lengths of chains, branched chains, and rings of carbon atoms, or combinations of these structures. In addition, hydrocarbons may differ in the types of carbon-carbon bonds present in their molecules. This leads to differences in geometries and in the hybridization of the carbon orbitals (Solomons & Fryhle, 2008). All alkanes are composed of carbon and hydrogen atoms, and have similar bonds, structures, and formulas; noncyclic alkanes all have a formula of C_nH_{2n+2}. The number of carbon atoms present in an alkane has no limit. Hence the general formula for a cycloalkane composed of n carbons is C_nH_{2n}. Organic compounds that contain one or more double or triple bonds between carbon atoms are described as unsaturated. You have likely heard of unsaturated fats. These are complex organic molecules with long chains of carbon atoms, which contain at least one double bond between carbon atoms. Unsaturated hydrocarbon molecules that contain one or more double bonds are called alkenes. The general formula for the alkenes is C_nH_{2n}, where n is the number of carbon atoms in the molecule Carbon atoms linked by a double bond are bound together by two bonds, one σ bond and one π bond. Cycloalkenes have the general formula $C_nH_{2(n-m)}$. Double and triple bonds give rise to a different geometry around the carbon atom that participates in them, leading to important differences in molecular shape and properties. The differing geometries are responsible for the different properties of unsaturated versus saturated fats. Hydrocarbon molecules with one or more triple bonds are called alkynes**;** they make up another series of unsaturated hydrocarbons. Two carbon atoms joined by a triple bond are bound together by one σ bond and two π bonds.

The use of International Union of Pure and Applied Chemistry (IUPAC) rules or nomenclature in naming organic compounds has been identified as one of students' difficulties (Adu-Gyamfi, Ampiah & Appiah, 2017). Researchers have found out that students' difficulties in using IUPAC nomenclature in drawing structural formulae of organic compounds resulted from their inability to identify the correct number of carbons atoms in a continuous chain; any substituent group and its point of attachment. Cyclic hydrocarbons are formed when atoms combine to form a ring. If you break down the term hydrocarbon, 'hydro-' represents the word hydrogen; the term 'carbon' represents, well, carbon. The presence of carbon in the structure of a cyclic hydrocarbon provides a great reminder that these compounds are organic. An empirical study by Adu-Gyamfi, Ampiah and Appiah, (2013), further exposed the weakness of senior high school (SHS) students in using the IUPAC nomenclature to name and write chemical formulae of organic compounds.

Swafford and Bryan (2000) in their study identified that students explore scientific concepts by observing or participating in hands-on, real experiences. They continued to say that these experiences serve to motivate, arouse curiosity and activate background knowledge, which is vital for students who experience learning difficulties. Teachers in this case, therefore need to create learning situations in which children`s natural behaviour could be utilised, modified or developed to enhance the acquisition of scientific knowledge.

According to Ogunkola (2011), the key factors in facilitating an effective learning environment in science class are the teaching strategies used by teachers. Ogunkola again stated that, teachers in many instances used the excuse of overloaded science curricula to explain their reliance on strict didactic methods of teaching. Though these claims may have some merit, these teaching strategies may in effect, portray the subject as difficult to many students. John Dewey in the early days criticized science teaching placing too much emphasis on the accumulation of information rather than an effective method of inquiry (Bybee, Trowbridge & Powell, 2008).

Behar and Polat (2007), identified that students' play a passive role in the classroom and for that matter see their teacher as the only source of knowledge, thus contributing to the perceived difficulty of the science topics. Duit (2007), in a study on student's conceptual difficulties in science also found that instruction often failed to engage the ideas that students brought to the classroom.

In Ghana, one of the general aims of the chemistry teaching syllabus is to help Ghanaian chemistry students to appreciate and use the IUPAC system to name chemical compounds

(Ministry of Education Science and Sport, 2010). According to MOESS (2010), the IUPAC nomenclature of carbon compounds is introduced at the SHS 2 level under section 6 of the Chemistry teaching syllabus, and is to be completed at the same level. Here, both the nomenclature of hydrocarbons and functional groups are introduced. On this part, Gillette (2004) has pointed out that the IUPAC nomenclature of hydrocarbons, which are organic compounds containing only carbon and hydrogen atoms, must be thoroughly treated first before that of organic compounds containing functional groups.

Gillette (2004), noted that once students have mastered the IUPAC nomenclature for the different types of hydrocarbons, they would be able to apply the same basic naming principles to organic compounds containing other functional groups. A look at the 2008 teaching syllabus for Chemistry at the SHS level showed that the study of alkanes, alkenes, and alkynes, is to be taught before the study of organic compounds with functional groups such as alkanols, alkanoic acids, amides and alkyl alkanoates (MOESS, 2008). This implies that the 2008 teaching syllabus for chemistry agrees with Gillette's assertion that a good understanding of students in the IUPAC nomenclature of hydrocarbons enhances student's understanding of the IUPAC nomenclature of other derivatives of the hydrocarbons often thought by students as abstract. In order to attain this kind of understanding among students, abstract concepts must be translated in tangible phenomenon. In order to represent ideas about abstract phenomeno, molecular models could be used.

A molecular model is an example of the concrete three-dimensional models used in organic chemistry to make abstract phenomena and concepts real to learners. They facilitate a phenomenon that cannot be physically seen to be better understood. Visualization elements such as the molecular models play important role by supporting the students in connecting levels of concept representation (Barke & Wirbs, 2002). This research was to assess the effect of the use of such molecular models in teaching and learning the structural formulae of cycloalkanes as it is a course that is taken at the department of Chemistry Education, University of Education, Winneba.

Statement of the Problem

The IUPAC Nomenclature of hydrocarbons are studied in first year as one of the courses of the chemistry curriculum. It covers areas such as monocyclic, spiro compounds and bicyclic compounds.

The IUPAC nomenclature of organic compounds and the rules that govern them have been with us for many years (Solomons & Fryhle, 2008). In Ghana, IUPAC nomenclature is taught in Senior High School through to the university in subjects such as Integrated Science and Chemistry. The report of West African Examination Council Chief Examiners, 2015 explained that the number of candidates who answered questions on organic Chemistry aspects was very low and such candidates showed poor performance in such areas. First year Chemistry Students of University of Education are no exception the inability of students to understand the IUPAC system of nomenclature of organic compound has become a matter of concern to many Chemistry lecturers.

Purpose of the Study

The purpose of this study was to use molecular models to enhance students' skills in drawing and naming the structural formulae of cyclic hydrocarbons such as monocyclic, spiro and bicyclic compounds which majority of them have challenges with.

Objectives

The following objectives were formulated to be achieved by the end of the study:

1. To identify some the difficulties students encounter in drawing and naming the structural formulae of monocyclic, spiro and bicyclic compounds.
2. To determine the skills students would develop on the use of molecular models to enhance their drawing and naming the structural formulae of monocyclic, spiro and bicyclic compounds.
3. To determine students perceptions about the use of the molecular models in drawing and naming structural formulae of monocyclic, spiro and bicyclic compounds.

Research Questions

The study will be guided by the following research question:

1. What are some of the difficulties students encounter to draw and name the structural formula of monocyclic, spiro and bicyclic compounds?
2. What skills would student develop through the use of molecular models to enhance their drawing and naming the structural formulae of monocyclic, spiro and bicyclic compounds?
3. What are students' perceptions about the use of the molecular models in drawing and naming structural formulae of monocyclic, spiro and bicyclic compounds?

Hypothesis

Ho: there was no significant difference on students' performance in using molecular models to enhance their drawing and naming on monocyclic, spiro and bicyclic compounds.

Significance of the Study

It is anticipated that this study will help lecturers of UEW to make informed decisions about the curriculum to be designed for teaching organic chemistry education. It will serve as a guide for organizing science curricula around sets of models and provide students with opportunities not only to learn about the conceptual subject matter but also about the nature of scientific knowledge –how it is constructed and justified. It will then again serve as a reference material for future researchers who might want to conduct a study along a similar direction. When the use of models become a focus in formulating organic structures in the classroom, students will learn that they are tentatively constructing ideas that explain the natural world and provide an explanation for a vast range of observed facts. This study was meant to promote a more student-centred approach by encouraging student participation in the learning process and also to strengthen their drawing and naming skills of hydrocarbons.

Delimitations

The study involved first year chemistry students in University of Education, Winneba. It is obvious that many students from other institutions may face similar problems across the nation but under the researcher's capacity in terms of time and finances to reach out to many institutions to gather the needed reliable data for the diligence of this work, it was delimited to students in U.E.W. Again, the study is focused on monocyclic, spiro and bicyclic compounds. Additionally, the hydrocarbons considered in this study comprised those that contained not more than ten (10) carbon atoms.

Limitations

The limitations of a study are those characteristics of design or methodology that impact on or influence the interpretation of the findings from ones research. The students' previous knowledge of drawing and naming of structural formulae of organic compounds may affect the progress of the study. The time table of the Chemistry Education department may also affect the progress of the study. The students may again not provide honest responses to the questionnaire items even though they will be informed that their responses to the items will not affect their end of semester examinations.

Organisation of the Study

This research consists of five chapters. Chapter one deals with the introduction under which the background of the study, statement of the problem, purpose of the study, research questions, significance of the study, delimitations, limitations, definition of terms and the organisation of work are discussed. The chapter ended with the definition of terms.

The second chapter deals with literature review. In this chapter, it covers the necessary topical issues raised in the research questions and the use of molecular model kits to improve the performance will be also reviewed. The summary of literature review ends the chapter. The third chapter also indicates the method that would be used to gather the necessary information about the issues raised in the study. Also issues in this chapter includes the population and sample selection, research design, research instruments and data analysis plan.

The fourth chapter of the study dwells on the analysis and discussion of results that will be obtained from the research instrument. The last chapter, chapter five, considers the summary, conclusion and recommendations of the study.

Definition of Terms

The following are the operational definition of some terms and abbreviations used in this study:

- *Molecular models*: A set of plastic balls showing the arrangement of atoms in a molecule (as of an organic compound).
- *Academic performance*: Regarded as the display of knowledge attained or skills, shown in the school subjects such achievements are indicated by test scores or by marks assigned by teachers. It is the school evaluation of students classroom work as quantified on the basis of marks or grades.
- *A cyclic compound (ring compound):* A term for a compound in the field of chemistry in which one or more series of atoms in the compound is connected to form a ring. A cyclic hydrocarbon is a compound composed only of carbon and hydrogen that forms a ring.
- *Monocyclic hydrocarbons*: hydrocarbons that contain a ring
- *Spiro hydrocarbons*: a bicyclic organic compound in which the two rings share one carbon atom. The ring size may be identical or different. The connecting atom is the spiro carbon.

- *Bicyclic compounds*: organic compound that contains two rings and share two carbon atoms in common. The two carbon atoms that are shared between the two rings are called bridgehead carbons and the chains of carbon atoms that link the bridgeheads are called bridges.
- *Instructional Materials*: What the teacher uses to make the lesson more interesting and understandable.
- *The International Union of Physics and Applied Chemistry (IUPAC):* An organisation who laid down procedures for naming and writing of the structure of chemical substances.
- MOESS: Ministry of Education, Science, and Sports.

CHAPTER TWO

LITERATURE REVIEW

Overview

This chapter deals with the review of literature related to the study. Issues that border on the topic such as the theoretical framework, classification of organic compounds, drawing and naming of hydrocarbon compounds, the IUPAC rule of drawing and naming cyclic compounds are discussed. The importance of teaching materials, the difficulties students have in naming and writing the structures of organic compounds were also reviewed. Similarly, the importance of teaching materials was treated, the description of molecular models, the impacts of organic models on students' performance and empirical evidence were also reviewed and summary of the chapter discussed.

Theoretical framework

The theoretical framework for this study is based on the constructivism theory.

The Constructivist learning and teaching perspective represents a shift from viewing learners as responding to external stimuli to seeing learners as "active in constructing their own knowledge." In knowledge construction it is asserted that "social interactions are important" (Bruning, Schraw, Norby, & Ronning 2004). In constructivist perspectives, learners directly develop knowledge by experiencing things and by reflecting on such experiences. Learners can actively learn through cognitive processes to construct and understand the world around them.

Educators such as Piaget, Vygotsky, and Bruner contributed to theories of constructivist learning. According to Gillani, (2003), Piaget believed that an individual coming into contact with a new learning situation draws on prior knowledge to make the new experience understandable. New events, situations, or learning environments can create contradictions with one's previous understandings. When this happen, individual insufficiency leads to perturbation and a state of disequilibration in the mental schemata, in which generic events and abstract concepts are stored and organized in terms of their common patterns (Gillani 2003).

Constructivism is best understood in terms of how individuals use information, resources, and help from others to build and improve their mental models and their problem solving strategies (Woolfolk, 2007). The constructivist model of teaching enables learners to construct knowledge. This construction could reflect objective realities, which sharpens one's cognitive development for acquiring higher-level intelligence. Examples of constructivist learning models are experiential learning, self-directed learning, discovery learning, inquiry training, problem-based learning, and reflective practice (Gillani 2003; McLeod 2003; Slavin 2000). This construction of knowledge could also happen in a social interactive setting through mediation of individuals. There is no specific constructivist pedagogy, but we can assess the principles that guide the development of pedagogies that enable learner-constructivist, by comparing it with traditional behaviourist perspective of teaching.

According to the constructivist theory, students do not just passively receive information but constantly create new knowledge based on prior knowledge in conjunction with new experiences. As opposed to the traditional approaches where students learn by copying "word for word", what teachers say, constructivism has shifted to a more radical conception of teaching and learning whereby the learners' own ideas are brought to class, acknowledged, and enhanced through a variety of teaching and learning techniques that actively engage them (Maclellan & Soden 2004).

In a study conducted by Eggen and Kauchak (2003), they found out that, constructivism is a view of learning in which learners use their experience to create understanding rather than having understanding delivered to them in already organized forms. From this perspective, the learner is viewed as actively constructing understanding through the use of authentic resources and social interaction (Eggen & Kauchak, 2003).

Constructivism modifies that role of teachers, so that teachers in this case help students to construct knowledge rather than to reproduce a series of facts. The constructivist teacher provides tools such as problem-solving and inquiry-based learning activities with which students formulate and test their ideas, draw conclusions and inferences, and pool and convey their knowledge in a collaborative learning environment (Fosnot, 2005). Constructivism transforms the student from a passive recipient of information to an active participant in the learning process. Always guided by the teacher, students construct their knowledge actively rather than just mechanically ingesting knowledge from the teacher or the textbook.

A study by Thompson (2000) also suggested that constructivism is a model of knowing but not a theory of learning and it may be used to build a theory of learning. He also made a point that the view of constructivism as a theory of learning has developed in constructivist pedagogy. Such constructivist pedagogy has been found to facilitate the study of abstract topics like cyclic compounds in organic chemistry and their clarifications.

Classification of Organic Compounds

The existing large number of organic compounds and their ever –increasing numbers has made it necessary to classify them on the basis of their structures. Organic compounds are broadly classified as shown in figure 1 below.

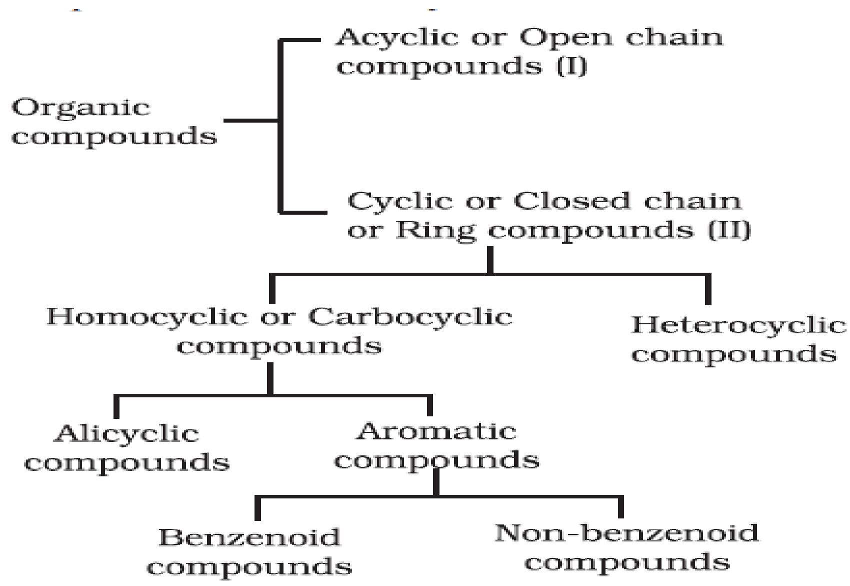


Figure1: Classification of Organic Compounds (Solomons & Fryhle, 2008)

A cyclic compound or ring compound is a compound at least some of whose atoms are connected to form a ring. Rings vary in size from 3 to many tens or even hundreds of atoms. Examples of ring compounds readily include cases where:

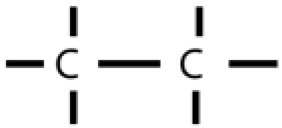
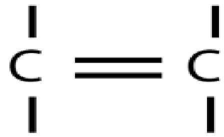
- all the atoms are carbon (i.e., are carbocycles),
- none of the atoms are carbon (inorganic cyclic compounds), or where
- both carbon and non-carbon atoms are present (heterocyclic compounds).

Drawing and Naming of Organic Hydrocarbon Compounds using IUPAC System of Nomenclature

Hydrocarbons provide the backbone of all organic compounds. Each carbon atom in a hydrocarbon forms a total of four bonds. These bonds are combinations of single bonds with hydrogen atoms and single or multiple bonds with other carbon atoms. For molecules that contain a large number of atoms or complex structures, drawing every bond and every atom is time and space consuming. A common notation developed to abbreviate the drawing without sacrificing the clarity of the structure is the condensed structural formula.

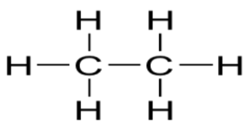
The bond-line structural formula is the notation that most organic chemists prefer to use. Bond-line formulas are easy to draw and quickly convey the essential structure of a molecule. Both the ends and the angles of the structure represent the carbon atoms. C—H bonds are not shown, but you should assume that the appropriate number of hydrogen atoms is present to complete the four bonds required by carbon to have its octet of electrons.

Gillette (2004) in his study revealed that there are three ways of representing the IUPAC names of organic compounds with structural formulae. The first is the Lewis structure also known to be the expanded structural formula. Lewis structures, however, can be simplified by representing the two-electron covalent bond by a dash (–). Such a structural formula focuses on the electrons involved in bond formation. A single dash represents a single bond, double dash is used for double bond and a triple dash represents triple bond.

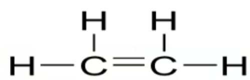




Single bond Double bond Triple bond

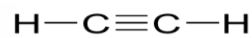
Lone pairs of electrons on heteroatoms (such as oxygen, nitrogen, sulphur, halogens) may or may not be shown. Thus, ethane (C_2H_6), ethene (C_2H4), ethyne (C_2H_2) and methanol (CH_3OH) can be represented by the structural formulas. These are represented as follows;



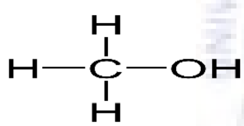
ethane
(an alkane)



ethene
(an alkene)



ethyne
(an alkyne)



Methanol

Such structural representations are called complete structural formula. These structural formulas can be further abbreviated by omitting some or all of the dashes representing covalent bonds and by indicating the number of identical groups attached to an atom by a subscript. The resulting expression of the compound is called a condensed structural formula. Example of a condensed structural formula is CH_3-CH_3 for ethane.

The condensed structural formula which is the second structure shows any carbon atoms in the straight chain together with any other atoms or group of atoms connecting to the chain without the covalent bonds or any unshared electron pairs. The covalent bond is shown only and only if there is the need to clarify a specific portion of the structure in the condensed structural formula (Gillette, 2004). For clarity, the researcher used a combination of a line-angle drawing and a condensed structural formula to depict a cyclic hydrocarbon parent compound (Gillette, 2004; Woodcock, 1996).

Drawing and Naming of Monocyclic Compounds using IPAC System of Nomenclature

In drawing and naming of cycloalkanes, some steps or rules are employed

Step 1: Determine the parent name of the compound by counting the number of carbons in the ring. Use the same parent name for the ring that you would use for the normal alkane containing that number of carbons.

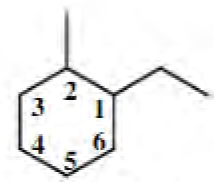
Step 2: Add the prefix *cyclo*– to the parent name.

Step 3: Name any alkyl group substituents the same way that you name any other alkyl group.

Step 4: Determine the position of the alkyl group or groups on the ring.

a. For a ring with only one alkyl group attached, you do not need a number to designate the group's position. The carbon bearing a single group is always carbon number 1.

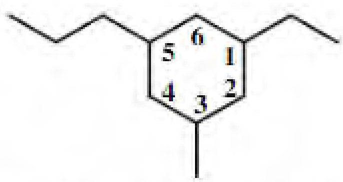
b. When a ring has more than one alkyl group attached, number the ring to give the lowest sum of numbers. If there are two groups, assign the number one to the first alkyl group alphabetically. Then count the shortest distance to the second substituent. With three or more substituents, determine a set of numbers to give the lowest sum of numbers. For example, the following structural compound is named as 1-ethyl-2-methylcyclohexane



1-Ethyl-2-methylcyclohexane

and not 1-ethyl-6-methylcyclohexane

c. If the sum of numbers is identical in either direction around the ring, then count towards the second group alphabetically on the ring. The following compound is 1-ethyl-3-methyl-5-propylcyclohexane.



1-Ethyl-3-methyl-5-propylcyclohexane

The more complex ring-containing alkanes need the following additional steps to name a given compound.

Step 5: When the alkane chain is complex or has more carbons than the ring, name the ring as a substituent on the alkane chain. The rules attached from 1 to 4 for naming a normal alkane and for naming a cycloalkane. The ring in this case is called cycloalkyl group.

Step 6: When one ring is attached to another ring. The larger ring is called the parent compound.

The following steps are followed in naming and drawing structures of cycloalkenes

1) Determine the parent name by selecting the longest chain that contains the double bond and change the ending of the name of the alkane of identical length from -ane to -ene

2) Number the chain so as to include both carbon atoms of the double bond, and begin numbering at the end of the chain nearer the double bond. Designate the location of the double bond by using the number of the first atom of the double bond as a prefix. The location for the alkene suffix may precede the parent name or come after the suffix.

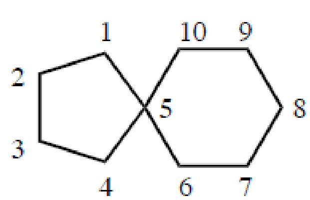
3) Indicate the locations of the substituent groups by the numbers of the carbon atoms to which they are attached.

4) Number substituted cycloalkenes in the way that gives the carbon atoms of the double bond the 1 and 2 positions and that also gives the substituent groups the lower numbers at the first point of difference.

5) Name compounds containing a double bond and an halogen group as bromine or chlorine give the carbon the lower number.

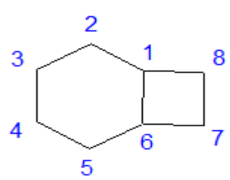
Drawing and Naming of Spiro compounds using IUPAC System of Nomenclature

In naming spiro compounds, the number of carbons in the two rings is used as the root name. The prefix spiro is followed by square brackets containing the number of carbons in the smaller ring and the number of carbons in the larger ring. The numbers are separated by a dot. In the structure above the smaller ring contains four carbon atoms and the larger ring five. The total number of carbons in the two rings is ten and hence the root name decane. Example of spiro compound is spiro [4, 5] decane as shown below.



Drawing and Naming of Bicyclic Compounds using IUPAC System of Nomenclature

1. The parent name is derived from the total number of carbon atoms in the bicyclic ring system preceded by the prefix *bicyclo* to show that it is a bicyclic compound.
2. Numbering starts from one of the bridgehead carbons and goes through the longest bridge and then along the next longer bridge and finally back to the starting bridge head carbon.
3. If two bridges are of equal lengths, the one in which a substituent has smaller number takes precedence over the other. If there is a choice of numbering pattern, the one that assigns smaller numbers to the substituents is the preferred choice.
4. The number of carbons in each bridge is put in brackets in a decreasing order. The numbers in the bracket are separated by dots. Example is bicycle [4.2.0] octane as shown below.



The Importance of Teaching Materials

Instructional materials are essential and significant tools needed for teaching and learning of school subjects to promote teachers' efficiency and improve students' performance. They make learning more interesting, practical, realistic and appealing. They also enable both the teachers and students to participate actively and effectively in lesson sessions. They give room for the acquisition of skills and knowledge and development of self-confidence and self- actualization. Ibeneme (2000) defined teaching aids as those materials used for practical and demonstration in class situation by students and teachers.

Ikerionwu (2000) explained instructional materials as objects or devices that assist a teacher to present a lesson to learners in a logical and manner.

In chemistry, the use of teaching material is one of the most frequently used methods that make the lessons to be more productive, dynamic and enhance active participation among students (Knudtson, 2015; Stringfield & Kramer, 2014). Studies have revealed that this method has many advantages such as increasing students' interest in the class, focusing their attention, affecting motivation positively, increasing their personal self-confidence and improving their social-cognitive skills (Kavak, 2012; Samide & Wilson, 2014). Teaching through the use of teaching materials in chemistry is an effective education method which can be applied in many stages of education from primary school to university (Samide & Wilson, 2014). In teaching chemical concepts, teaching materials like molecular models are used as educational tools that contribute to strengthen the materializing and identification of the concepts (Knudtson, 2015). With the aim of reinforcing the concepts in the scope of any topic, it is possible to create educational activities that are suitable to be applied individually, in teams or at all grades. (Samide & Wilson, 2014).

Instructional materials used in teaching science help to enrich learning; while the lack of these materials in the classroom makes teaching and learning less interactive and more difficult to understand. Most schools in the rural areas lack many of these instructional materials for teaching and learning of science. The inadequacy of these materials has been of serious concern to science teachers in rural areas because it makes teaching less attractive to students (Aina, 2013). This suggests that the availability and effective use of instructional materials like organic molecular models will make the teaching of the nomenclature of organic compounds more interactive and promote classroom teaching and learning. Inadequate resources for teaching and learning usually results in teachers having less positive impact on students' academic development (Lingam & Lingam 2013).

Onasanya (2004) gave various kinds of models used in educational instruction namely: mathematical model, theoretical models, diagrams concrete models and so on. These are of special pedagogic significance in science and technology instruction due to the nature of knowledge getting process in these disciplines. Concrete models are materials objects which are likeness of natural or manmade structures or systems and which are intended to highlight and explain or describe structures, functional processes and relationships in the original. Concrete models are constructed in the effort to understand the behavoiur of the physical world and the causes of such (Onasanya & Omosewo, 2011). He then summarized the role of concrete models as follows: simplification of complex phenomenon, concretization of complex phenomenon, bridging of gaps in distance and time between phenomenon and classroom events, enhancing of students ability to communicate in science.

Isola (2010) also described instructional materials as objects or devices that assist teachers to present their lessons logically and sequentially to learners. Oluwagbohunmi and Abdu-Raheem (2014) acknowledged that instructional materials are such used by teachers to aid explanations and make learning of subject matter understandable to students during teaching learning process. Abdu-Raheem (2011) asserted that non availability and inadequacy of instructional materials are major causes of ineffectiveness of the school system and poor performance of students in Nigerian schools. Obanya (2004) also noted that several studies carried out in some areas in Nigeria indicated that the results of Senior School Certificate Examinations was completely bad in nearly all subjects offered by the students. He stressed further that only about 10% of candidates 'meaningfully passed' the examination. Ahmed (2003) confirmed that in most secondary schools in Nigeria, teaching and learning take place under a most un-conducive environment without access to essential materials. Eniayewu (2005) posited that it is very important to use instructional aids for instructional delivery to make students acquire more knowledge and to promote academic standard. These revelation from literature suggests that the use of molecular model in this study could have the potential to improve and elicit students' interest in learning chemistry.

In addition, Ajayi and Ayodele (2001) stressed the importance of availability of instructional materials to achieving effectiveness in educational delivery. Ogbondah (2008) alerted on the gross inadequacy and underutilization of instructional materials necessary to compensate for the inadequacies of sense organs and to reinforce the capacity of dominant organs. He noted that school teachers should try their possible best in the provision of teaching materials to promote their lessons. In a similar study, Olumorin, Yusuf, Ajidagba and Jekayinfa (2010) observed that instructional materials help teachers to teach conveniently and learners to learn easily without any problem. They asserted that instructional materials have direct contact with all sense organs. Kochhar (2012) supported that instructional materials are very significant learning and teaching tools. He suggested the need for teachers to find necessary materials for instruction to supplement what textbooks provide in order to broaden concepts and arouse students' interests in the subject. Concrete materials like the ball-and-stick model and computer simulations are among instructional materials that are helpful in teaching chemistry.

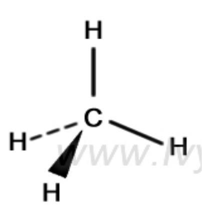
According to Abolade (2009), the advantages of instructional materials are that they are cheaper to produce, useful in teaching large number of students at a time, encourage learners to pay proper attention and enhance their interest. However, Akinleye (2010) attested that effective teaching and learning requires a teacher to teach the students with instructional materials and use practical activities to make learning more vivid, logical, realistic, and pragmatic. Esu, Enukoha and Umorem (2004) agreed that instructional materials are indispensable to the effective teaching and learning activities. Ekpo (2004) also supported that teaching aids are always useful in supporting the sense organs. Despite the fact that instructional materials are essential tools that can make learning practical and knowledge acquisition easier, they are not readily available in Nigerian secondary schools leading to low level of performance of learners in government examinations (Abdu-Raheem 2014). Therefore teaching of organic chemistry which has a lot of structures and symbols need proper teaching materials to enhance the learning of conceptual understanding of the subject which is likely to make understanding difficult.

In the chemistry classroom, the primary source of information input come from the teacher's talk, teacher-student and student-student interactions. According to Fatokun and Eniayeju (2014), chemistry teaching in undergraduate classes is usually limited to the traditional lecture method. Such classrooms are often teacher-centred and thus students assume a passive role. The students get an opportunity to engage with the learning process and develop critical thinking/understanding in these classrooms. Research in chemistry education has indicated that active engagement of students in the learning process is useful and results in more meaningful learning.

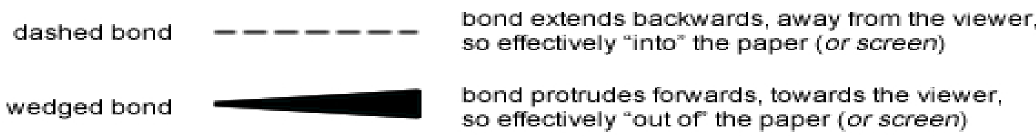
Teachers are supposed to help students to overcome the fear in chemistry and approach the chemistry course with confidence, apply principles of chemistry when solving problems by developing the problem-solving skills. There is also the need to provide real-life application to his teaching as to help the students to evaluate their learning.

Three-Dimensional Representation of Organic Molecules

The three-dimensional (3-D) structure of organic molecules can be represented on paper by using certain conventions. For example, by using (1) solid lines (—) to represent bonds which are in the plane of the paper, (2) dashed lines (---) to represent bonds that extend away from the viewer, and (3) wedge-shaped lines ( ) to represent bonds oriented facing the viewer. In these formulas the solid-wedge ( ) is used to indicate a bond projecting out of the plane of paper, towards the observer. The dashed-wedge is used to depict the bond projecting out of the plane of the paper and away from the observer. Wedges are shown in such a way that the broad end of the wedge is towards the observer. The bonds lying in plane of the paper are depicted by using a normal line (—). 3-D representation of methane molecule on paper has been.



The 3-D structural Formulae of Methane, where



Molecular models

Molecular models are physical devices that are used for better visualisation and perception of three-dimensional shapes of organic molecules. These are made of wood, ceramics, plastic or metal and are commercially available. Such a model emphasizes the pattern of bonds of a molecule while ignoring the size of atoms. In the ball-and-stick model, both the atoms and the bonds are shown. Balls represent atoms and the stick denotes a bond. Compounds containing C=C (such as ethene) can best be represented by using springs in place of sticks. In chemistry, the ball-and-stick model is a molecular model that is used to display both the three-dimensional position of the atoms and the bonds between them. The atoms are typically represented by spheres, connected by rods which represent the bonds. Double and triple bonds are usually represented by two or three curved rods, respectively.

The balls have representative colours: **black** represents carbon (C); **red**, oxygen (O); **blue**, nitrogen (N); and white, hydrogen (H). Each ball is drilled with as many holes as its conventional valence (C: 4; N: 3; O: 2; H: 1) directed towards the vertices of a tetrahedron.

Diagrams as we know are static, so inferences about the results of rotations and other spatial transformations involve mentally simulating the transformations, a process that is demanding of spatial working memory (Hegarty, 2004). In contrast, 3-D models often have moving parts, so that spatial transformations (such as the rotation of planets or molecular components) can be carried out externally on models. This reduces the demands on spatial working memory and enables students to observe the relevant spatial processes.

Manipulating chemical structures in 2D/3D representations help students relate the macroscopic, microscopic, and symbolic representation levels of chemicals to each other (Gilbert, 2005) and enhance students' conceptual understanding and spatial ability (Barak & Dori, 2011). The different representations of molecules of which the molecular model is said to be one is a form of teaching model that can also be considered to be scientific model. Models can be used in a constructivist manner to challenge students' internal knowledge schemes when teaching.

Chemists use two general types of spatial representations of molecules: concrete models, which are physical 3D models that represent the 3D spatial relations between atoms in a molecule; and 2D diagrams, which use conventions to represent 3D relations in the two dimensions of the printed page (see Figure 1). The term model refer to concrete models, as this is consistent with chemists' use of the term. We use the term diagram to refer to 2D representations. Expert chemists rely routinely on both concrete models and diagrams in their work and teaching, although computer visualizations of molecular structure are becoming more common (Francoeur & Segal, 2004).

Scientific models have implications for science teaching. Model sets around the curricula provides the students with the opportunity to learn about the conceptual subject matter of the disciplines and also learn about the nature of scientific knowledge: how it is constructed and justified. Students learn that they are tentative constructions that explain the natural world. The use of the molecular model encourage students to use active techniques (experiments, real-world problem solving) to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing. The teacher makes sure he/she understands the students' pre-existing conceptions, and guides the activity to address them and then build on them.

Some Difficulties that Students encounter in Naming and Writing Structures of Hydrocarbons

Adu-Gyamfi, Ampiah and Appiah (2012) reported that students had difficulties in writing structural formulae of alkanes, alkenes, alkanols, alkanoic acids, and alkyl alkanoates. The difficulties of students in writing structural formulae of organic compounds from the IUPAC names could be attributed to students' inability to identify from given IUPAC names the correct number of carbon atoms in the parent chain, the chemical symbol or formula of substituents or functional groups, the correct position of and number of multiple bonds. For instance, in naming substituents groups in organic compounds, Adu-Gyamfi, 2012 et al. concluded that some students were not used to the prefixes di, tri, tetra and others which were used to give an indication of the number of the same substituent group present.

A study conducted by Baah (2009) at New Juaben Municipality of the Eastern Region of Ghana revealed that 334 Senior High School form 3 chemistry students had difficulty in writing chemical formulae of inorganic compounds from their IUPAC names. He attributed this challenge of chemistry students in writing chemical formulae from IUPAC names of inorganic compounds to their lack of understanding of the Roman numerals that are put in the brackets of the IUPAC names such as ‘II’ and ‘V’ in Copper(II) tetraoxosulphate (IV). In Organic Chemistry more symbols are represented and so there is a higher probability of students not being able to write names of organic compounds which will require these, if not taught well. Wu, Krajcik, and Soloway (2001) revealed that chemistry students have difficulty in writing structural formulae of organic compounds such as CH_3CH_2OH because they see them as a combination of letters and numbers.

In a cross sectional survey conducted to identify the difficulties that chemistry students from Kumasi Metropolis have in writing structural formulae of organic compounds, it was revealed that only 39.2% of the students wrote the correct structural formula of 2-methylpropan-1-ol as $(CH_3)_2CHCH_2OH$. This implies that, 60.8% of the students found it difficult to write the correct structural formula of a simple compound suc as 2-methylpropan-1-ol using the IUPAC nomenclature system (Adu-Gyamfi, Ampiah & Appiah, 2012). The inability of chemistry students to correctly name organic compounds indicates that they lack the necessary understanding in applying the rules for naming compounds and so should be given much attention.

Chemical formulae are considered to be abstract and specialized chemical language expressed in the reduced form of a symbol or an image (Justi, Gilbert, & Ferreira, 2009). The usefulness of this abstract mode of representation has been developed and set by the community of practicing scientists to enable them to communicate using a common short, reduced, form of precise specialised language that could be easily understood by the students (Taasoobshirazi & Glynn, 2009). These formulae require the use of not only symbolic letters but numerals, in the forms of subscripts and superscripts.

To understand chemistry, it is necessary to learn its terminology and associate it with chemical principles and concepts (Suits, 2000). When the chemical terminology and the organization of it is structured well to the students, it is easier for them to learn the new information (Sarma, 2006). The main problem in chemistry education is how to improve the conceptual comprehension of students and to make it easier for them to learn concepts (Sanger, Phelps, & Fienhold, 2000). Educational activities like teaching through game as well as teaching and learning materials like organic molecular model in chemistry classes provide positive motivation and self-confidence of success and eases to learn concepts by changing the apprehensive perspective of the students against chemistry classes (Bayir, 2014; Kavak, 2012).

In a study conducted by Omole (2011) to identify difficulties first year students have in naming organic compound from given structures and also write out the organic structures from given, names, he concluded that none of the candidates scored up to 50% in the content. This goes to show that there is a general problem of a lack of understanding of the organic nomenclature as a whole. Some of the students in Omole's study attributed their reason to inadequate time spent on teaching of organic chemistry. They stressed the fact that the organic chemistry is taught towards the end of their chemistry course, thereby giving them little or no time to master the subject. Some complained of not being taught at all.

Another difficulty students have in organic chemistry is that of understanding the three-dimensional nature of molecules. Students have no good background in three-dimensional visualization and have great difficulty in navigating between the two-dimensional drawings used in text books and classroom chalkboard drawings to represent molecules and their three-dimensional structures (Girija & Deepa 2004; Gilbert 2005; Uttal & Doherty 2008; Burger, Corrin, Deslongchamps & Jenkinson, 2013). Without this understanding, students memorize a large vocabulary of molecules and rules to fake an understanding of the three-dimensional structures in order to survive in the course.

Most of the problems encountered by students in learning nomenclature are from teachers and chemistry textbooks. Some chemistry textbooks are not consistent with the names given to organic compounds. Some of these texts go with old names side-by-side with the IUPAC names (Skonieczny, 2006). Scientists routinely employ many diverse representations in practice, although novices often have difficulty in mastering the use of representations in scientific disciplines, such as biology, physics, chemistry, geosciences, and mathematics (Ishikawa & Kastens, 2004; Kastens & Ishikawa, 2006; Kozma, 2003; Novick & Catley, 2007). For example, children as well as adults often fail to understand that a graph is a representation of trends in a data set rather than a picture of its referent (Kozhevnikov, Hegarty & Mayer, 2002). These difficulties are compounded when multiple representations are needed to be related and integrated for meaningful learning (Ainsworth, 2006). Without integrating information across representations, students run the risk of developing disjointed knowledge.

Subscripts used in chemical formulae possess a central problem to students. Arasasingham, Taagepera, Potter, and Lonjers (2004) investigated students' ideas about the meaning of subscripts in chemical formulae. The results showed that only half of the students gave correct explanations. Almost all of the students stated that the subscripts in chemical formulae indicated the number of atoms in a molecule. This is because most of the students did not know the rules involved in the naming of the organic compounds. Another cause of students' inabilities to define the subscripts was attributed to the traditional teaching method.

According to Taber (2001) many chemistry teachers lack both content and pedagogical knowledge to teach chemical formulae and nomenclature. As a result, students are bombarded with wrong facts and ideas. Teachers need to understand the rules that govern the nomenclature of organic compounds so that they can teach them understand the concepts of the chemical formulae and nomenclature whenever they are taught. Another difficulty students have in organic chemistry is that of understanding the three-dimensional nature of molecules. Students have no good background in three-dimensional visualization and have great difficulty in navigating between the two-dimensional drawings used in text books and classroom chalkboards drawings to represent molecules and their three-dimensional structures (Girija & Deepa 2004; Gilbert 2005; Uttal & Doherty 2008; Burger, Corrin, Deslongchamps & Jenkinson, 2013). Without this understanding, students memorize a large vocabulary of molecules and rules to fake an understanding of the three-dimensional structures in order to survive in the course.

Again, the use of second language possesses some difficulties in the learning of chemistry because the students lack chemistry language skills (Danili & Reid, 2004). Teachers particularly in rural areas are sometimes poorly qualified in both their scientific content and their command of English. A teacher should be able to put any scientific message into a suitable code, such as language, gesture, signs or symbols which can adequately be understood by students. Chemistry is an ideal domain in which to study representational competence. Chemists rely heavily on multiple external representations, such as chemical formulas, molecular diagrams, and concrete models (Cheng & Gilbert, 2009; Goodwin, 2008; Harrison & Treagust, 2000).

Impact of organic models on students' ability to identify and represent organic molecular structures

According to Kaberman and Dori (2012), a model is a representation of an object, event, process, or system (physical or computational), which interactively constructs the composition and structure of molecular phenomena. Models can give a visualization of complex ideas, processes and systems (Dori & Barak, 2001), a mental model is formed in the brain. A mental model is an idea of the mind (Gilbert & Boulter, 2000). It is inaccessible for others because everyone constructs his one version of a model in the mind (Gilbert, 2005). We construct mental models to display our understanding (Treagust, Cittleborough, & Mamiala, 2002). Mental models become expressed models when they are placed in a public domain. The application of model kits therefore enables teachers to know their conception understanding.

Okunloye and Awowale (2011) stated that students' academic performance in any subject is an important tool for measuring the effectiveness of teaching and learning and the extent to which the intended objectives of the subjects are achieved. Learning difficulties can be solved to a great extent by using appropriate teaching methods. Different approaches can be adopted for instruction in order to induce, promote and direct learning. Teachers can impart knowledge by lecture method, team teaching method, demonstration method, discussion method, audio-visual instruction, activity method, tutoring method and complementary method (Subair, 2001).

Multiple Intelligence theory has long modelled student learning by dividing it into a range of distinct domains. These include linguistic, logical, spatial, kinesthetic, musical, interpersonal, and intrapersonal learning styles. Different subjects and teaching styles require different aspect of these educational spectrum (Snyder, 2000). In particular, organic chemistry intrinsically requires high level spatial reasoning skills. This is because an understanding of chemical structure is integral to broader aspects of the course and is greatly influenced by a student's spatial ability (Dori & Barak, 2001). Chemical modelling kits are therefore frequently used as a visualization tool for understanding the 3-dimensional conformations of molecules. In particular, this physical representation should benefit students with poorer intrinsic spatial ability. Harle and Towns (2011) opined that chemistry problem solving involving the drawing structures of organic compounds is correlated with spatial ability. Spatial ability has been shown to be specifically related to performance in organic chemistry (Pribyl & Bodner, 1987), although not always (Keig & Rubba, 1993).

Organic chemistry is considered a challenging subject for students for a variety of reasons. In part, this reputation is justified by the demanding requirements of the class. To perform well, students must learn to build their knowledge base into a high-level conceptual understanding. Unfortunately, it can be difficult to motivate students, especially within an anonymous lecture hall environment. Devising methods for simplifying this learning process is therefore highly desirable for educators. Habraken (2004) argues that emphasizing the spatial components of chemistry, along with extensive use of visualization aids and molecular kits could improve accessibility to the field. The "true nature" of chemistry can be realized "only when the importance of visual-spatial thinking in chemistry is acknowledged.

Again, with the help of models, students can visualize molecules, give statements about possible interactions and are able to relate the structure of a molecule to the function (Kozma & Russell, 2000). Recent technologies make it possible to use computerized modeling tools for constructing molecular models. With the help of these software tools a scale of possibilities for molecular modeling becomes available (Sutch, Romero, Neamati, & Haworth, 2012). Molecular modeling is popular topic within chemistry education. Some insights are gained about working with modeling tools in science and chemistry education in particular but, there is still a lack of knowledge and especially materials to incorporate these scientific tools well in science and chemistry education (Kaberman & Dori, 2009).

In Harrison and Treagust's (2000) study of students' mental models of atoms and molecules, students had a strong preference to select the space-filling molecular model as a better representation of a molecule. In their findings, the students used both ball-and-stick and space-filling models to represent the structure of given compounds on their webpage and considered them as a more realistic depiction. However, without showing bond orders, the space-filling model was not the most visualisable models for students to identify functional groups and make translations during interviews. Thus, although the ball-and-stick models do not demonstrate appropriate atom sizes and electron cloud surrounding atoms, using them to provide a concrete experience of chemical bonds, atoms, and molecule is necessary for high school students. After students develop basic understanding of bonding, teachers could provide various 3D models and guide group discussions of how different models convey different information of bonding, atom size, and electron. Through class discussions, students would be able to realize limitations and benefits of using different types of representations and learn to appropriately use different models to solve problems.

While teaching the challenging topics of electricity, light, and so on, Slotta and Chi (2006) adopted ontology training before teaching scientific the concepts to the students. The results obtained revealed that students understood concepts on electric current far better after the ontology training. In this study, a similar hypothesis was developed; students could learn better about scientific concepts after getting instructions on modelling. Both the modelling ability framework and the theory of cognitive apprenticeship could be considered in developing modelling ability instruction.

A study conducted by Stull, Hegarty, Dixon and Stieff (2012) suggest that using models can assist the process by allowing difficult internal processes to be replaced or augmented by external actions on models. Students should be encouraged to use models in organic chemistry, at least in the beginning stages when they are first developing their understanding of the 3D structure of molecules and of molecular representations. The importance of student discourse when using models constructively emphasises the social aspect of learning as reported by Boulter (2000). The use of teaching models can bring about discussion and the articulation of explanations among students and encourage them to evaluate and assess the logic of their thinking.

Many researchers such as Gilbert, (2005), Kozma and Russell, (2005) and Schonborn and Anderson, (2010) identified that students need to necessary skills to make use of external representations and becomes visually literate in order to improve their cognitive skills. Such skills improved students' ability of making sense of symbolic information and representation. Using representations help to explain phenomenon to the extent of making predictions and solving problems and also spatially manipulating representations etc.

Models and modelling are considered integral parts of scientific literacy (Gobert & Buckley, 2000). They are an intermediary between the abstract theory and the concrete actions of an experiment. A research by Dori & Barak, 2001 concluded that models help students make to predictions, guide inquiry, summarize data, justify outcomes and facilitate communication. Gobert and Buckley (2000) also described a model as a simplified representation of a system, which concentrates attention on a specific aspect of that system.

In chemistry education, different models, such as, mathematical models, chemical equations and iconic and symbolic models are used to represent molecules (Prins, Bulte, Driel, Van & Pilot, 2009). Models of molecules take a dominant position, probably because the focus of chemistry is on the molecular structure of substances (Kaberman & Dori, 2009). Models of molecules enable students to do mental transformations and visualizations from a two dimensional to a three dimensional structure (Cody, Craig, Loudermilk, Yacci, Frisco & Milillo, 2012). The models therefore enhance students' ability to visualize and draw organic molecular structures thereby improving their academic performance. According to Martin and Schwartz (2005), the idea that students learn most effectively from models and other learning aids that provide them in active learning and grapple with the problems or situations in advance.

Chemistry as a discipline is dominated by the use of models. As a consequence, chemistry teaching is dominated by the teaching of models, some from within the discipline, others from other related disciplines such as physics and mathematics. A further complication for teaching arises from verbal shorthand like water (H_2O) and visual clues commonly used by experts and teachers. The scientist, expert modeller, or teacher may forget that he or she is communicating a model, instead of presenting a consensus teaching model as if it were a real entity (e.g., an atom) or a proven fact rather than as a well-established theory or model (Treagust, Chittleborough, & Mamiala, 2002). The ability to design and interpret controlled experiments is an important scientific process skill and a common curricular objective of science standards (National Research Council, 2012; NGSS Lead States, 2013).

Dori and Barak (2001) found that, the inquiry–based learning tasks in which models were used to encourage the understanding of organic compounds and provided students with tools for explaining their answers. In their work, experimental group students were more capable of defining and implementing isomerism and functional group concepts than their control group counterparts. When required to explain their choices, most of the experimental group students used mainly sketches of ball-and-stick models and some space-filling models. Most students of the control group did not provide any explanation (although required to do so) and those who did, used mainly 2-D wireframe models that resemble their teacher's chalk and board structural formula. Whereas most control group students did not provide any explanation for their answers, most experimental group students explained their answers correctly. An interesting finding was that experimental low academic level students expressed their explanation graphically. The researchers thus argued that students' gradual discovery of the molecules' 3D structure through model building and drawing enhanced their learning abilities. It enabled them to provide correct answers and explained their answers textually, graphically or the combination of both. Experimental group students understood the model concept better and were more capable of applying transformation from one-dimensional to two- dimensional (structural formula or ball-and-stick model drawing) or three-dimensional (space filling model drawing) molecular representations and from 2D or 3D back to the one-dimensional representation. The significant improvement in experimental students' understanding can be attributed to their increased exposure to virtual and physical models and the active learning these students were engaged in.

Grove and Bretz (2012) in their study believed that students' encounter many difficulties in learning organic chemistry ultimately stem from an over-reliance on rote memorization without using more meaningful technique. For example, many students have memorized the molecular formula of ethanol to be C_2H_5OH, but are unable to explain why it is so in terms of bonding structure and cannot relate it to C_2H_6O, or draw the expanded or graphic structure. Cooper, Grove, Underwood and Klymkowsky (2010) found out that many students were confused about how to construct valid bonding structure of organic molecular structures. They also noted in their study that as the number of carbon atoms in the structure increased, the percentage of students who were able to draw the structures fell significantly. The students had little idea as to how to convert or change between molecular formula, condensed formula, expanded structural formula, and skeletal structures. (Lawrie, Appleton, Wright & Stewart, 2009). All the above issues show that students' conceptions of organic molecular structures in chemistry can differ from what they are expected to learn. Chiu (2005) posits that students' conceptions can arise from peer interaction, gender, media, symbolic representation, school instruction and text books.

Scientific modelling is a practice that requires constructing a representation that can "abstract and simplify a system by focusing on key features to explain and predict scientific phenomena" (Schwarz, Reiser, Davis, Kenyon, Acher, Fortus, Swartz, Hug, & Krajcik, 2009). These scientific models explicit in a manner that allows the scientist to more precisely characterize a phenomenon and to communicate an understanding of the phenomena more effectively. Yip, Jaber, and Stieff, (2011) have shown that students who sketch during simulation activities develop more accurate mental models of chemical phenomena and produce more accurate sketches of scientific models.

Empirical Evidence

Chemistry is an ideal domain in which to study representational competence. Chemists rely heavily on multiple external representations, such as chemical formulas, molecular diagrams, and concrete models (Cheng & Gilbert, 2009; Goodwin, 2008; Harrison & Treagust, 2000). Abstract concepts such as organic molecular structures belong to the symbolic level of chemistry. Empirical studies by Cokelez (2012) have shown that, understanding symbolic representations is especially difficult for students, because these representations are invisible and abstract, while students' thinking relies heavily on sensory information. Horton (2007) noted that not all misrepresentations are students' conceptions. Some mistaken expressions are nothing more than difficulties in explaining new phenomena. Most students' conceptions in 3-D molecular structures in chemistry may have been generated by them, as they grapple with information and models presented in school, which they are unprepared to imagine or understand. The problem may also be that students have difficulty believing in something they cannot see (Kind, 2004).

Stieff, (2007) found out that organic chemistry is commonly a problem and chemistry students eventually develop a wide range of alternative conceptions. Jimoh (2005) also identified organic chemistry as one of the difficult topics in chemistry curriculum which can contribute to poor achievement in chemistry. Empirical studies by Wu, Krajcik and Soloway (2001) have shown that understanding symbolic representations in chemistry are especially difficult for students because, these representations are invisible and abstract as their thinking rely heavily on sensory information. Additionally, without substantial conceptual knowledge and spatial ability, students are unable to translate one given representation into another, (Wu &Shah, 2004). To help students understand chemistry at the symbolic level, Vesna, Vrtacnik, Blejec and Gril (2003) suggested the use of concrete models and technologies as learning tools.

Subscripts used in chemical formulae possess a central problem for students. Arasasingham, Taagepera, Potter, and Lonjers (2004) investigated students' ideas about the meaning of subscripts in chemical formulae. The results showed that only half of the students gave correct explanations. Almost all of the students stated that the subscripts in chemical formulae indicated the number of atoms in a molecule. This is because most of the students did not know the rules involved in the representation and naming of the organic compounds. Another cause of students' inabilities to define the subscripts was attributed to the traditional teaching method.

Childs and Sheehan (2009) contend that the organization of most curricula and the teaching design of most commercial textbooks do not match learners' thinking capacity. Topics are often introduced when students are not developmentally and psychologically ready to learn them. Curriculum instruction and assessment are significantly improved, when teachers are aware of learner's developmental considerations.

Reaching the formal operational stage of development should mean that these learners can then handle abstract ideas and think logically. When learners lack the cognitive ability necessary to learn and understand the basic concepts, they adopt personal ideas. This is why an understanding of students' conceptions in naming, construction and application of organic molecular structures is needed to cause conceptual change in chemistry. Any instruction that fails to acknowledge and address students' conceptions will not foster real growth in understanding of the subject (Horton, 2007). Thus, being able to recognize or identify and work with the students' previous held ideas and conceptions is the key component of an effective educational strategy in learning of the molecular structures. In this study, organic molecular models was used to improve upon students understanding in the learning of alkanes, alkenes and alkynes.

The chemical models in focus here can be generalised and separated into three different categories. These different categories, which are differentiated through their intent and use, are referred to as scientific models, educational models" and "students' expressed models" (Gilbert, 2005). With scientific models as a background, educators derive simpler models for educational purposes. Here such models are referred to as educational models. The third class of models, categorised as students' own expressed models, is in this study used for gaining insight in to students' growing repertoire of models, and their use of educational models.

Curriculum developers interpret scientific models and transform them into school science curricula that is curricula models (Justi & Gilbert, 2000). Textbook writers then interpret the curricula models and these are subsequently transformed into consensus target models (Gilbert, 2005) designed for different educational levels. These consensus target models are commonly used for learners at different levels of education and can be deduced from textbooks. Examples of this models from chemistry at this educational level forms the composition of an atom and placing of its subatomic particles or symbolic representations, for example "chemical symbols, formulas and equations" (Talanquer, 2006).

Teaching models include a variety of representations that may or may not accurately portray all aspects of a phenomenon (Treagust, Chittleborough, & Mamiala, 2002). Many of the representations employed in the chemistry curriculum support thinking and reasoning about spatial relationships within and between molecules (Wu & Shah, 2004). Spatial thinking is an important aspect of chemistry problem solving, because the reactivity of molecules is predicted not just by the number and type of atoms that make up a molecule, but by the spatial configuration of these atomic substituents (such as functional groups of atoms).

Summary

Drawing and naming of cyclic hydrocarbons is one of the fundamental topics in organic chemistry. It has for some time now continued to be a concept that students really struggle to understand. The research tackled on the theoretical framework based on constructivism where Paiet, Vygosky and Bruner contribute to this theory.

Again, students' difficulty in writing and naming aliphatic hydrocarbons and organic compounds in general is as a result of lack of teaching material. In chemistry, teaching through the use of teaching material is one of the most frequently used methods in education practices that provide the lessons to be more productive, dynamic and enhance active participation of students in teaching (Knudtson, 2015; Stringfield & Kramer, 2014). Chemical modelling are therefore frequently used as a visualization tool for understanding the 3-dimensional conformations of molecules. This physical representation benefit students with poorer intrinsic spatial ability and also address students' difficulties in visualizing 3D molecular structures. There have been several studies on the use of the molecular models. Most of these studies used Senior High school students. This study would fill the gap by using first year undergraduate students of the University of Education, Winneba. These students were chosen because they are the trainee teachers who would go out very soon as professional teachers to teach.

CHAPTER THREE

METHODOLOGY

Overview

This chapter describes the research design, population, research instruments, ethical consideration, data collection procedure, pilot testing, validation of instrument, reliability of the instrument. The study employed a case study design, weekly tests as in intervention to help student drawing and naming structures of some hydrocarbons such as monocyclic, spiro and bicyclic compounds. The students were taught for six weeks and at the end of each week they were made to take a test. Data collection was done by monitoring students' outputs in the pre-intervention and post-intervention exercises.

Research Design

The study adopted a case study design which used the action research approach. The researcher used molecular model kits to enhance first year chemistry students' performance in naming and writing structures of aliphatic hydrocarbons in University of Education, Winneba. Johnson (2012), defined action research in education as the process of studying a school situation to understand and improve the quality of the educational process. It provides practitioners with new knowledge and understanding about how to improve educational practices or resolve significant problems in the classrooms and schools (Mills, 2011; Stringer, 2008). According to Hensen (1996) action research helps teachers to develop new knowledge directly related to their classrooms, promotes reflective teaching and thinking, expands teachers' pedagogical repertoire, puts teachers in charge of their craft, reinforces the link between practice and student achievement, fosters an openness toward new ideas and learning new things, and gives teachers ownership of effective practices.

In this study, students' difficulties were identified through a pre-test which was later addressed using intervention strategies. The students' performance after the implementation of the intervention strategies was evaluated through a post-test. Frabutt, Holter, and Nuzzi (2008) opined that action research enables researchers to develop a systematic, inquiring approach toward their own practices oriented towards effecting positive change.

Population

According to Castillo (2009), research population is a well-defined collection of individuals or objects having similar characteristics. It involves all the people, objects, and institutions who are the subject of the study and intended to be studied by the researcher. Castillo distinguishes between two types of population: the target population and the accessible population. The target population which is also known as the theoretical population refers to the group of individuals to which researchers are interested in generalizing conclusions. The accessible population which is also known as the study population is the population in research to which the researchers can apply their conclusion.

The study's target population was all first year chemistry students in the Faculty of Science Education, Winneba. The study was however, limited to only first year science students reading Chemistry as their major subject at the University of Education, Winneba.

Sample and Sampling Procedure

This study used purposive sampling to select one hundred and three undergraduate chemistry major students for the study. According to Cohen, Manion and Morrison (2007), purposive sampling is the selection of a sample on the basis of the judgement of their typicality or possession of the particular characteristics being sought. The researcher used purposive sample because the said sample were the only group who were more knowledgeable in elective chemistry among the accessible population.

Research Instruments

The instruments for data collection would be through tests, questionnaires. This was supplemented with observation.

Ethical Considerations

Permission to conduct the study was obtained from the Head of Department. The researcher also had permission from the lecturer taking the organic chemistry course. The participants were informed not to work under pressure but feel free to participate since their score will not be part of their continuous assessment.

Data Collection Procedure

Test and Exercises

The researcher administered tests and exercises to students in order to determine their conceptual understanding in drawing and naming structural formulae of cyclic compounds. The performance was low in the pre-test. A quite similar test, herein called the post-test was administered at the end of the study to find out the effectiveness of the intervention procedure.

Observation

Observation (Appendix D) was done to obtain information on how the use of organic molecular kits influenced students' attitude and behaviour during the learning process. Observational research techniques have advantages over other qualitative data collection methods when the focus of research is on understanding actions, roles and behaviour (Walshe, Ewing, & Griffiths, 2012) because it enable the researcher to witness the various actions leading to the problem at stake.

Questionnaire

Questionnaire was chosen because it is effective in securing information from the respondents within the shortest possible time. A set of self-developed questionnaire (Appendix C) was used to solicit students' perceptions on the use of the molecular models in naming and writing structural formulae of cyclic compounds. The questionnaire was administered after the implementation of the intervention strategy. The options included 'Strongly Agree (SA)', 'Agree (A)', 'Disagree (D)' and 'Strongly Disagree (SD).' The respondents were to tick appropriate options that applied to their case.

Pilot Testing

The questionnaires were pre-tested on first year organic chemistry minor students. These students were selected because they shared similar characteristics with chemistry major students for the study. The pilot study enabled the researcher to restructure the research instruments to help elicit the right responses.

Validation of Instrument

To maximize the content validity of the test items, expert advice was sought from my supervisor who guided and ensured the selection of only questions that fitted the objectives of the study. Validity is ‘the extent to which an indicator accurately measures a concept (Fielding & Gilbert, 2000). In other words, validity can be defined as the degree to which a test measures what it is supposed to measure.

Reliability of the Instrument

Reliability means the likelihood of obtaining the same results when the researcher measures the same variable more than once, or when more than one person measures the same variable (Brink, 2000). Reliability therefore relates to the measurement accuracy of the data collection instrument. An instrument can be said to be reliable if its measurement accurately reflects the true scores of the attribute under investigation (Polit & Beck 2004). Joppe (2000) defines reliability as the extent to which results are consistent over time. According to Creswell (2009), reliability refers to whether scores to items on an instrument are internally consistent, stable over time, and whether there was consistency in test administration and scoring. In this study, a reliability test was conducted by determining the Cronbach’s alpha (Appendix E). Cronbach alpha was then used to calculate the coefficient of reliability. The coefficient for students’ responses in the pilot study on chemistry minor students was found to be 0.789. These were then compared with the tabulated coefficient of reliability which according to Aryl, Jacobs & Razavieh (2002), for test item instrument which measures intellectual achievement to be accepted, it should have Cronbach alpha Coefficient reliability of not less than 0.72.

Data Analysis

The instruments used for data collection were administration of exercises and tests as well as questionnaire and observation. The results obtained from the tests were grouped for analysis. In the analysis, descriptive statistics such as mean and standard deviation were calculated and used for discussion. Also, inferential statistics like t-test (confidence level of 95%) were determined to establish the relationship between students' performance at the pre-intervention and post-intervention stages. The data collected from the observational check list was discussed.

Pre-Intervention

Prior to the intervention, the problem was identified by going through students exercise books and interviewing them. It was observed during the first three weeks that most of the students had difficulty in naming and drawing structures of aliphatic hydrocarbons. The students' exercise books also testified that they had low score for exercises conducted in naming and drawing structures of organic compound. The researcher interviewed students and conducted pre-test to evaluate students understanding. The results from the test were recorded and analysed. The analysis of the data revealed the urgent need to intervene with a measure of remediation.

Pre-Test

The researcher conducted pre-intervention test on the concept of naming and drawing of some cyclic hydrocarbons. The pre-intervention test contained 20 items. The items were to test students' understanding in drawing and naming of monocyclic, spiro and bicyclic compounds (Appendix A). The total score for the test was twenty (20). The total score for each student was collated and tabulated.

Intervention Design

After the findings from the pre-test, an intervention was designed to enable students to improve on their understanding and hence reduce their poor performances in drawing and naming of structural formulae of cyclic compounds. The topic was divided into sub-headings so that organic molecular models could be used to improve students' understandings and hence their performance. Five Chemistry periods comprising 120 minutes each were used to address the problem. The intervention activities included:

Table 3.0: Work schedules for the five periods.

Week	Topic Treated	Time allocation
1	Revising with students and allowing them to model some simple alkanes and alkenes using the general rules for naming of organic compounds.	120 minutes
2	Teaching students to apply the rules of IUPAC nomenclature with reference to monocyclic, spiro and bicyclic compounds	120 minutes
3	Teaching students to improve their concepts on naming alkyl substituents such as isopropyl, tertbutly, secbutyl, phenyl etc.	120 minutes
4	Modeling of monocyclic, spiro and bicyclic compounds with different structural formulae to improve upon students' ability to identify least carbon positions for substituents.	120 minutes
5	Modeling and naming of monocyclic, spiro and bicyclic compounds using the IUPAC rules.	120 minutes
6	Modeling and drawing structural formulae for monocyclic, spiro and bicyclic compounds.	120 minutes

Revising with students and allowing them to model some simple alkanes and alkenes using the general rules for naming of organic compounds

Sub topic: Structure and bonding in alkanes, alkenes and alkynes

Planning lesson one

Before the presentation of the lesson students were introduced to the use of the molecular models;

1. Students were taught the use of the molecular models
2. Students were shown the different colours of the models and what each represents for them to be acquainted with the content. For example the black ball represent the carbon and white ball hydrogen.

The various atoms, symbols, colours codes and the holes as they are employed for models in them are shown in Table 3.1 was shown to the students.

Table 3.1: Atoms and their symbols, colour codes and number of holes

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

3. They were also taught how to form the double and triple bonds using the models.

The longest hydrocarbon chain is selected and is termed as parent chain in case of alkanes. In case of alkenes hydrocarbon chain with double bond and longest carbon chosen as parent chain. A parent chain is named with the help of Greek alphabets such as metha, etha etc. For alkanes the suffix '-ane' is used, for alkenes, the suffix '-ene' is used and suffix 'yne' is used for alkynes. For example: C_2H_6 is known as ethane, C_2H_4 is known as ethene and C_2H_2 is known as ethyne.

A Parent chain is numbered such that the double bonded or triple bonded carbon is considered as the earliest atom. The position of carbon atom with double bond is mentioned in numerals.

The researcher decided to deepen students' conceptual understanding on the types of bonding formed by each of the hydrocarbons

Students were made to model for each type of compound that they identified.

Steps:

i. Students were made to model given structures using the molecular model

ii. Carbons which were not having enough hydrogen surrounding them were made either double bond or triple bond.

iii. Students were asked to check the number of bond formed by each carbon to confirm their arrangement since carbon does not form more than four bonds.

iv. Students were asked to identify the bond in alkanes, alkenes and alkynes.

v. Students were made to model Ethane, ethene and ethyne hydrocarbons after explaining the bond formation in each case. The formation of ethane, ethene and ethyne are represented in figure 2.

Ethane Ethene Ethyne

Figure 2: Formation of ethane, ethene and ethyne using the molecular models

Teaching students to apply the rules of IUPAC nomenclature with reference to monocyclic, spiro and bicyclic compounds.

Sub topic: The Rules of IUPAC Nomenclature with respect to Monocyclic, Spiro and Bicyclic Compounds.

Planning of lesson two

The researcher guided students to identify longest continuous carbon chains in branched hydrocarbons. Modelling, drawing and numbering of carbon chains were the activities that facilitated the teaching process.

Lesson presentation

The lesson presentation involved the modelling of cyclic compounds of given hydrocarbons. Students were asked to draw the modelled hydrocarbons on paper and count the number of carbon forming the longest chain. The students were informed that the number of carbons in the longest carbon chain gives the parent name of the hydrocarbon. In naming cycloalkanes, the prefix *cyclo* precedes the name of the number of carbons in the ring. They were also informed that for *spiro* compounds, the prefix *spiro* is followed by square brackets containing the number of carbons in the smaller ring and the number of carbons in the larger ring. They learned how numbers are separated by a dot. They were further informed that naming bicyclo compounds, the parent name is derived from the total number of carbon atoms in the bicyclic ring system preceded by the prefix *bicyclo* to show that it is a bicyclic compound. After these basic rules were introduced, they were presented with a chart as shown table 3.2 to guide them in the day's class activities.

Table 3.2: Number of atoms, molecular formula and basic structure for cyclic compounds

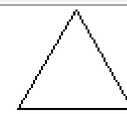
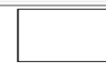
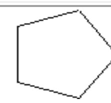
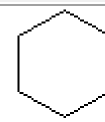
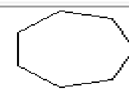
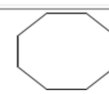
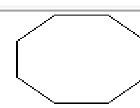
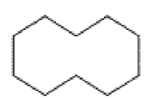
Number of carbon atoms	Cycloalkane	Molecular Formula	Basic Structure
3	Cyclopropane	C_3H_6	
4	Cyclobutane	C_4H_8	
5	Cyclopentane	C_5H_{10}	
6	Cyclohexane	C_6H_{12}	
7	Cycloheptane	C_7H_{14}	
8	Cyclooctane	C_8H_{16}	
9	Cyclononane	C_9H_{18}	
10	Cyclodecane	$C_{10}H_{20}$	

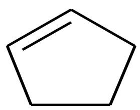
Table 3.2: Shows examples of cyclic compounds introduced to the students

Monocyclic

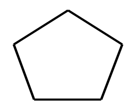
Cycloalkanes and cycloalkenes are ring structures with the general formula: $C_nH_{(2n)}$ and $\mathbf{C_nH_{2(n-m)}}$. The following are basic rules for naming cycloalkanes:

Parent Chain

a. The students were asked to identify the parent chains for cycloalkane and cycloalkane as the parent chain if it has a greater number of carbons than any alkyl substituent.

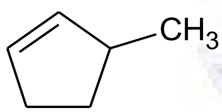


Cycloalkene

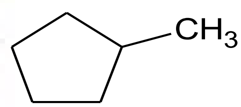


cycloalkane

b. The students were asked to identify the alkyl chain for cycloalkanes and cycloalkanes cycloalkane as a cycloalkyl-substituent.



3-methylcyclopentene



methylcyclopentane

The alkyl substituents are presented in table 3.3

Table 3.3: Alkyl substituents with their corresponding names

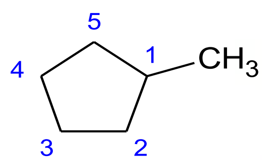
Substituents	**Name**
$-CH_3$	Methyl
CH_2CH_3 or C_2H_5	Ethyl
$-CH_2CH_2CH_3$ OR C_3H_7	Propyl
$-CH_2CH_2CH_2CH_3$ or C_4H_9	Butyl

Table 3.3 gives examples of alkyl substituents on cyclo compounds

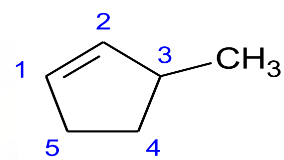
Naming of Cycloalkane and cycloalkenes using the IUPAC rule

Students were expected to know that:

a. Students were taught how to name the monocyclic compounds. Numbering the carbons of a cycloalkane, start with a substituted carbon so that the substituted carbons have the lowest numbers (sum). In the case of alkenes, they were taught to start with the carbon that has the double bond before considering the substituents.

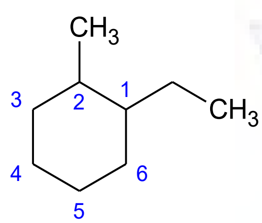


Methyl cyclopentane



3-methylcyclopentene

b. Students were asked to number the substituents with two or more different substituents. This was done in alphabetical order.



1-Ethyl-2-methylcyclohexane

Halogen Substituents

Halogen substituents are treated exactly like alkyl groups. .

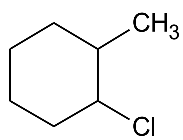
Table 3.4 shows some substituents and their names.

Table 3.4: Some substituents and their respective names

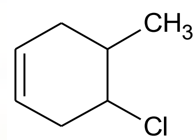
Substituents	Name
-Br	Bromo
-Cl	Chloro
-F	Floro
-I	Iodo
-OH	Hydroxy
$-NO_2$	Nitro

Table 4.3 describes the substituents with their respective names.

Students were asked to name the students with the alkyl and halogen substituents.



1-Choloro-2-methyl cyclohexane

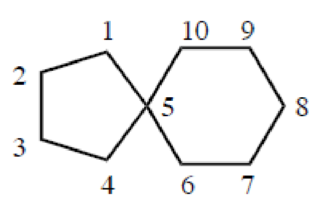


4-Choloro-5-methylcyclohexene

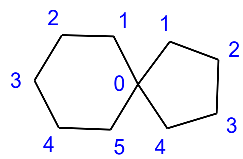
Spriocyclic compounds

To name spiro compounds, students are expected to follow these three steps:

1. Locate the bridgehead carbon, the only carbon part of the two rings
2. Now, spot the two rings system having 2 or more carbons; arrange these in increasing order of number of carbon atoms (excluding the bridgehead, again). Sat these two numbers are p, q [p < q]

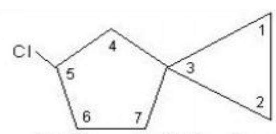


3. Write the name of the compound as: spiro[p.q] “p+q+1” alkane”



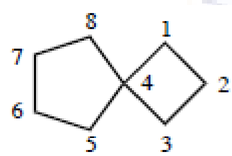
Spiro[4, 5]decane

4. In case there is a substituent or a functional group present, you need to number your carbons: start from the atom next to bridgehead in the smaller ring through the bridgehead carbon to the bigger ring.

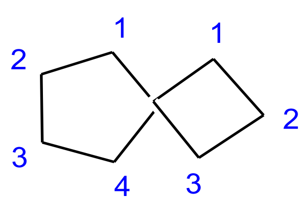


5–Chlorospiro[2,4]heptane

Another example



1. Count the total number of carbons. In this case there are 8 carbons so the parent name is octane
2. Count the total number of carbons between bridgeheads. In this case there are 2, 2, and 1 carbons between the bridgehead. Count in clockwise direction in ascending order between brackets it is [3,4]



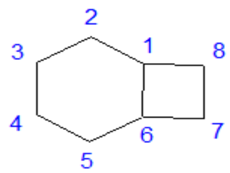
Put the word spiro in the front of the name

The name is thus spiro[3,4] octane

Bicyclic compounds

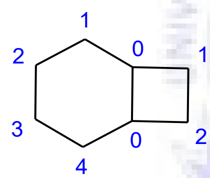
To name the bicyclic compounds, students are expected to:

1. Locate the bridgehead carbons, the carbons part two rings



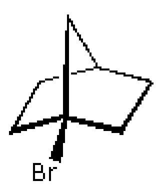
2. Identify the tree connections between the two bridgeheads, called bridges: arrange these in decreasing order of number of carbon atoms (excluding the bridgehead). Say these three numbers are m > n > o

3. Write the name of the compound as bicyclo[m.n.o]“m+n+o+2 alkane



Bicyclo[4, 2, 0]octane

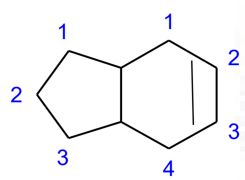
3. In case there is a substituent or functional group is present, you need to number your carbons; start from the bridgehead, through the longest bridge to the shorter and the shortest if any.



1-bromobicyclo[2.2.1]heptane

Another Example:

1. Count the total number of carbons. In this case there are 7 carbons so the parent name is heptane
2. Count the total number of carbons between bridgeheads. In this case there are 4.3.0 and 1carbons between the bridgehead. Placed in descending order between brackets it is [4.3.0].
3. In case there is a functional group is present, you need to number your carbons; start from the bridgehead, through the longest bridge to the shorter and the shortest if any.



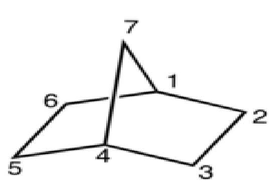
[4, 3, 0]

The double bond is on the 2nd and 3rd carbon.

The name therefore becomes;

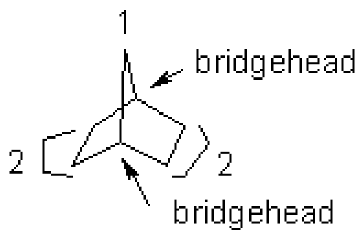
Bicyclo[4, 3, 0]non-3-ene.

Example: Name the following molecule by the IUPAC system of nomenclature.



1. Count the total number of carbons. In this case there are 7 carbons so the parent name is heptane

4. Count the total number of carbons between bridgeheads. In this case there are 2, 2, and 1 carbons between the bridgehead. Placed in descending order between brackets it is [2,2,1]



4. Put the word bicyclo in the front of the name

The name is thus *bicyclo [2, 2, 1] heptane*

Sub topic: Identification of least carbon positions for substituents and functional groups

Planning of lesson Four

In order to improve students' ability to indicate correct positions for substituents and functional groups in nomenclature, the researcher used drawing and modelling of hydrocarbons as well as counting carbons of parent chains of hydrocarbon compounds to facilitate teaching.

Lesson presentation

It was presented that counting and numbering of carbons forming the parent chain must be done from the left to right and vice versa. The numerical carbon positions of substituents and functional group on the parent chain were noted. Students were taught to sum the numeral positions of each substituent from left to right and compare to that from right to left. The direction in which the substituents had least counts was used for naming. Substituents in nomenclature were also ordered in alphabetical order. This was done to solve students difficulties associated with substituent positions and their arrangement.

Activities

Students were asked to identify the least counts of substituents and state the direction of nomenclature and it should be done in alphabetical order.

They were expected to follow some required steps in answering the problem given to them. They were to:

i. Identify the parent carbon chain.

ii. Count in the left and right directions and identify the direction where substituents have least counts.

iii. Indicate the numerical positions of each substituent by using hyphen between letters and numbers while using comma between numbers.

Arrange inorganic substituents first before organic substituents and name the compound below.

Modelling, drawing and naming structures of cyclic hydrocarbons using the IUPAC rules

Molecular models were used to enhance and drawing naming of structural formulae. Teaching was activity-oriented and a strict application of the IUPAC rule for naming and drawing structures were observed.

The researcher grouped students for the activity oriented lesson where her ultimate focus was to guide students name and draw organic structural formulae. The essence of the group work was to enable the bright students to assist the identified weak students. Cyclic compounds were modelled before naming or drawing structures.

Sub topic: IUPAC rule of nomenclature and modelling of alkyl substituent

Planning of lesson Three

The researcher explained how to apply the rules of IUPAC nomenclature and modelled some alkyl substituents. The purpose was to enable students understand the rules for naming and become familiar with structures of alkyl groups.

Lesson presentation

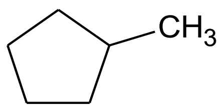
The lesson presented gave students the opportunity to come out with vocabularies that they did not understand in the IUPAC rule for clarification. The lesson also involved discussions and modelling of some alkyl groups used in compound and the prefixes *n*–, iso, *sec*–, and *tert*– explained. While these prefixes are not part of the IUPAC system, chemists commonly use them. Improving students' ability to identify the various substituents and the kind of prefixes they should use when the substituent is more than one is important in nomenclature. To name a compound with a substituents, one has to:

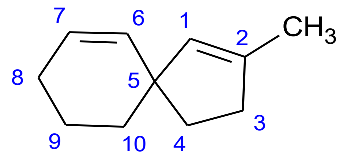
- Find the longest carbon chair and name it
- Number the chain to give the substituents the lowest possible number
- Identify and name the substituent
- Arrange the substituents alphabetically.

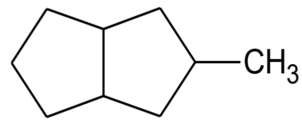
Activity

1. Students were asked to model monocyclic with five carbon chains with a methyl substituent See picture below.

a. b. c.

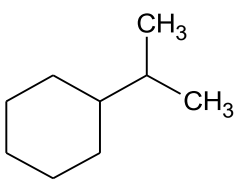


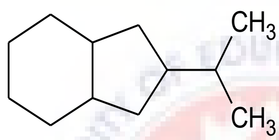


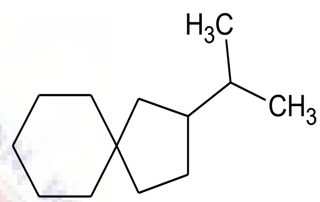


1-Methylcyclopentane 2-Methyspiro [4, 5] deca-1, 6-diene 8-Methylbicyclo [4, 3, 0] nonane

2. Students were asked to remove the other hydrogen on that same carbon and replace with another methyl substituent.







1, 1-Dimethyisopropyl cyclohexane 7, 7-Dimethylisopropyl bicyclo [4, 3, 0] nonane 2, 2-Dimethylisopropyl spiro decane

Sub topic: Modelling, a drawing and naming structure of cyclic hydrocarbons using the IUPAC rules

Planning of lesson Five

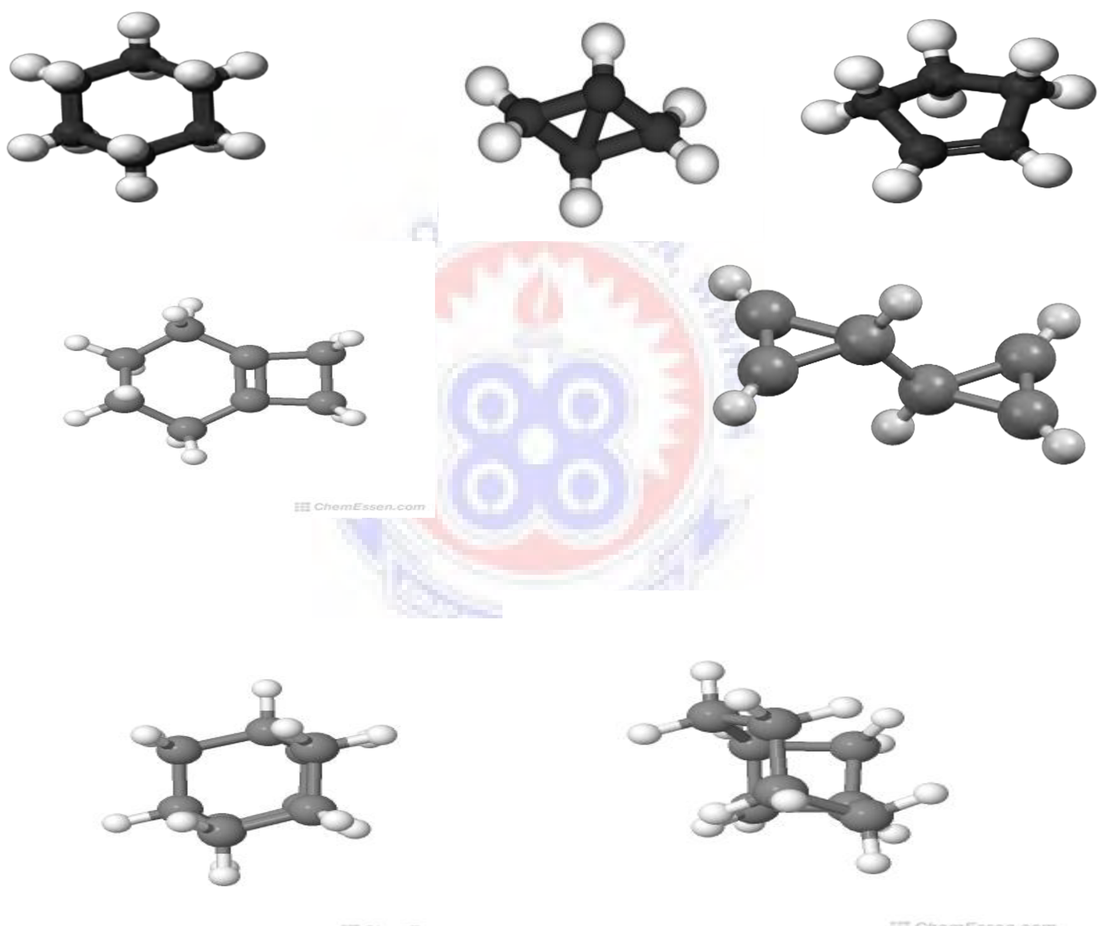
Molecular models were used to enhance drawing and naming structural formulae. Teaching was activity oriented and strict application of the IUPAC rule for naming and drawing structures was employed.

Lesson presentation

Students were then guided to model the structures of monocyclic, spiro and bicyclic compounds using the molecular models (stick-and-ball). This was done to improve students’ understanding of cyclic compounds.

The researcher grouped students for the activity-oriented lesson where the ultimate focus was to guide students name and write organic structural formulae. The essence of the group work was to enable the bright students assist the weak students. Cyclic compounds were modelled before naming or drawing structures. The students were given activities to try their hand on. They were asked to;

Categorise the modelled compound into mono, spiro and bicyclic compounds



Post-Intervention Test

A post intervention test (Appendix B) was conducted to determine students understanding in their ability to name and write structural formula of monocyclic, spiro and bicyclic compounds after the implementation of the intervention design. The results obtained were analyse and used for discussion in chapter four.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

Overview

The chapter discusses the results obtained from the pre-intervention test, post-intervention test and the questionnaire which were administered. The research questions were answered accordingly.

Pre-intervention test

A pre-intervention test was conducted to identify the various difficulties that students have in drawing and naming of structural formulae of mono, spiro and bicyclic compounds of alkanes and alkenes.

Research question 1: What are some of the difficulties students encounter in drawing and naming the structural formulae of mono, spiro and bicyclic compounds?

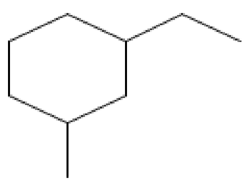
The mean score obtained by students in the pre-intervention test is presented in Table 4.1.

Table 4.1: Mean score of students in the pre-intervention test

Test	N	Min	Max	Mean	SD
Pre-intervention	103	1	16	8.88	4.05

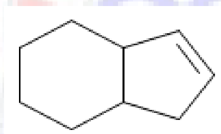
Table 4.1 shows that, the minimum score obtained by students in the pre-intervention test was 1.0 while the maximum score obtained was 16. The mean score obtained by students in the pre-intervention test was 8.88 (SD = 4.05). The small standard deviation indicated that majority of the students scored close to this mean value. The mean score obtained in the pre-intervention test suggests that majority of the students were not able to score more

than half of the overall score (20 marks) as shown in Appendix F. Their poor performance can be attributed to their inability to properly write and name the structural formulae of organic compounds in general, hence, their difficulties in writing and naming structural formulae of mono, spiro and bicyclic compounds of alkanes and alkenes. Some of the difficulties identified included their inability to identify the parent chain ring for monocyclic compounds with monocyclic alkyl substituents, inability to identify the correct starting position for monocyclic compounds with two or more substituent groups and inability to arrange substituents in alphabetical order. For instance, some of the students could not name the structure below:



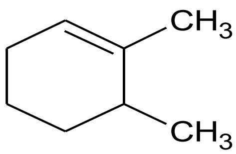
This structure was named by some students as 3-methyl-1-ethylcyclohexane instead of 1-ethyl-3-methylcyclohexane. Others named this same structure as 3-ethyl-1-methylcyclohexane. They could not figure out the substituent group that should take the first position. Also, some of the students who were able to identify the correct starting position were not able to name the substituent in alphabetical order. Majority of the students misapplied the rules required for naming bicyclic compounds for spiro compounds. The order of numbering of the carbons as well as naming of spiro compounds was done wrongly. Some of the students were not able to introduce the prefix bicyclo or spiro in naming bicyclic or spiro compounds. In cases where students were asked to draw structures for named compounds of spiro and bicyclo, almost all the participating students were not able to draw the structures for the compounds. Similarly, Adu-Gyamfi, Ampiah and Appiah (2012) reported that Chemistry students from the Kumasi Metropolis showed difficulties in writing structural formulae of organic compounds in a similar study that they carried out. It was revealed in their study that only 39.2% of the students wrote the correct structural formula of 2-methylpropan-1-ol as $(CH_3)_2CHCH_2OH$. Hence, 60.8% of the students found it difficult to write the correct structural formula of 2-methylpropan-1-ol using the IUPAC nomenclature system. Their poor performance could be attributed to lack of conceptual understanding of IUPAC rules and how to apply them. This current study supports that of Wu, Krajcik, and Soloway (2001). They concluded that most chemistry students have difficulty in writing structural formulae of organic compounds.

In one of the questions students in the current study were to give the IUPAC name of the bicyclo compound below:

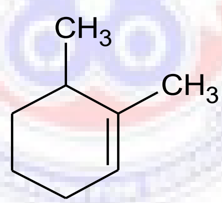


They were to start counting from one of the bridge head carbons and move through the bigger arm that had more carbons to the side with less number of carbons. Students rather counted the smaller arm with less carbon chains before the bigger arm. This suggests that students did not know that counting on the bigger arm with more carbons implies giving priority over the carbon-carbon double bond functional group. Students repeated this error in their naming of the spiro compounds as well. The study agrees with that reported by Omole (2011). He identified difficulties first year students had in naming organic compounds from given structures and drawing out the organic structures from given names. He concluded that none of the candidates scored up to 50% in the content assessment test he administered. Research report from different parts of the world, as outlined show that there is a general problem of a lack of understanding of the organic nomenclature. Some of the students in Omole's study attributed their challenges to inadequate time spent on the teaching of organic chemistry by teachers. Also, Cooper, Grove, Underwood and Klymkowsky (2010) found out in their study conducted in Clemson University in South Carolina in the United States of America that many students were confused about how to construct valid bonding structures of organic molecules. They also noted in their study that as the number of carbon atoms in the structure increased, the percentage of students constructing correct representations fell significantly.

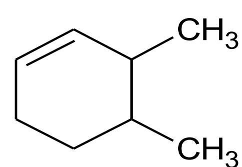
The structures below were some of the wrong structures drawn by students for 1,2-dimethylcyclohexene.



a



b

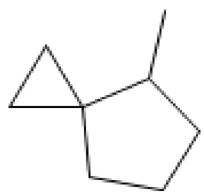


c

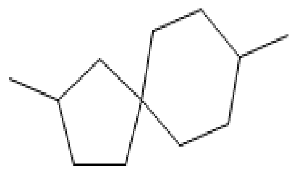
All the above structures have different IUPAC names other than what students were to draw. The above responses show that they have good understanding in identifying the parent names of structures. They however lack understanding of the particular carbon that should take the first position. In the IUPAC nomenclature for cycloalkenes, the carbon-carbon double bonds take the first and second positions, and counted in the direction where substituents bear the least count. The correct structure for 1, 2-dimethylcyclohexene is shown below.

If students are not able to represent correct structural formula of organic compounds in examination it may lead to low performance. Similarly, Clark (2000) opined that in any chemistry examination, if students find it difficult to understand what the examiner is looking for, then they will find it difficult to write a structural formula of any named compound. Hence, the performance of such students is affected on such questions.

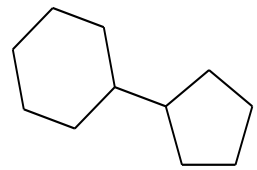
Students demonstrated some difficulties in the naming of Spiro compounds.



a



b



c

Students did not recognize the structures above (**a, b, c**) them as spiro compounds. They were confused with the cyclic substituent attached to another mono cyclic compounds (as shown in **a**) and two monocyclic compounds that are fused to form spiro compounds (as shown in **a** and **b** above).

The rules for naming formulae **a** and **b** are the same. In determining the total number of carbons forming the parent chain, carbon atoms in the two rings are counted. The next is to count the carbon starting from the smaller ring followed by the larger ring and counting in the directions where substituents bear the least count. The carbon which joins the two rings is never the starting point for spiro compounds but most students start counting from that point. This means that they had difficulty in applying the rules in naming spiro compounds. In compound **c** the ring with the least number of carbon atoms is a substituent.

Again students had difficulty in identifying the position of the functional groups in the compound. Skonieczy (2006) as cited by Adu-Gyamfi, et al., identified the first most important step in naming organic compounds as the identification of the presence of the functional group in the molecule of that compound. In instances where there are more than one functional groups, the principal group must be given preference.

According to Gillette (2004) any written IUPAC name of an organic compound has three aspects. These are number of carbon atoms in the longest continuous carbon chain, which usually forms the parent name; the ending which indicates the family or the functional group of the given organic compound indicates the root; and the number, position, and identity of any atoms or group of atoms in place of the hydrogen atom in a hydrocarbon that indicates the prefix.

Research question 2: What skills would students develop through the use of molecular models to enhance their drawing and naming the structural formulae of mono, spiro and bicyclic compounds?

Data gathered to find out the effect of molecular models to draw and name the structure of termed organic compounds is presented in Table 4.2

Table 4.2: Comparison of students' scores in pre-intervention test and post-intervention test

Test	N	Min	Max	Mean	SD
Pre-intervention	103	1	16	8.88	4.05
Post-intervention	103	7.5	20	17.47	3.67

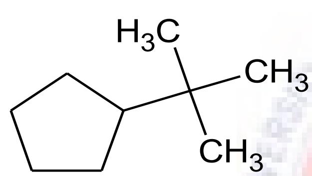
Table 4.2 shows a comparative analysis of students' pre and post intervention test scores.

From Table 4.2, the minimum score obtained by students in the pre-intervention test was 1.0 while that obtained by students in the post-intervention test was 7.5. The highest score obtained by students in the pre-test was 16 compared to 20 marks obtained in the post-intervention test. The mean score obtained by students in the pre-intervention test was 8.88, with a standard deviation of 4.05. This mean score suggests that most of the students were not able to obtain more than half of the marks. The mean score in the post-intervention test was 17.47 (SD=3.67). The mean score with a smaller standard deviation suggests that majority of the students obtained the mean score or obtained a score consistent with the mean value and hence performed better in the post intervention test. The improvement of students' performance in the post test can be attributed to the effectiveness of the intervention strategy which was the use of models. In a similar study, Dori and Barak (2001) found that, inquiry–based learning tasks in which models were used encouraged understanding of organic compounds and provided students with tools for explaining their answers. In their work, experimental group students were more capable of defining and implementing isomerism and functional group concepts than their control group counterparts.

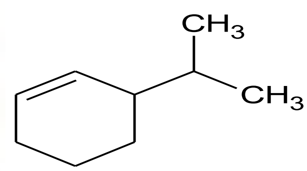
In this study, students became conscious of the IUPAC rules for naming spiro and other cyclic compounds. Also, through modelling of molecular models identification of least counts positions of substituents in substituted cyclic, spiro and bicyclo compounds were enhanced. They were assisted through modelling and counting of carbon chains at both forward and the reverse directions and choosing the direction where substituents bear least counting positions. Again, the difficulties that students have in drawing named compounds were improved since students developed the habit of modelling organic structures before drawing. This supports the finding of Yip, Jaber, and Stieff, (2011), who concluded that students who sketch during simulation activities develop more accurate mental models of chemical phenomena and produce more accurate sketches of scientific models. Similarly, Stull, Hegarty, Dixon and Stieff (2012) made models available to students as they performed diagram translation tasks and found that most students ignored the models and but performed well. In later studies, when they encouraged students to use the models, successful students aligned the model with the given diagram and then transformed it (by rotation) to align it to the diagram to be drawn, so that they used the model to externalize the relevant spatial transformations. However, many of the students still ignored the provided models. Students who used models had much better performance (ranging from 45% to 66% accuracy in different experiments) compared with students in no-model control groups (around 25% accuracy). Students who had models available, but did not use them consistently, performed no better than these in the control groups.

Again, through the use of models rote memorization of structures was discouraged. Models of molecules enabled students to do mental transformations and visualizations from a two dimensional to a three-dimensional structure (Cody, Craig, Loudermilk, Yacci, Frisco & Milillo, 2012). In the same view, Wu and Shah (2004) reported that concrete models such as ball-and stick models and space-filling models and their animated electronic versions, by which students can inspect each molecule from different angles, facilitate students' visualisations of these chemical characteristics.

The researcher realised that students who had difficulties in writing prefixes and arranging substituents in alphabetical order had less difficulties through modelling and strict application of the IUPAC rules. Dori and Barak (2001) stated that concrete models help students practice some of these cognitive skills. They believed that using modelling kits accelerates the process of acquiring these skills and makes learning more efficient. Some of the substituents that were modelled included isopropyl and tertbutyl. Students were able to give the correct names for the structures of tertbutylpentane and 3-isopropylcyclohexene as shown below.



Tertbutylpentane



3-isopropylcyclohexene

The improvement in students' performance suggests that modelling is an effective tool for teaching organic nomenclature. The interactive nature of the models facilitated students to develop mental models of organic structures. The model constructed was a simplified representation of a system, which directed students' attention on a specific aspect of nomenclature. The use of models enhanced their spatial ability of molecular identification. Similarly, Harle and Towns (2011) opined that chemistry problem solving that involves the drawing structures of organic compounds is correlated with spatial ability. The mastering of spatial ability has been shown to be specifically related to enhance the performance in organic chemistry (Pribyl & Bodner, 1987), although not always (Keig & Rubba, 1993). Due to the spatial nature of the representation of the translation task, the performance on this task will be correlated with students' spatial ability. However, a prior prediction about the interaction between spatial ability and model availability. This implies that the availability of a model might affect the relation between spatial ability and performance. On the one hand, a model can support an internal process such as mental rotation by replacing or augmenting it with a physical action or rotating model so that models might be particular helpful for students with low spatial ability (who are poor at mental rotation). Again, another possibility is that spatial ability is needed to map the units in the model to those in the diagram or to interpret the new view of a model that results from a rotation. In this case students with high spatial individuals may be more able to benefit from a model.

The mean score results obtained from the pre-test and the post-test made through sample paired t-test analysis are as presented in table 4.3

Table 4.3: Paired sample t-test analysis of pre-intervention test and post-intervention test

Test	N	Mean	SD	t-value	p-value
Pre-intervention	103	8.88	4.05	-17.29	0.000
Post-intervention	103	17.47	3.67		

The mean scores obtained for pre-intervention test and post-intervention test were 8.88 (SD = 4.05) and 17.47 (SD=3.67) respectively. To determine whether there was any statistical difference in academic performance of students in the pre-intervention test and the post-intervention test, research question two was formulated into a null hypothesis (Ho).

Ho: There is no significant difference between students' performance in the pre-intervention test and post-intervention test.

From Table 4.3, $t = -17.29$; $p = 0.00 < 0.05$, and indicates that statistical significance difference exists between students' performance before the implementation of the intervention and after the intervention. This confirmed that students' scores were significantly higher in the post-test than in the pretest. The null hypothesis was therefore rejected for the alternate hypothesis to be accepted, since $p = 0.00 < 0.05$. The higher performance was achieved due to the effectiveness of the molecular models that was used to teach the writing and nomenclature of organic structures since it was the only new tool introduced into the lesson. In a related study, Dori and Barak (2001) reported that experimental group students understood the model concept better and were more capable of applying transformation from one dimensional (molecular formula) to two-dimensional (structural formula or ball-and-stick model drawing) or three-dimensional (space-filling model drawing) molecular representations and from 2D or 3D back to the one-dimensional representation. They added that the significant improvement in experimental students' understanding was attributed to their increased exposure to virtual and physical models as well as the active learning these students were engaged in. Springer (2014) suggested that students may not necessarily need to perform specific manipulations themselves and that simply viewing the appropriate manipulations being performed by an instructor could be enough to improve understanding.

Research question 3: What are students' perceptions about the use of the molecular models to enhance their drawing and naming structural formulae of monocyclic, spiro and bicyclic compounds?

Data gathered to find out students' perceptions about the use of molecular models is presented in Table 4.4

Table 4.4: Students response on the perceptions about the use of molecular models

S/N	Items	Mean	SD
1.	Modelling of compounds has deepened my conceptual understanding on the type of bond formed by each of the hydrocarbons	3.51	0.71
2.	I can apply the IUPAC rule for naming and modelling of alkyl substituent	3.43	0.77
3.	I can identify the longest carbon chain easily	3.50	0.87
4.	The ability to indicate the correct position for substituents and functional groups has been improved	3.52	0.68
5.	I enjoyed the use of the molecular model kits	3.38	0.91
6..	Molecular model kit has enhanced my understanding in naming and writing of organic structural formulae	3.45	0.75
7.	The use of the molecular model kits made lesson more interactive	3.56	0.78
8..	The model usage has improved my ability to share ideas with colleagues	3.49	0.71
9.	Molecular model kits provided an effective visualization of extended structure solids	3.39	0.75
10.	Modelling of cyclic compounds before writing the structure improved my performance on the subject matter	3.31	0.78
	Mean score	**3.45**	**0.77**

N = 103

A four-point Likert scale was used in scoring students' responses. On the Likert scale "Strongly Agree was scored 4 points, which was the maximum on the scale, "agree" was scored 3 points, "disagree scored 2 points and strongly disagree was scored 1 point, which was also the minimum point. Overall means above 2.5 were interpreted as positive responses in appreciation of the use of the molecular models in naming and drawing structural formulae of the cyclic compound while means below 2.5 indicated a negative response in the use of the molecular models.

From Table 4.4, it is observed that students scored a mean of 3.51 (SD = 0.72) to agree that modelling of compounds had deepened their conceptual understanding of the type of bond formed by each of the hydrocarbons. The small standard deviation supports that most of the students agreed to this statement and were very consistent in their decision. This might be due to the fact that modelling formulae makes the learning real and reduces rote learning. In a related study Stull, Hegarty, Dixon and Stieff (2012) noticed that students who struggled with difficulties are replaced by external actions on models. Representations and relating them to each other improved their understanding in representational competence and meta-representational competence (Hinze et al., 2013; Kozma & Russell, 2003). The students accepted (mean = 3.42; SD = 0.77) that they were able to apply the IUPAC rules of naming compounds effectively. Students indicated that their ability to identify longest carbon chain and correct position of substituents improved through the use of organic models. The students enjoyed the use of models in learning (mean = 3.4; SD = 0.91) and agreed (mean 3.44; SD = 0.75) that the use of models increased their performance and understanding in naming and drawing of organic formulae. Similarly, Wu et al. (2001) pointed out that with the help of eChem which had model kits embedded, Chemistry students were able to apply modern rules of IUPAC nomenclature to draw structures of some given organic compounds. For instance, the students were made to name and draw the structure of a six-carbon atom compound with a side group. The understanding of the high school Chemistry students who participated in the study was said to have improved reasonably, resulting in high performance on IUPAC nomenclature of organic compounds.

The students noted the interactive nature of the models and mentioned how easy it was to use. Again, the students agreed (mean =3.4; SD = 0.76) that models provide an effective visualisation of extended structure solids. The small standard deviation indicates that majority of the students were consistent in their choices. The modelling process encouraged sharing of ideas among students and enhanced team learning. According to Knudtson (2015), in teaching chemical concepts, teaching materials like molecular models are used as education tools that contribute to strengthen the identification of the concepts. With the aim of reinforcing concepts in the scope of any topic, it is possible to create educational activities that are suitable to be applied individually, in teams or at all grades (Samide & Wilson, 2014). This study used models to effectively reinforce students' conception in naming and drawing of monocyclic, spiro and bicyclic compounds. An overall mean score of 3.45 (SD = 0.77) suggests that students perceived the use of molecular kit as an effective tool for teaching.

Observational check list for students

A check list (see Appendix D) was designed to assist the researcher to assess the students' perceptions through their behaviour in organic chemistry lessons in which organic molecular model kits were used as the main teaching aid. Students were noted to pay much attention during the activity- oriented lesson. This suggests that, the students were not ready to miss any stage of the lesson presentation. Almost every student in the class was seen demonstrating this kind of seriousness. The researcher indicated that students worked well with their colleagues when put into groups to carryout group activities. The teaching strategy employed in the intervention strategy encouraged peer teaching and motivated students to share ideas with colleagues. It was not surprising that majority of them always engaged in class discussions. In most cases, students were observed to take independent initiative. For instance, during one of the organic chemistry lessons, the researcher could not go to class early but when entering the class, it was noted that students were already working with the molecular models instead of idling around. The students in their pre-assessment test delayed in answering the questions on naming and drawing structures of cyclic compounds but after they had gone through the lesson activities for a while, they developed the eagerness to finish any assignment that was given them. This attitude, if nurtured, could go a long way to help students achieve higher goals in life.

It was observed that some students got discouraged and stop working. For instance, in the first lesson, students were made to do some activities but it appeared that they were not able to continue because they had difficulties. The researcher indicated that students were able to overcome the difficulties they faced and were able to complete assigned task they were given. The students' cognitive understanding increased and so was their ability to model organic structures. It was observed that students mastered in modeling and drawing of organic compounds.

It also observed that the students' enhance abilities to name and write the structures of compounds was due to their strict adherence and application of the IUPAC rules. The researched noted that students who assisted their colleagues made reference to the IUPAC rules of naming compound before further explanation was made. The researcher observed was how students approached new assignments with sincere effort. At the initial stages of the lesson students used to copy the assignments of their colleagues but that practice stopped. This suggests that the teaching strategy that was employed was very effective and improved students' initiative performance, perception and behaviour in learning of organic chemistry. The students were observed to have improved in how they asked relevant questions in class.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER STUDIES

This chapter presents a summary of the findings made from data analysis and conclusions that were drawn from the analysis made. It went on further to outline some recommendations and suggestions for further research studies

Summary of Major Findings

The summary was done by considering each of the research questions.

Research question 1: What are some of the difficulties students encounter in drawing and naming the structural formulae of mono, spiro and bicyclic compounds?

A number of difficulties that the first year undergraduate chemistry students demonstrated in naming and writing the structural formula of some cyclic hydrocarbons included their inability to:

- identify the parent chain ring for monocyclic compounds with monocyclic alkyl substituents.
- identify the correct starting position for monocyclic compounds with two or more substituent groups.
- use prefix such as di, tri,tetra, etc. for two or more substituents and functional groups.
- separate of numerals from numerals and numerals from words using commas and hyphens respectively.

- to indicate bonds positions and longest chains
- arrange substituents in alphabetical order
- give preference to functional groups other than substituents
- apply the IUPAC rules in drawing and naming monocyclic, spiro and bicyclic compounds.

Research question 2: What skills would students develop through the use of molecular model to enhance their drawing and naming the structural formulae of mono, spiro and bicyclic compounds?

Through the use of molecular models as a teaching aid, students had better understanding in drawing and naming of monocyclic, spiro and bicyclic compounds. Also, students' performance was better in the post-test than the pre-test and statistical significant difference was observed between the test results. The null hypothesis was established between the scores obtained by students in the pre-intervention test and post-intervention test. The molecular models are therefore effective for teaching the drawing and naming monocyclic, spiro and bicyclic compounds. Students were able to:

- be conscious of the IUPAC rules for drawing and naming spiro and other cyclic compounds.
- Identify of least counts positions of substituents in substituted cyclic, spiro and bicyclic compounds were enhanced.
- to model and count of carbon chains at both forward and the reverse directions and choosing the direction where substituents bear least counting positions.
- Model the cyclic compounds using the IUPAC rules.

Research question 3: What are students' perceptions about the use of the molecular models in drawing and naming structural formulae of monocyclic, spiro and bicyclic compounds?

Students' perceptions on the use of molecular models on their ability to draw and name structural formulae of monocyclic, spiro and bicyclic compounds included:

- It made learning real and reduced abstract learning
- It made learning enjoyable
- It enhances understanding in the application of IUPAC rules to draw and name structural formulae of some given organic compounds
- It is interactive in nature and easy to use
- It improves the ability to share ideas with colleagues

Through the use of molecular models students adopted new skills that helped them to improve upon their ability in drawing and naming structural formulae of cyclic hydrocarbons. Some of these new attitudes identified were:

- to name and write the structures of compounds by adhering and applying of the IUPAC rules.
- identifying the correct positions for substituents on ring structures through modelling.
- Peer teaching and motivating colleagues by sharing of ideas.
- Convention of graphical structures into condensed formulae in IUPAC presentation.
- Improvement in their skills of modelling cyclic structures

Conclusion

The study investigated the effectiveness of using organic molecular models to improve first year undergraduate chemistry students' ability to understand and interpret how to draw and name monocyclic, spiro and bicyclic organic compounds in the University of Education, Winneba. The perceptions of students on the use of the organic molecular models in teaching the nomenclature of monocyclic, spiro and bicyclic compounds were sought.

The study revealed that first year chemistry education students had not developed appropriate conceptual understanding in drawing and naming organic structures of monocyclic, spiro and bicyclic compounds. A number of difficulties were revealed in their pre-test. In the study, the concept of students on the drawing and naming of organic structures of monocyclic, spiro and bicyclic compounds was improved through the use of organic molecular model. The post-intervention test results indicates that students performed better after the intervention had been implemented. This suggests that the molecular models is an effective tool for teaching the nomenclature of organic compounds. This explains why there was significant difference between the pre-intervention test and post-intervention test results.

The questionnaire results on students' perceptions revealed that students had positive attitude toward the use of molecular models. Also, students agreed that the molecular models was interactive and easy to use. The study further revealed that the more students practiced the modelling of more organic structures, the higher their interest was kindled, which further enhanced their conceptual understanding in nomenclature of organic compounds. The researcher assessed the students' perceptions through questionnaire. Their attitudes was also observed using the behaviourial check list. Students did not miss any stage of the lesson presentation because they were regularly in class and payed much attention during the activity oriented lesson. They were really seen demonstrating this kind of seriousness in class. There was also an indication that students worked well with their colleagues when put into groups to carryout group activities.

Recommendations

Based on the findings of the study, the following recommendations were made.

- Students should use molecular models to enhance students' ability in naming and drawing of structural formulae of organic compounds.
- The Chemistry Department of University of Education, Winneba needs to purchase more molecular model kits to ensure their availability and usage in teaching. This will help the students to do more modelling on their own to write and name structural formulae meaningfully. It will also help the students to actively construct and organize knowledge to solve problems in other real life situations.
- The Department of Chemistry education could adopt the use of the molecular models as an instructional material in teaching and learning of structural formulae of organic compounds and other related topics in chemistry such as balancing of equations.

Suggestions for Further Studies

- It is suggested that the study be conducted in the Senior high School.
- It is suggested that the study be conducted using computer animations instead of the molecular models.

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APPENDIX A

UNIVERSITY OF EDUCATION, WINNEBA

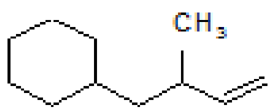
DEPARTMENT OF CHEMISTRY EDUCATION

PRE-TEST

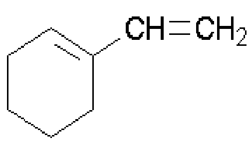
Answer all questions **Time: 30 minutes**

1. Name the following cycloalkanes/enes using the IUPAC system.

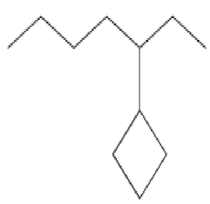
a.



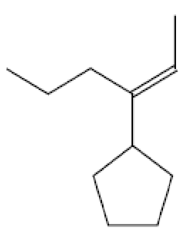
b.



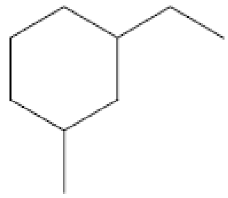
c.



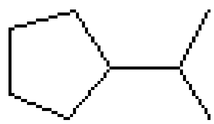
d.



e.



f.



2. Draw the following structures using the IUPAC system of nomenclature

a. 1,2-dimethylcyclohexane

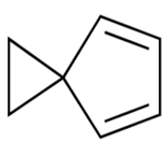
b. 1-cyclopropyl cyclopropane

c. 1-isopropyl Cyclohexane

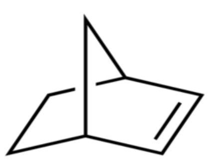
d. 3,3-Dimethyl-1,4-cyclohexadiene

3. Name the following compounds in accordance with the IUPAC system of nomenclature

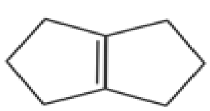
a.



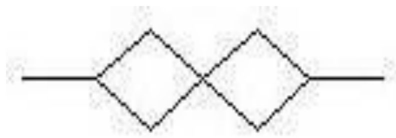
b.



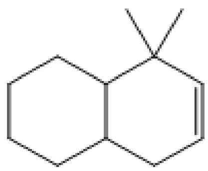
c.



d.



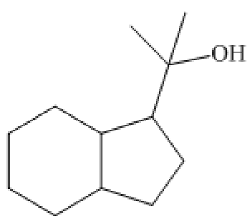
e.



.

f.

g.



4. Draw the following structures using the IUPAC system of nomenclature
   a. Bicyclo [3.1.1] heptane
   b. 2-methylspiro [4.5.] deca-1, 6-diene
   c. Bicyclo [4.2.0]octa-1(8), 5-diene
   d. 5-methylspiro[3.5] nonane

MARKING SCHEME

1 a. 4-cyclohexyl-3-methylbutane

b. 1-ethylcyclohexene

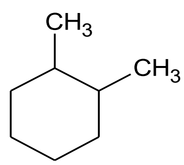
c. 3-cyclobutylheptane

d. 3 –cyclopentyl-2-hexene

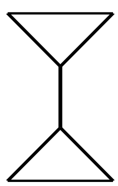
e. 1-ethyl-3-methylcyclohexane

f. 1- isopropyl cyclopentane

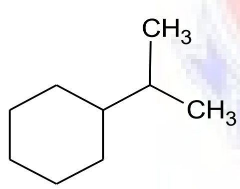
2. a.



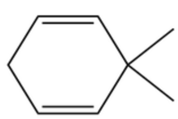
b.



c.



d.



3. a. Spiro [2,4] hepta-4,6-diene

b.Bicyclo [2, 2, 1]-2-heptene

c. Bicyclo [3, 3, 0] octane

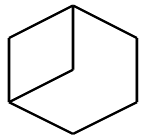
d. 2, 6 –dimethylspiro [3, 3] heptane

e. 2, 2 dimethyl bicyclo[4.4.0] -3-decene

f. spiro [4,5] decane

g. 1-hydroxyl-1-methylethylspiro[4,5]nonane

4. a.



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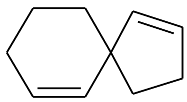
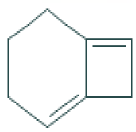
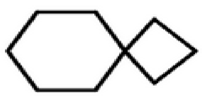


c.



d.



APPENDIX B

UNIVERSITY OF EDUCATION, WINNEBA

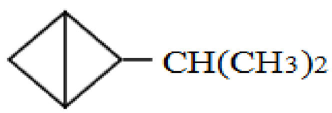
DEPARTMENT OF CHEMISTRY EDUCATION

POST-TEST

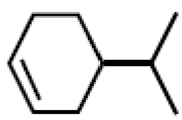
Answer all questions **Time: 30 minutes**

1. Name the following compounds using the IUPAC system of nomenclature.

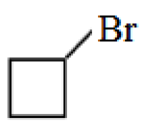
a.



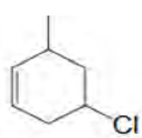
b.



c.



d.



2. Draw the following structures using the IUPAC system of nomenclature.

a. 1,3-dimethylcyclobutane

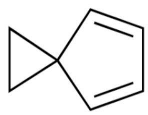
b. 1-cyclopropyl-2-cyclohexane

c. l-chloro-2-methylcyclopentene

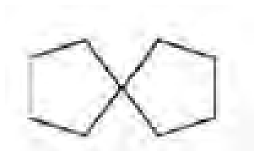
d. 3-cyclobutyl-3-methylpentane

3. Name the following compounds using the IUPAC system.

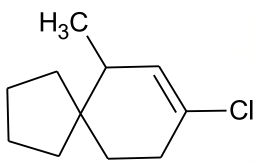
a..



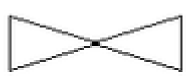
b.



c.



d.

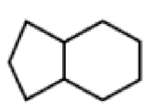


4. Draw the following structures using the IUPAC system of nomenclature

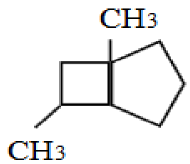
a. 2-chlorospiro[3,4] octane
b. Spiro[3,3] heptane
c. 2-methylspiro[4,5] dec-1-ene
d. Spiro[3,4]octane

5. Name the following compounds using the IUPAC system.

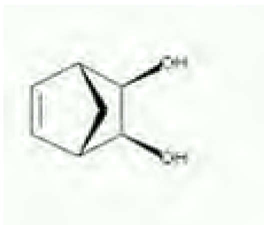
a.



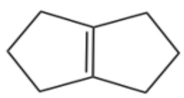
b.



c.



d.



6. Draw the following structures using the IUPAC system of nomenclature

a. Bicyclo[2.2.0]hexane

b. 2-isopropylbicyclo[1.1.0]butane

c. 3-chloro-2-methylbicyclo[4.4.0]octane

d. Bicyclo[2.1.0]pentane

MARKING SCHEME

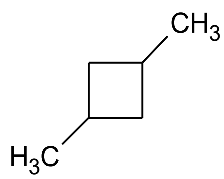
1. a. 2-isopropylbicyclo[1.1.0]butane

   b. 4-isopropylcyclohexene

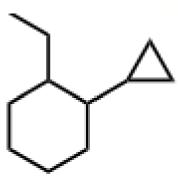
   c. 1–Bromocyclobutane

   d. 4-Chloro-6methylcyclohex-1-ene

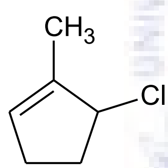
2. a.



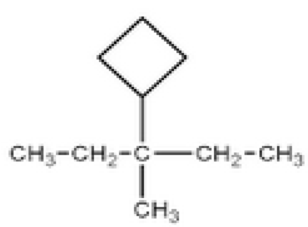
b.



c.



d.



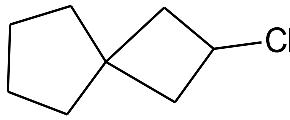
3. a. Spiro[2,4]hept-4,6-diene

   b. Spiro[4,4]nonane

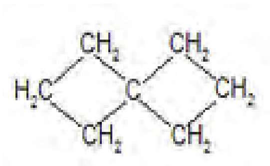
   c. 8-Chloro-10-methyl[4,5]dec-8-ene

   d. Spiro[2,2]pentane

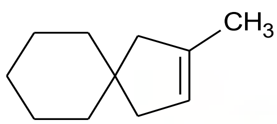
4. a.



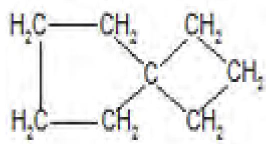
b.



c.



d.



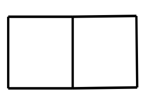
5. a. bicyclo[4.3.0]nonane

   b. 1, 6-dimethylbicyclo[3.2.0]heptane

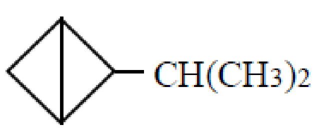
   c. Bicyclo[2.2.1]hept-5-ene-2,3-diol

   d. bicyclo[3.3.0]hept-4-ene

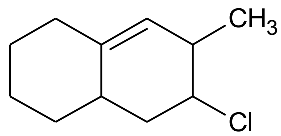
6. a.



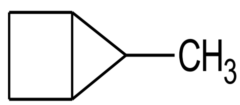
b.



c.



d.



APPENDIX C

Questionnaire for students on the appreciation in using the molecular models to enhance students' ability in naming and writing structural formulae of some cyclic hydrocarbons. Please tick (√) which item best describe their appreciation as they use the molecular models in writing the IUPAC names and structure of cyclic compounds.

Items	Strongly Agree	Agree	Disagree	Strongly disagree
1. Modelling of compounds has deepened my conceptual understanding on the type of bond formed by each of the hydrocarbons				
2. I can apply the IUPAC rule for naming and modelling of alkyl substituent.				
3. I can identify the longest carbon chain easily.				
4. The ability to indicate the correct position for substituents and functional groups has been improved.				
5. I enjoyed the use of the molecular models.				
6. Molecular model kit has enhanced my understanding in naming and writing of organic structural formulae.				
7. The use of the molecular models made lesson more interactive.				
8. The model usage has improved my ability to share ideas with colleagues.				
9. Molecular models provided an effective visualization of extended structure solids.				
10. Modelling of cyclic compounds before drawing the structure improved my performance on the subject matter.				

APPENDIX D

Observational Check list for students

S/N	Statement	YES	NO
1	Students pay attention in class		
2	Students work well with colleagues		
3	They participate actively in discussion		
4	Students do not take independent initiative		
5	Students try to finish all assignment assign to them		
6	Get discouraged and stop working when encounter with an obstacle		
7	Students are able to name modelled cyclic organic compounds		
8	Students strictly followed the IUPAC rules in naming and writing cyclic compounds.		
9.	Students approached new assignments with sincere effort		
10	Students asked a lot of relevant questions during lessons		

APPENDIX E

Reliability Statistics for questionnaire

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.580	.789	10

APPENDIX F

04

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF CHEMISTRY EDUCATION

PRE-TEST

Answer all questions   Time: 30 minutes

1. Name the following cycloalkenes using the IUPAC system.

a.

1-butyl-1-methylcyclohexene

b.

1-ethylcyclohexene

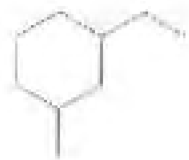
c.

3-methyl-cycloheptene

d.

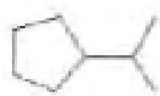
1-methyl-1-isopropylpentene

e.



1-ethyl-3-methylcyclohexane

f.



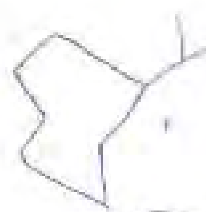
2-isopropylcycloheptane

2. Draw the following structures using the IUPAC system of nomenclature

a. 1,2-dimethylcyclohexane

b. 1-cyclopropyl cyclopentane

c. 1-isopropyl Cyclohexane

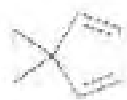


d. 3-Ethyl-methyl-1,4-cyclohexadiene

2

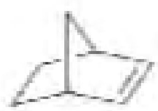
2. Name the following compounds in accordance with the IUPAC system of nomenclature

a.



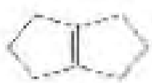
Spiro [2.4.2] pentadiene

b.



Bicyclo [2.2.1] hexene

c.

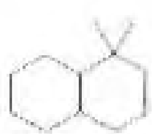


Bicyclo[3.3.1]nondiene

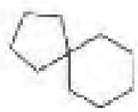
d.

[illegible] 1,1-dimethyl[illegible] [3.3] [illegible]

e.



3-[illegible] 3-isopropyl bicyclo[4.4.1]nonene



Spiro [4.5] nonane

d)

Spiro 1-isopropyl spiro[3.4.[illegible]] nonane

2. Draw the following structures using the IUPAC system of nomenclature

a. Bicyclo [3.1.[illegible]] hexane

b. 7-methylspiro [4.5] deca-1,5-diene

c. Bicyclo [[illegible]] [illegible]-diene

d. [illegible] spiro[[illegible]] nonane